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(a) Author (Print/Sign): H. S. Berman, per telecon	Date: 5/13/05
(b) Responsible Manager (Print/Sign): G. P. Duncan	Date: 5/13/05
(c) Reviewer (Optional, Print/Sign): C. E. Jensen	Date: 13 MAY 05
(d) Reviewer (Optional, Print/Sign):	Date:

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(a) Name	(b) MSIN	(a) Name	(b) MSIN
K.S. Tollefson	H6-03	G.P. Duncan	R3-26
P.C. Miller	R1-51		
M.J. Ostrom	R3-26		
C.E. Jensen	R3-26		
J.L. Castleberry	R3-26		
V.C. Callahan	H6-60		
H.S. Berman	R3-26		

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RATIONALE FOR REQUESTING DELETION OF THE DOUBLE-SHELL TANK BOTTOM PLATE ULTRASONIC INSPECTION REQUIREMENT

H. S. Berman
CH2M Hill Hanford Group Inc.
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-99RL14047

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Abstract: This is a white paper describing the remote ultrasonic tank inspection equipment capabilities effectiveness with respect to HFFACO M-48-14 inspection requirements.

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Rationale for Requesting Deletion of the Double-Shell Tank Bottom Plate Ultrasonic Inspection Requirement

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC27-99RL14047

CH2MHILL
Hanford Group, Inc.

P.O. Box 1500
Richland, Washington

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LIST OF TERMS

DST	double-shell tank
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
IQRPE	Independent Qualified Registered Professional Engineer
NDE	non-destructive examination
RUTI	remote ultrasonic testing and inspection
SCC	stress corrosion cracking
TSAFT	tandem synthetic aperture focusing technique
UT	ultrasonic testing
VT	visual/video examination

1.0 BACKGROUND

The Hanford double-shell tanks (DSTs) are subject to a robust non-destructive evaluation (NDE) program to help establish and maintain DST integrity. The basis of the Hanford DST Integrity Program (DSTIP) derives from *Brookhaven National Laboratory Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks* (BNL 52527). The NDE approach is designed to use NDE in assessments aimed at identifying: pitting, uniform corrosion, and stress corrosion cracking (SCC), in the vapor, liquid and/or settled solids (sludge) regions. The Hanford NDE requirements are codified in *Double-Shell Tank Integrity Program Plan* (RPP-7574), and external commitments are shown in *Hanford Federal Facility Agreement and Consent Order* (HFFACO; Ecology et al. 1989). Specific requirements for assessing DST integrity are included in the HFFACO M-48 series of milestones.

Specifically, the HFFACO Milestone M-48-14, paragraph (e) (3), on tank bottom inspection requires:

> Examination of tank bottoms through accessible air slots of six (6) DST's. Tanks selected for examination will be recommended by USDOE and will be subject to approval by Ecology. This examination shall include all areas accessible within the limits of best available equipment. This examination shall extend at least ten (10) feet toward the center of the tank from the lower knuckle joint, or to the length practicable within the limits of best available equipment. The progress of the examination shall be reported to the Ecology project manager during the monthly ORP Project Manager's Meeting held pursuant to HFFACO Appendix D, Section 4.1. Findings and conclusions from this examination data may necessitate examination of additional DSTs in this area, or may be required upon review of this Integrity Assessment Report by Ecology.

The Hanford tank integrity baseline/condition assessments are being accomplished primarily through ultrasonic testing (UT) and visual/video examination (VT). The UT is accomplished in the DST annulus region, and the VT is done both in the annulus and tank interior. All this testing must be done remotely because of the hazardous nature of tank contents, the high radiation fields associated with the waste, and the space restrictions for access to the tank interior and annulus regions. Because of the difficulty of access to the air slots in the insulating concrete pad beneath the primary tank, a special robotic crawler was developed. This remote ultrasonic testing and inspection (RUTI) equipment is shown in an overview photograph in Figure 1, and at the bottom plate mock-up in the photograph of Figure 2.

Figure 1. RUTI Equipment Showing Dual Tandem Robotic Components.

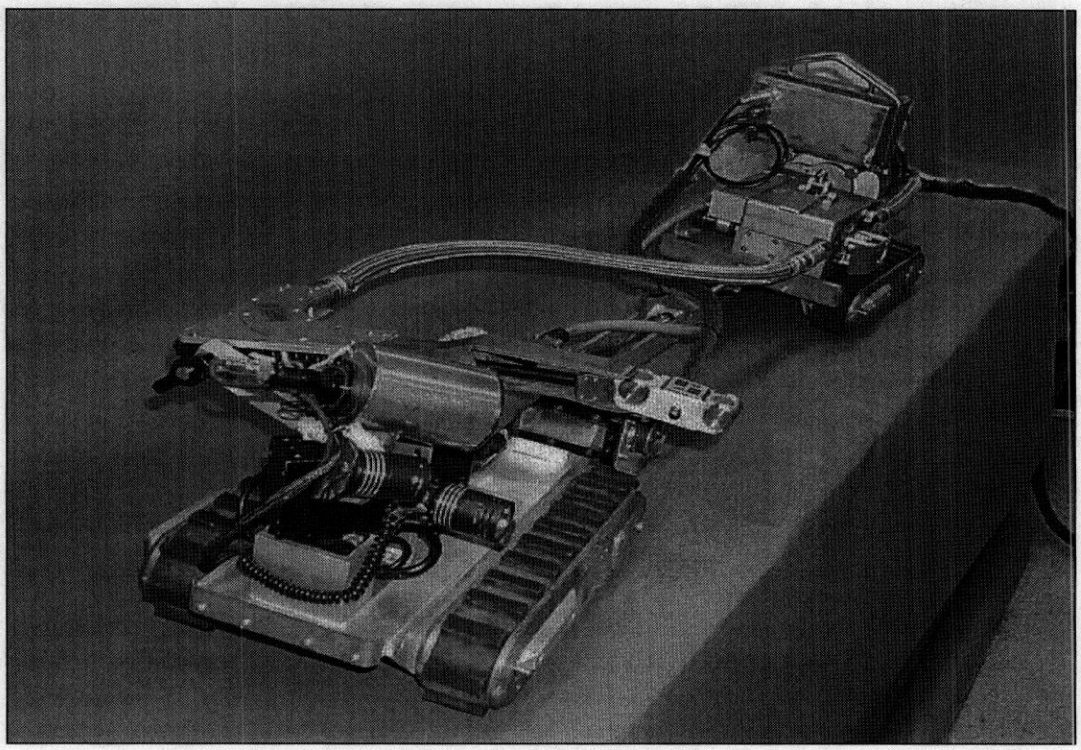
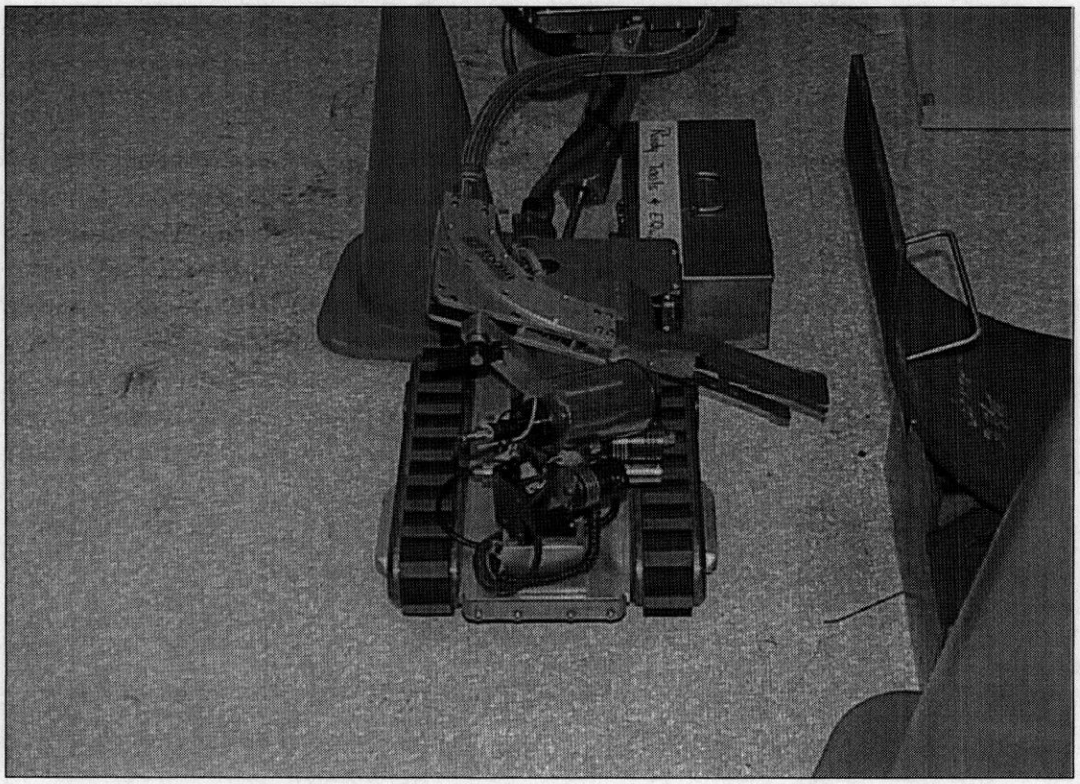
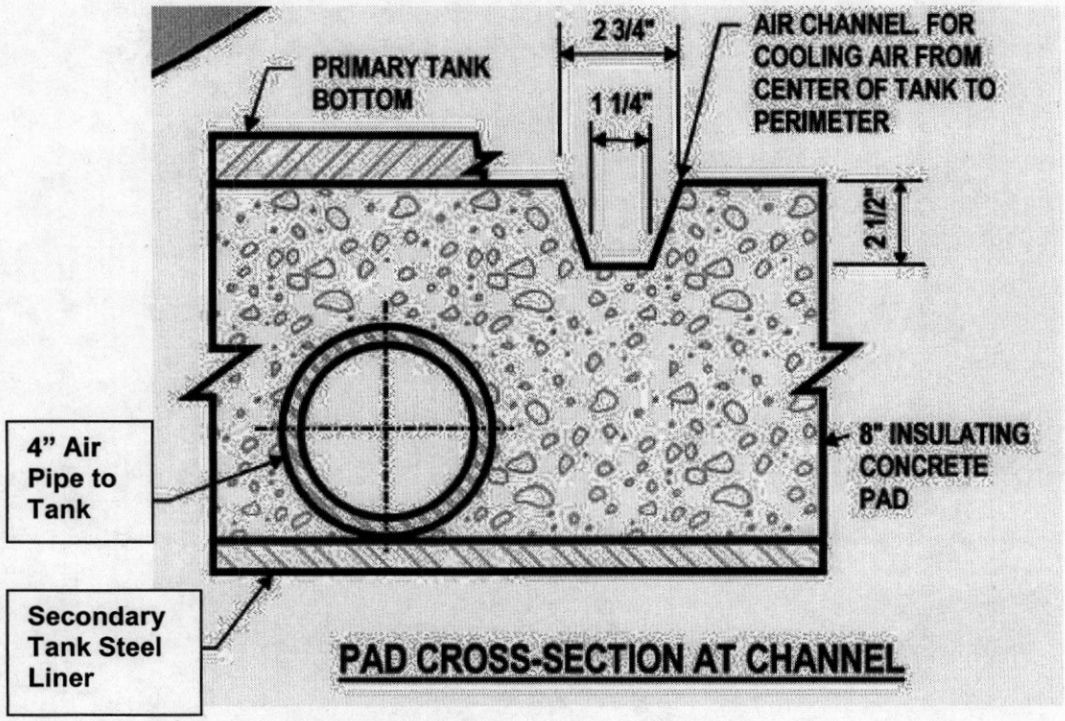


Figure 2. RUTI Air Slot Probe at Bottom Plate Mock-Up.



The complete RUTI unit is about 6 feet long and about 1 foot wide at the treaded tractor drive units. As with other UT robotics used on the DSTs, a sizable cable bundle/tether for power, instrumentation and handling is attached to the RUTI equipment. The length of the RUTI chassis limits maneuverability, and the number of air slots that can be accessed from the DST annulus region. Additionally, the actual air slots have a small opening/cross-section as shown in Figure 3.

Figure 3. Insulating Pad Cross-Section Showing Air Slot Geometry.



Further, many of the few accessible air slots have thermocouples installed (either for present use, or from new construction for monitoring the stress relief temperature) and there is presently no apparatus to remove or relocate these wires. The presence of the thermocouple wires prevent entry of the RUTI probe, and further limits the opportunities to make bottom plate thickness measurements using the UT transducer on the RUTI extendable probe arm.

Additionally, the tank farms used a construction method with a steel retaining ring to hold the castable insulating concrete when it was poured; but at the SY tank farm a solid ring with subsequent holes flame-cut into this steel ring was used, to allow the air slots to communicate with the annulus. These SY tank farm cut-in openings are too small to allow the RUTI probe to be properly positioned to enter the air slots. Finally, the AP farm tank annulus space contains ventilation piping that severely limits placement and maneuvering of the RUTI equipment.

2.0 DISCUSSION

The RUTI equipment has been deployed in multiple DSTs in an attempt to meet the six DST requirements of the HFFACO milestone. The following is the RUTI equipment inspection status to date:

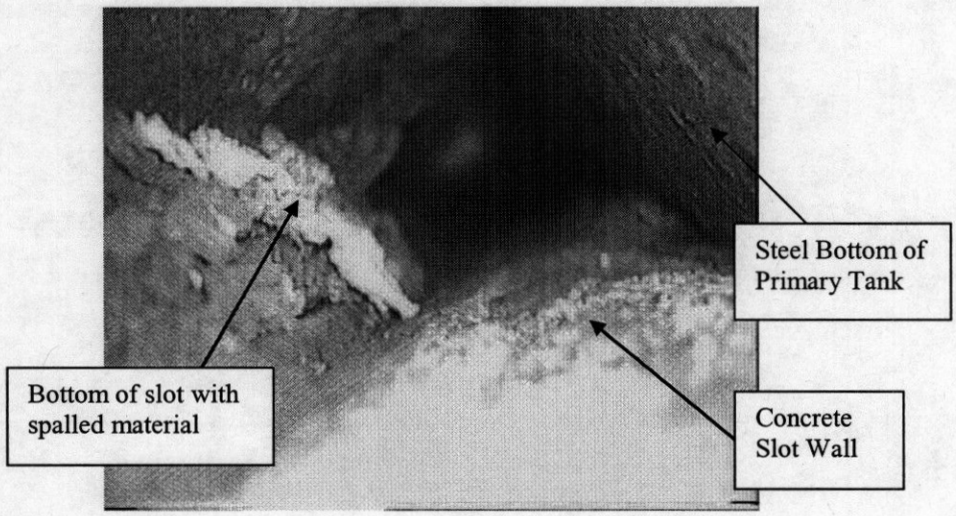
- Completed the RUTI bottom plate UT in two DSTs (241-AN-107, 241-AW-101)
- Unable to obtain RUTI access to slots in four DSTs (241-AY-101, 241-AY-102, 241-AZ-102, 241-SY-103)

The RUTI work has run into multiple difficulties and barriers, including the very limited number of slots that can be accessed, and the limited probe extension into the air slots, because of the maneuverability and slot access issues described in Section 1.0. Similar existing interferences near the insulating concrete prevented any access to the air slots of DSTs 241-AY-101 and 241-AY-102.

One of the more serious additional issues was the discovery of cracked and spalled insulating concrete in the air slots of DST 241-AZ-102. The RUTI device contains a video camera for placement and guidance, which allows video examination of the concrete air slots before and during probe entry. Attempts to examine the tank bottom in DST 241-AZ-102 with the RUTI showed that the condition of the cracked and spalled insulating concrete in the air slots was exacerbated by the movement of the RUTI probe into the slots.

All of the slots available for the RUTI probe in DST 241-AZ-102 showed refractory material that was cracked or had fallen from the sides. None of the slots was completely obstructed. Figure 4, showing the insulating concrete condition, was taken from a video made by the RUTI equipment as it attempted to deploy a camera into the slots. This photograph provides a general idea of what was found during the inspection. This and other insulating concrete concerns resulted in a detailed analysis (*Evaluation of Insulating Concrete in Hanford DSTs* [RPP-19097]) that quantified the relative fragility of the insulating concrete, and the preferred 'hands-off' protocol (i.e., visually examine, but do not mechanically disturb the air slots when the concrete appears frangible). This visual inspection requirement has been added to procedure *Video Examination of DST Interiors, DST Annuli and Exposed Waste Transfer Piping* (TO-020-142) and provides specific instructions in Section 5.2 to visually examine the concrete insulation support pad.

Figure 4. Video Picture of DST 241-AZ-102 Insulating Concrete Air Slot.



The effort to use the RUTI equipment to examine the tank bottom in DST 241-AZ-102 was halted when the probe became temporarily lodged inside an air slot. At the time, a management decision was made to halt further attempts to scan the tank bottom because of the possibility of the RUTI probe being permanently wedged in an air slot by spalled concrete debris. This decision was reinforced in Section 3.0 of RPP-19097, which recommends only visual examination. Thus, considering the mechanical constraints in SY tank farm, and the insulating concrete concerns in the AY and AZ tank farms, only the AN, AP, and AW tank farms are potential candidates for RUTI equipment examination.

At present, further deployment difficulties are now delaying the program because of the necessity to do all tank farm work in supplied air, for worker protection. There are several reasons for the difficulty of RUTI equipment operation with supplied air:

- RUTI work is limited by the length of the tether (cable bundle). The tether contains control cables for the Inuktun Services Limited (Nanaimo, British Columbia, Canada) crawler, the probe pusher, the deployment arm, the signal cable for the ultrasonic transducer, and two camera cables. (Some of these cables might be lengthened without too much design work, but others like the camera cable would be a real problem.)

- Because of cable length constraints, the control trailer/tent would have to be located inside the tank farm boundaries, with all RUTI personnel (inspectors in the trailer and operators at the DST) continuously on supplied air.

- Furthermore, the deployment of RUTI equipment (whatever the cable length) requires many operators to be attendant at the riser because of the RUTI size and weight. This constitutes an added safety concern when supplied air lines are also in use.

- Even after RUTI deployment, operation of RUTI equipment requires at least two operators to be stationed at the riser at all times for tether management.

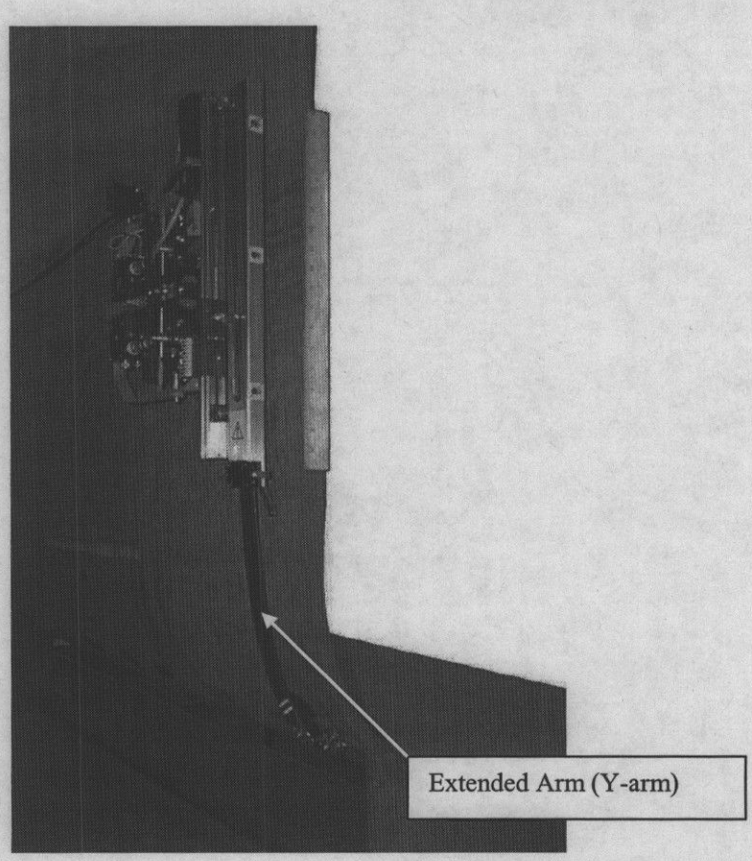
Thus, under present operating conditions, use of the RUTI equipment with the supplied air requirement is both difficult, adds additional safety concerns, and it appears that the remaining tank bottom inspections may impact the delivery of a DST integrity assessment report (per HFFACO Milestone M-48-14), which is due to the Washington State Department of Ecology by March 31, 2006.

The RUTI examination results on DSTS 241-AN-107 and 241-AW-101 show little corrosion loss on the bottom plate, and frequently show thicknesses above the nominal plate thickness. The deepest pit found was less than 5% of nominal tank bottom plate thickness in DST 241-AN-107, with the majority of measurements showing little or no loss. The results of the extended arm UT (using the robotic UT 'wall crawler') of the various DST lower knuckle plates, which are in the same corrosion environment as the tank bottom plate, confirm the lack of any significant corrosion. On reflection it is not surprising that these results (RUTI equipment and extended arm) indicate little or no attack on the DST tank bottoms, as the tank bottom waste sludge environment is not conducive to corrosion because of the lack of oxygen transport from the waste surface to the stagnant bottom layers.

Thus, compared to UT examinations of the DST vertical walls and welds, and the examination of the high-stress lower-knuckle region, the bottom plate inspection is of doubtful value for adding any new information. This is especially true considering the few data points obtainable, the limited access into even acceptable slots (e.g., most slot penetrations are only a few feet), and the small number of DSTs amenable to RUTI equipment inspection. Unfortunately, the oldest tanks (AY, AZ, SY), where the most amount of corrosion might be expected, cannot be examined by the RUTI equipment.

However, as noted on the previous page, robotic UT 'wall crawlers' (used for the vertical tank walls) are currently outfitted with an extended arm (Y-arm) that is extended down the lower knuckle plate (see Figure 5), at the air slot regions, to obtain UT P-scan plate measurements to a point just above the area of maximum stress in the lower knuckle. The lower knuckle plates are exposed to the same corrosion environment as the bottom plate, and such knuckle plate UT measurements of the DST, coupled with laboratory chemical analysis of the waste near the tank bottom, can provide enough information for a comprehensive assessment of the extent of corrosion on the tank bottom, without the need for the limited RUTI data. The extended arm was used to access four air slots in DST 241-AZ-102, which were inaccessible by the RUTI technique.

Figure 5. UT Crawler Extended Arm (Y-arm) for Inspecting DST Lower Knuckle Region.



The extended Y-arm examination of the lower knuckle plate, which is now required for UT inspection of the lower knuckle, provides superior and more complete data relevant to the bottom plate for the following reasons:

- The lower knuckle plate is in the same corrosion environment as the bottom plate, so thinning, pitting and potentially cracking, would be essentially identical.
- The lower knuckle plate contains the highest stressed region of the DST, so the knuckle plate deterioration would be conservatively bounding to the bottom plate.
- The extended Y-arm UT scans an approximately 20-foot by 10-inch swath of plate, plus multiple extensions into the air slot regions to UT near the highest stress region of the knuckle plate; while in comparison, the RUTI equipment only measures a single line, a few feet along the bottom plate.
- The extended arm UT has both zero beam and angled beam transducers which can detect thinning, pitting and cracking; while in comparison, the RUTI device can only obtain plate thickness measurements.
- The extended arm UT measurements provide enough data for statistical analysis (extreme value statistics) that enable us to predict the deepest pitting, if we could examine the

entire plate. The few RUTI measurements do not have enough information to adequately make this statistical extrapolation.

The Independent Qualified Registered Professional Engineer (IQRPE), who must certify the DST systems for service in 2006 (per an HFFACO requirement), also has reservations about the value of the RUTI inspections. Discussions with the IQRPE confirm the doubtful value of the sparse RUTI data, primarily from the newer DSTs, for contributing to the DST systems certification. It appears that existing UT and other NDE data have provided enough evidence that there is not a corrosion problem with the tank bottoms. The IQRPE considers that the DST visual examinations, UTs of the vertical tank wall and welds, along with the lower knuckle examinations (by both TSAFT[1] and extended arm UT techniques), provide the bulk of the necessary information on DST health and projected mission life.

3.0 CONCLUSIONS

As described above, the situation with RUTI examination of the bottom plate of DSTs can be summarized as follows:

- To date, in spite of multiple attempts to deploy the RUTI equipment, only two DSTs have had UT measurements accomplished, due to physical and operational barriers; and of the six tank farms, only the AN, AP and AW tank farms have been found to be accessible by RUTI equipment.
- Bottom plate measurements taken by RUTI equipment show relatively insignificant corrosion, as reinforced by knuckle plate data, and visual sighting of the tank bottom in the air slots shows little or no external corrosion.
- RUTI examinations have the potential to worsen damage of the insulating concrete pads that support the primary DST vessel.
- RUTI deployment, even in the three tank farms available (AN, AP and AW), is difficult because of lack of maneuverability in the DST annulus, and the few open air channels available for use.
- Supplied air personnel protection requirements have greatly increased the difficulty and safety concerns for RUTI operations.
- RUTI data has little value in determining DST integrity and lifetime, because of the few farms accessible, and the limited data points obtained in a short, single-line scan extending only a few feet into the air slot; representing a tiny fraction of the bottom plate

[1] Tandem Synthetic Aperture Focusing Technique – This is a specialized UT inspection technique that propagates ultrasonic waves down into the plane of the plate and measures returning reflections to identify defects.

surface. Additionally, the older DST farms (e.g., AY, AZ, SY), which would be of most interest, cannot be accessed by the RUTI technique.

- Extended arm UT scans of the lower knuckle plate, and at the slot regions, near to the high-stress knuckle region, examine a large plate area in the same corrosion environment as the bottom plate, and coupled with laboratory analysis of waste solids near the tank bottom, provide adequate information to assess the bottom plate condition.

- The combination of DST visual examinations, UTs of the vertical tank wall and welds, along with the lower knuckle UT examinations, provide the bulk of the information necessary to establish DST health and projected mission life, without the need for RUTI data.

4.0 RECOMMENDATION

The Hanford DST Integrity Program has made a good faith effort to accomplish the DST bottom plate inspections as required by the HFFACO M-48-14 series of milestones. The process has been found to be very difficult, with only three of the six DST farms amenable to the bottom plate measurements using the RUTI equipment. The data obtained from the two completed RUTI measurements, out of multiple attempts, is sparse and of little value in determining the health of the DSTs. However, the extended arm lower knuckle plate UT results, along with the other UT and visual testing, provide sufficient information to assess the bottom plate and overall DST condition. Therefore, it is recommended that the requirement for DST bottom plate measurements by RUTI be deleted from the HFFACO milestones.

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