INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0507

# Non-Intrusive Liquid Level Detection System

Deactivation and Decommissioning
Focus Area

*Prepared for*
U.S. Department of Energy
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Office of Science and Technology

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INNOVATIVE TECHNOLOGY
Summary Report

# Non-Intrusive Liquid Level Detection System

OST/TMS ID 2403

Deactivation and Decommissioning
Focus Area

*Demonstrated at*
Hanford Site
Richland, Washington

**INNOVATIVE TECHNOLOGY**
Summary Report

## *Purpose of this document*

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine whether a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

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SECTION 1

# SUMMARY

Infrared Thermography is the process of converting heat emitted from an object into a visible dynamic TV-like picture. Infrared Imaging Cameras can display the temperature variations that are obtained of the surveyed object as tones of gray or color contours in the picture. These color or gray image contours map the temperature variations of the object being viewed with great precision. Temperature variations are often produced in tanks, vessels or pipes due to the differences in the thermal conductivity of the materials from which these objects are fabricated and the materials that they may contain. These variations result from changes in the ambient temperature surrounding the objects or can be induced artificially by the application of a small amount of external heat. Infrared Imaging Technology provides an ideal method for non-intrusively detecting the existence of liquids in tanks, piping or other vessels. The NLLDT is an attractive alternative to the current baseline manual procedures for detecting liquids in tanks and piping assemblies. The cost to conduct a NLLDT liquid detection project is as much as a factor of 10 less expensive than the baseline procedure and use of the NLLDT enhances as low as reasonably achievable (ALARA) practices compared to the baseline by reducing the time the operator spends in the proximity of the potentially contamination sources.

## ■ Technology Summary

This section summarizes the demonstration of an Infrared-based Non-Intrusive Liquid Level Detection Technology (NLLDT) at the 221-U Facility located within the Hanford site. This demonstration was conducted by Infrared, Inc. of Reno Nevada in conjunction with Bechtel Hanford Inc. (Environmental Restoration Contractor) and DOE Engineers.

The Infrared Imaging System demonstrated by Infrared, Inc. provides an attractive alternative to the baseline technology which employs mechanical methods of opening vessels to detect liquid level. An Infrared Imaging Systems is able to exploit the variations in physical properties of tanks, vessels and piping systems and the enclosed liquid and air to produce clearly defined locations of liquids, if they exist. For decontamination and commissioning (D&D) projects, the use of the NLLDT System to detect liquids in vessels eliminates the need to physically open and inspect these vessels. Risks to workers associated with gaining access to these type objects and the possible exposure to radioactive or contaminated materials can nearly be eliminated. This demonstration was conducted with the goal of characterizing a number of target vessels located on the deck of the 221 U Facility. This technology is suitable for DOE nuclear facilities D&D sites or similar public or commercial sites that must be decontaminated.

### Problem

Radiologically contaminated pipes, vessels and other containers are a major concern within the U.S. Department of Energy (DOE) and Private Sector facilities that are planned for decontamination and decommissioning (D&D). A first step in evaluating the potential disposition hazards of these objects is the determination of the presence of liquids. Performing radiological surveys of pipes, vessels and other containers provide information on their type and degree of contamination. Infrared Imaging Technology offers a non-intrusive method to determine if liquids are present in piping, vessels and other containers. Used as part of a complete piping and container survey program, infrared technology offers a number of distinct advantages over the baseline technology approach to the inspection

**Figure 1 Infrared Imaging 221-U Facility**

of these vessels.

**Features and Configuration**

- The technology is applicable to a wide variety of Tanks, Vessels and Pipe Systems.
- The system can be successfully operated allowing the operator to conduct the survey at a remote distance from the target vessels.
- The equipment is lightweight, portable and can be operated by one technician and an assistant.
- Electronic storage of imaging data that can be reviewed in real time or analyzed with computer software to generate more detailed information.
- Flexible report generation capabilities that are easily integrated with existing software capabilities.

The Non-Intrusive Liquid Level Detection (NLLDT) system consists of the following components:

- Handheld Infrared Imaging Camera and tri-pod which weights approximately 8 pounds
- Handheld Digital Visual Camera, weight approximately 4 pounds
- Customized software and a portable computer used to conduct post-test analysis
- Portable heating unit to be used as required

**Potential Markets**

Infrared Imaging Technology is suitable for DOE, U.S. Environmental Protection Agency (EPA), or U.S. Nuclear Regulatory Commission (NRC) or similar sites that must be surveyed to detect liquids in potentially hazardous areas.

**Advantages of Infrared Imaging Technology**

The following table summarizes the use of Infrared Imaging Technology against the traditional (baseline) procedures and processes.

**Table 1 Summary Advantages of Infrared Technology**

| Category | Comments |
|---|---|
| Performance | The NLLDT produces results much more quickly than the Baseline |
| Cost | The cost of operating the NLLDT to detected liquids in tanks and piping assemblies is substantially less than that of the Baseline procedure. (roughly, $625 to $3625 for target tanks and vessel, $115 to $975 for pipe assemblies) |
| Implementation | No special services are required. |
| ALARA | Use of the NLLDT enhances as low as reasonably achievable (ALARA) practices compared to the baseline by reducing the time the operator spends in the proximity of the potentially contamination sources. |
| Secondary Waste Generation | Unlike the Baseline Technology the Liquid Level Detection (NLLDT) System does not generate any significant secondary waste. |

**Shortfalls/Operator Concerns**

The principal component of the NLLDT System is the Infrared Imaging Camera. During the demonstration there was no apparent degradation of the camera's performance, nonetheless, it is important to exercise various measures to minimize its exposure to unnecessarily high contamination levels. As configured during the demonstration the NLLDT System can be wrapped in plastic. However, the camera lens must be kept clear of any obstructions.

**Skills/Training**

Operation of the NLLDT System should be performed by a thermographer and a technician trained in the proper use of thermography equipment. In addition, knowledge of the use of personal computers and analytical software is required to conduct the analysis and prepare the survey reports. Once the operator or technician enters the radiological hazardous site, setup and operating the NLLDT Systems requires approximately 30 minutes per target tanks or piping assemblies.

## ■ Demonstration Summary

This report presents an evaluation of infrared imaging technology for performing surveys of vessels, tanks and piping systems. This report covers the period of June 1 through July 24$^{th}$ 1999 during which time Infrared Inc., the Hanford Environmental Restoration Contractor and the DOE Richland Operations Office demonstrated the NLLDT system in the 221-U Facility.

**Demonstration Site Description**

The U. S. Department of Energy (DOE), at its former weapons production sites, is conducting an evaluation of innovative technologies that might prove valuable for the decontamination and decommissioning (D&D) of facilities. This NLLDT demonstration was conducted on tanks and piping assemblies on the canyon deck of the 221-U facility, which is the pilot project for the Canyon Disposition Initiative (CDI).

**Key Demonstration Results**

The key results of the demonstration are as follows:

- The NLLDT surveys were successfully conducted on ten target vessels and a section of the Pipe Gallery located in the 221-U Facility.
- The NLLDT system successfully demonstrated the ability to “Non-Intrusively” detect the presence of liquids or sludges in vessels at a unit cost substantially lower than the current baseline method.
- The NLLDT system functioned in the high radiation environment with no apparent degradation in performance and with minimum exposure to the operators.

**Regulatory Issues**

There are no special regulatory permits required for the operation and use of NLLDT. Normal worker safety practices should be applied when using this equipment in accordance with applicable regulations, particularly Code 10 of Federal Regulation (CFR), Parts 20, 835 and proposed part 834, for the protection of workers and the environment from radiological contaminants; and 29 CFR Occupational Safety and Health Administration (OSHA) worker requirements.

**Availability of Technology**

The majority of the components that make up the NLLDT system are commercially available. The apparatus for applying external heat when required is manufactured with readily available materials.

**Technology Limitations/Need for Future Development.**

An ongoing signature database should be maintained to support future surveys. The Signature Database is defined as an organized digital file of infrared images of targets that are similar in physical attributes to the expected objects that are to be surveyed during the characterization studies.

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### Other

All published Innovative Technology Summary Reports are available at http://em-50.em.doe.gov under "Publications." The Technology Management System, also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST Reference Number for the Non-Intrusive Liquid Level Detection Technology is 2403.

# SECTION 2

# TECHNOLOGY DESCRIPTION

## ■ Overall Process Definition

The DOE nuclear facility D&D program requires that tanks, vessels and piping systems be characterized as to their contents. The purpose of the Non-Intrusive Liquid Level Detection Technology (NLLDT), demonstrated by Infrared, Inc., was to determine if liquids were present in tanks, vessels and piping assemblies located on the canyon deck of the 221-U Facility. The NLLDT System provides a viable alternative to the current baseline procedure of manual/physical measurement and/or tap and drain.

**How an Infrared Imaging System Works**

All matter – animate or inanimate, liquid, solid, or gas – constantly exchanges thermal energy in the form of electromagnetic radiation with its surroundings. If there is a temperature difference between the object in question and its environment, there will be a net energy transfer in the form of heat; a colder object will be warmed at the expense of its surroundings, a warmer object cooled. The differences in the physical properties of various materials (i.e. stainless steel tanks or pipes and liquids that may be contained there in) will result in temperature variations that can be detected using infrared cameras.

Thermography is the process of converting this emitted heat into a visible dynamic TV-like picture. This can be accomplished by means of an infrared mechanical scanning system or by the use of a "phased array" of detector elements that can either be electronically scanned or preferably used as a staring system where the infrared image is directly formed on the array. By creating a detailed two-dimensional temperature pattern (thermogram) of the surveyed surface, information on temperature is obtained from several thousand points in the field of view of the scanner, or detector array, in about one thirtieth of a second.

The voltage variations that are obtained of the surveyed surface are amplified and shown on a CRT display. The differences in heat radiation appear as tones of gray or color variations in the picture. For example, a black and white thermogram may show a person's face where white indicates hotter and black indicates colder areas. The continuous gray tone makes the interpretation of detailed thermal patterns of the surfaces possible with temperature differentials as low as 0.2°C.

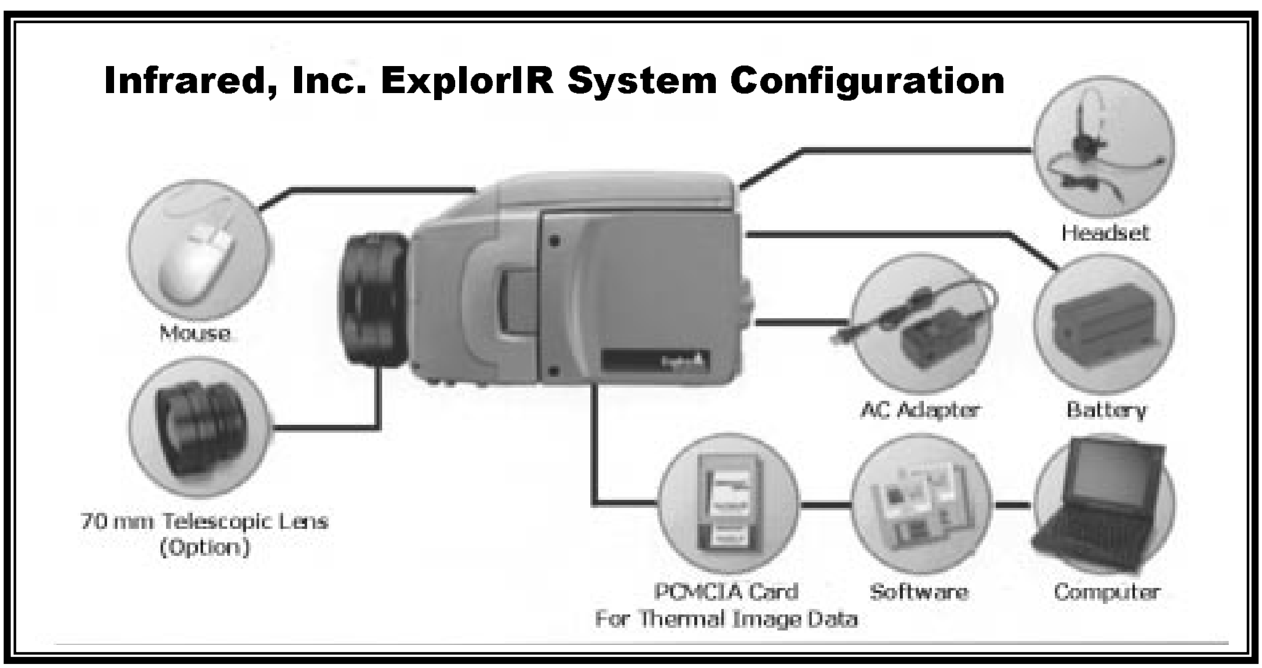



**Figure 2 Infrared Camera System and Accessories**

Color shades are often used in lieu of gray scale for added clarity

A typical thermographic scanning unit produces a thermal image 30 times each second detecting temperature differentials as low as 0.2°C at ambient temperature. Surfaces with temperatures ranging from –20 to +900°C can be measured from almost any distance. The correlation of the voltage measurements to temperature contours is accomplished by use of an isotherm function that recognizes areas of identical temperatures. A marker and scale indicates the relative temperature of a reference color area, thus enabling the temperature differences to be measured between any point within the field of view of the camera.

All infrared-imaging cameras consists of at least five basic parts (See figure 2 on the previous page): optical components, filter, detector, electronics, and temperature display. Two Infrared Imaging Cameras were utilized in the demonstration of the detection of liquid levels in tanks and piping. The CAM\IR 3000 is a real time, full color radiometer that operates in the 3 to 5 µm waveband featuring temperature resolution of less that 0.5°C. The Explorer utilizes an array of microbolometers configured as a staring system that operates in the 8 to 14µm waveband with temperature resolution of less than 0.25°C. Both cameras come equipped with a variety of optical lenses that allow operations from nearly any location and proximity to the target.

## ■ System Operation

### Setup and Operation Procedures

Approximately 30 minutes is required to setup the Infrared Imaging System for operation. This does not include the time required to put on special protective clothing, wrap the equipment and to meet other requirements for entering hazardous areas. The setup involves the following steps:

- Set the Infrared Camera, Video Camera and tripod at a convenient, safe location and distance from the target.
- Capture a series of video images of the target equipment. to match the expected field of view and location of the Infrared Camera.
- Measure and record ambient temperature, relative humidity and other physical information (size, geometry, materials, surface finish, etc.) related to the target.
- Determine the emissivity or emittance value of the selected target.
- Set camera to record a series of images at predetermined intervals, i.e. 15 sec.
- Capture the images.

In addition, if external heat is required to produce a temperature gradient in the target samples the following additional steps are required:

- Capture two or more Infrared Images of the target while at ambient temperature.
- Apply external heat, consistent with the heat application method and the target characteristics. As much as possible all targets of the same type that are to be surveyed must be heated using exactly the same procedures, i.e. location and distance of the heating assembly relative to the target, heat application time, etc.
- Capture a series of Infrared Images. The initial image should be captured within the first 5 seconds. Images should be collected at 15 sec intervals for at least 5 minutes.
- At the completion of the surveys exit the facility utilizating all approved safety procedures.

Conduct post-test analysis as required to characterize the targets that were surveyed.

The demonstration survey conducted in the 221-U Facility was performed with three people. Figure 3 at the top of the next page shows the number and activities of the crew during the demonstration. The number of personnel can be reduced to two in routine surveys. In this three-person operation two separate Infrared Imaging Cameras were utilized. The third technician captured visual images of the

**Figure 3 NLLDT Equipment Survey in 221-U Facility**

targets and provided other support functions as required. In a two-person crew, there will be one Thermographer and a technician. The technician will assist the thermographer and apply the external heating if it is required.

**External Heating Assembly**

The collection of infrared temperature contours is enhanced by incorporating daily environmental changes (warming in the morning, cooling in the evening) into the data acquisition process. When this is not possible, such as in the case of the surveys in the 221-U Facility, external heating was required. The environmental temperature changes or the external heating cause the target component equilibrium temperature conditions to alter. The variation in the physical properties of the target components results in small incremental temperature differences. These differences can be detected using an Infrared Imaging Camera.

When necessary and where possible one or more of the following techniques were employed to affect small changes in the demonstration target environment:

- Produce a 5 to 10°F general increase or decrease in the temperature of the vessels, tanks and pipes.
- Apply a modest heating or cooling strip to the target surface.
- Utilize a Radiant Space Heater; elevate the temperature in the area of the target samples.

Figure 4 is sketch of a Cal-Rod Strip Heating Unit designed and manufactured by Infrared, Inc. The heating element is 48 inches long. The unit features a telescoping handling assembly that permits the application of external heat while allowing the operator to stand back 8 to 10 feet from the target vessel.

Suggestions for additional development of remote heating elements are discussed later in this report.

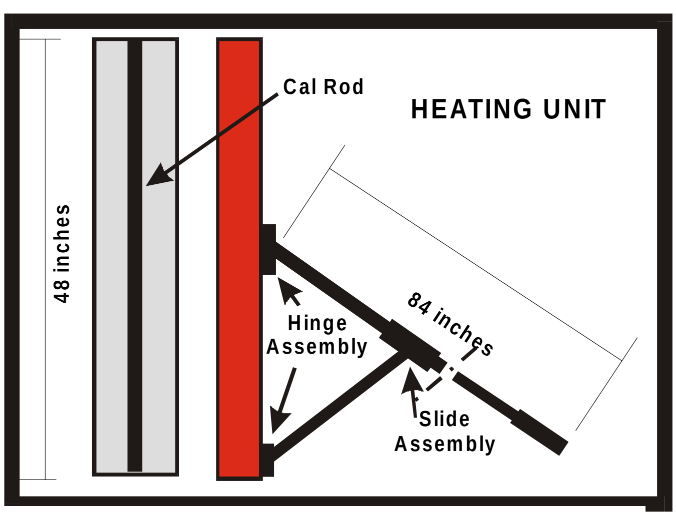



**Figure 4 Strip Heating Assembly**

# SECTION 3

# PERFORMANCE

## ■ Demonstration Plan

### Site Description

Infrared, Inc. and site personnel conducted the NLLDT demonstration at the DOE's Hanford Site. The demonstration program was conducted according to the approved test plan *Canyon Disposition Initiative Demonstration of "Non-Intrusive Liquid Level Detection Technology"* and was carried out at the 221-U Facility. The DOE nuclear facilities D&D program requires accurate characterization of tanks, vessels and piping systems in order to plan future activities for their use. Ten target vessels and a number of piping assemblies were selected for evaluation. Visual images of the targets are presented on pages 24 and 25 of Appendix B. These targets were located in the canyon area of the 221-U Facility.

### Demonstration Objectives

The purpose of the demonstration was to evaluate the capability of the NLLDT System to detect liquids in a number of selected targets. This included:

- Capability to detect liquids or other foreign matter in vessels and piping assemblies
- Capability to operate in a radiologically contaminated environment and to (perform the demonstrations in such a way as to) avoid contamination
- Ability to operate at temperatures between 0°C and 45°C
- Easy to decontaminate with conventional practices
- Capability to store and download electronic data to an available PC system
- Capability of the computer and software to analyze data

### Demonstration Chronology

Following is listed the main steps in conducting the demonstration:

- Check all components of the NLLDT System for proper operation
- Establish communication procedures for accurate recording and coordination of data
- Prepare signature database from sample tanks and piping systems located in building 336, June 16 – June 21
- Selection of demonstration target vessels by the ER Contractor, June 24
- Conduct survey of piping systems located in the Pipe Gallery, 221-U Facility, June 22 – June 23
- Survey tanks and vessels located on the canyon deck of 221-U Facility, June 24 and July14 – July 18
- Conduct computer analysis of all surveyed targets

**Test Methodology and Procedures**

Infrared imaging cameras were used to capture (thermography) images of selected target vessels located in the 221-U Facility. These cameras operate in the 3 to 5µ and 7 to 14µ wavebands. In addition, visual images were collected of each target sample along with environmental data and other physical information required to properly describe the tests.

The detection of freestanding liquid in tanks and piping, as described in the Canyon Initiative, required special procedures. Spatial constraints, working limitations (Hazardous Protection Clothing), unknown material properties, orientation and configuration of the piping had to be considered. To better understand these factors a comprehensive target signature database was prepared. The sample vessels that were surveyed to prepare this database were located in Building 336 (See Appendix page B-4 for a description of these vessels). This database was than used to compare images and other collected date with those acquired in the demonstration program conducted at 221-U Facility (See Data Acquisition and Analysis Methods).

Following are the test parameters and conditions that were established and utilized when conducting the surveys of each target or target type group.

- Aspect angle of the camera to the target (clear of all obstructions)
- Distance of the Infrared Camera to the target (8 to 10 feet)
- The location, when required, of the heating strips (strips were placed in the same relative location and applied in the same manner for each target or each target group)
- The time duration that heating or cooling is applied (15 to 30 sec)
- The elapsed time between the heating or cooling of a target or target group and the capture of the first image (30 seconds)
- The elapsed time for acquisition of subsequent images (15 seconds)
- Images were collected in the 3 to 5.5 and 7 to 14 microns wavebands
- Other parameters that were recorded included, Relative Humidity RH, once every hour, Environmental (Air) temperature every hour, and the time of day of each test sequence.

**Data Acquisition, Analysis Methods and Reporting**

**<u>Daily Reports</u>**

A thermographic report was prepared that presented an infrared image and a visual photograph, side by side. All information important to the thermographic analysis, such as surface material, condition, emittance, sources of reflection and temperature references were noted. Environmental data important to the test sequence such as date, time, ambient air temperature, relative humidity were recorded.

**<u>Visual Correlation</u>**

A photographic (visual/digital) picture or videotape was prepared that matched the thermal image for each object surveyed. This information was than used to orient the thermographic image and as an aid in identifying and locating temperature contours.

**<u>Data Reduction And Analysis</u>**

Infrared Image Analysis software was used for detailed study of the information recorded during the signature and demonstration target surveys. This software provides a comprehensive method of determining the information content of an image in numerical terms. The digital information allow for computer processing of the thermograms for mass storage, pattern enhancement and identification and mathematical conversion of the thermo information to radiant or true surface temperatures. The photographs, video, digital images were analyzed for pattern identification and temperature contours.

## Analytical Considerations

Three types of tanks, vessels and piping assembly conditions were analyzed. These were full, empty, and partially filled with liquids or other foreign matter. In addition, since the average daily summer temperature on the Canyon Deck of 221-U Facility did not vary more that a few degrees F., external heat was applied to most of the selected targets. When utilized, its' location and duration were evaluated.

The following is a list of factors that were considered when conducting the thermographic analysis.

- Materials used to fabricate target, i.e. stainless steel
- Target surface finish, i.e. painted, treated, etc.
- Target geometry, spherical, square, flat surface, etc.
- Local environmental conditions, relative humidity, ambient temperature, etc.
- Target internal conditions, full, partially full, empty, physical properties of contained materials
- Target accessibility, is the view obstructed, partially obstructed, i.e. wrapped in protective material
- Internal structure, heating coils, heat transfer elements, etc.
- Location and duration of applied external heating
- Elapsed time and time sequence after the application of the heat

**Partially Filled Vessels**

Analysis of partially filled tanks and vessels is usually straightforward and the existence of liquid levels can often be determined in real time by the thermographer. Under conditions where the ambient temperature will vary substantially over the course of the day (20 to 30 degrees F), external heating of target vessel is usually not required. Figure 5 at the bottom of this page presents a side-by-side view of a visual and infrared image. This test was conducted as a part of the signature database development procedure in Building 336 at the Hanford site. The ambient temperature variation over the course of an average day in summer is approximately 30 degrees F. As can be seen from the image the temperature variation produces a temperature contour that clearly indicates the liquid level.

Where the ambient temperature variation is not sufficient to produce temperature gradients in partially filled tanks or vessels; suitable gradients can be produced by the application of an external heat source. Appendix B page 22 presents a visual summary of the infrared survey of the Kennewick Tank located in 221-U Facility. The Radiation Technician located at the site confirmed the liquid or sludge level indicated in the visual image. Image 2 presents the temperature contour that resulted from the application of the external heating strip at the beginning of the sequence. Images 3 and 4 clearly demonstrated the efficient heat sink affect of the liquid or sludge as that portion of the contour quickly returned to ambient conditions.

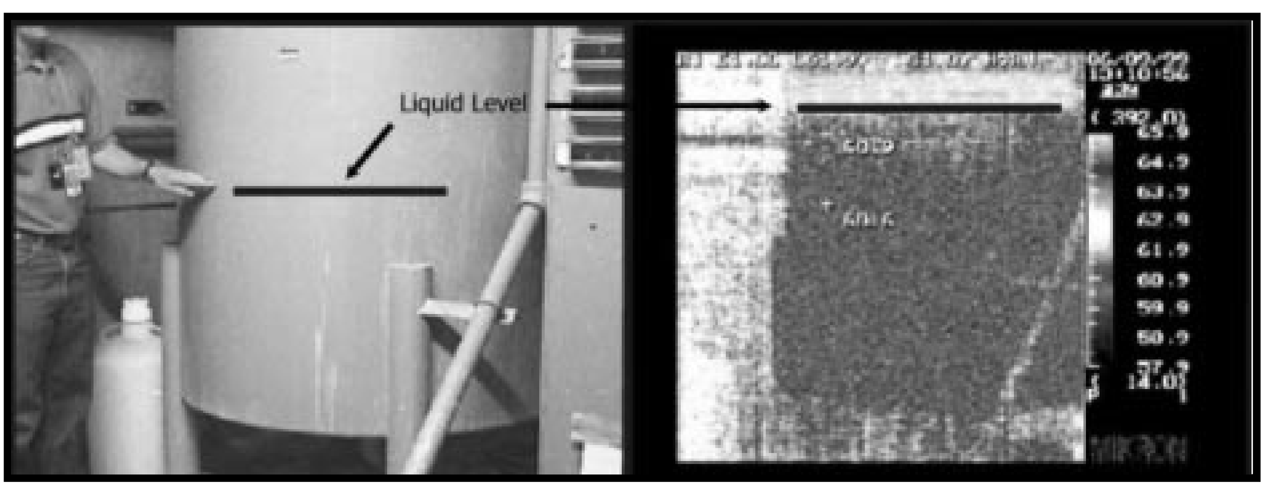



**Figure 5 Temperature Contour Showing Liquid Level**

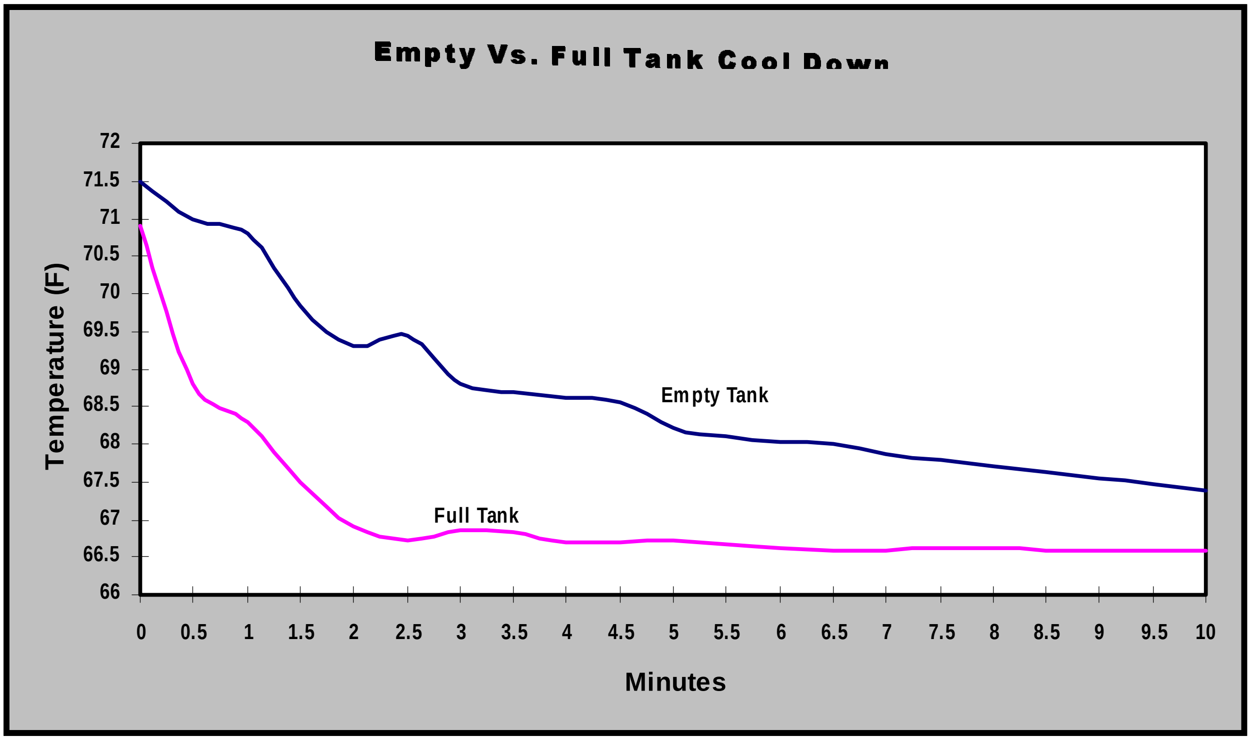



**Figure 6 Graph of Cooling Rate for Empty and Full Tank**

**Empty vs. Full Vessels**

An empty or a full tank will often produce nearly identical images to the Thermographer. Qualitatively, an experienced thermographer can frequently estimate the condition of a target tank or vessel by observing the rate of heating or cooling of the target after the application of an external heat source. As can be seen from figure 6 above the rate of cooling of a full tank is much more rapid than the empty tank. Also, the clarity of any external structure provides an indicator to the operator. Such structure, if it exists and if it is in close proximity to the surface of the vessel will be more readily detected in an empty tank.

A timed sequence of thermographic images of an empty or filled tank, even though they may look the same, provides important temperature information on the condition of the tank or vessel. The temperature graph shown at the top of this page was prepared from spot pixel temperature data collected on two similar tanks located in Building 336. These tanks were approximately the same size and geometry and manufactured out of the same material. One was empty and one was full. The spot pixel

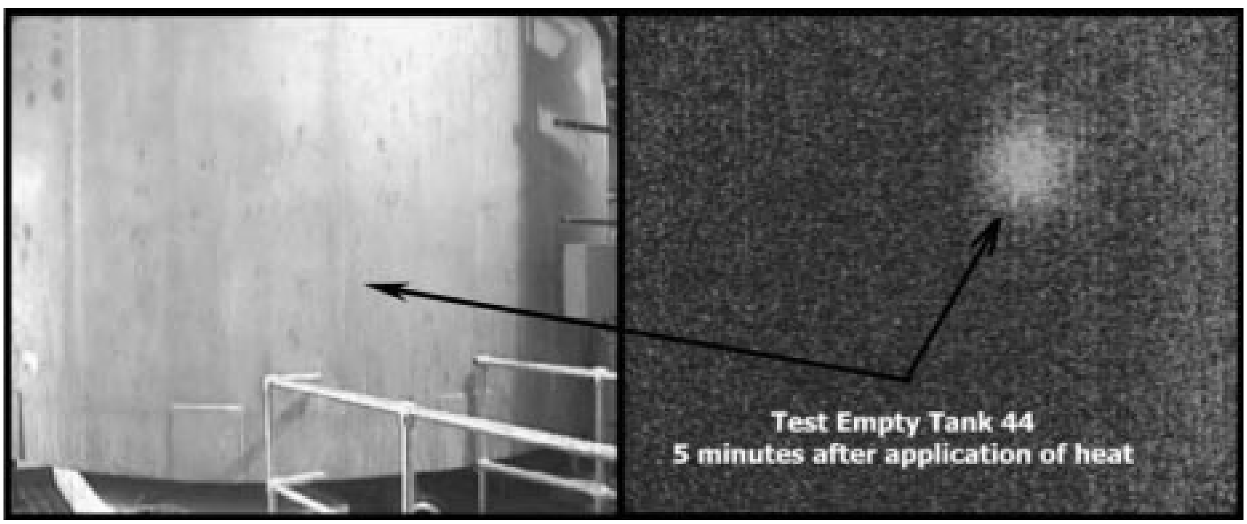



**Figure 7 Thermograph Showing Heat Persistence in Empty Tank**

temperatures were plotted over a period of ten minutes. External heat was applied in the same relative location for the same amount of time. Figure 7 at the bottom of the last page shows that the empty tank still had a detectable temperature contour after 5 minutes. The temperature contour on the full tank disappeared after approximately 1 minute.

**Piping Systems**

Detection of Freestanding Liquid in piping represents a more complex problem when compared to that in tanks. For example piping can be expected to exist in a number of orientations, from vertical to horizontal to any angle in between. Liquid within this piping may be seen in various configurations. Liquid in a vertical pipe, or one at least elevated on one end, will have characteristics similar to that of tanks. Freestanding liquid in other piping orientations could result from the effects of corrosion or some other such problem that might plug up a pipe so that it holds liquids where otherwise it would not.

Two physical properties, Emissivity and Emittivity, are extremely important in determining temperature contours and absolute temperatures. Emissivity is a property of the material being surveyed, i.e. stainless steel. Emittivity is a property of the object being surveyed, i.e. painted surfaces, spherical bodies, etc. Often the values of Emittivity and Emissivity are nearly identical. This would be the case, for example, of a flat, unpainted surface of stainless steel. However, where the geometry of the object is radically different, such as a small diameter pipe, the values for emissivity and emittivity can be substantially different.

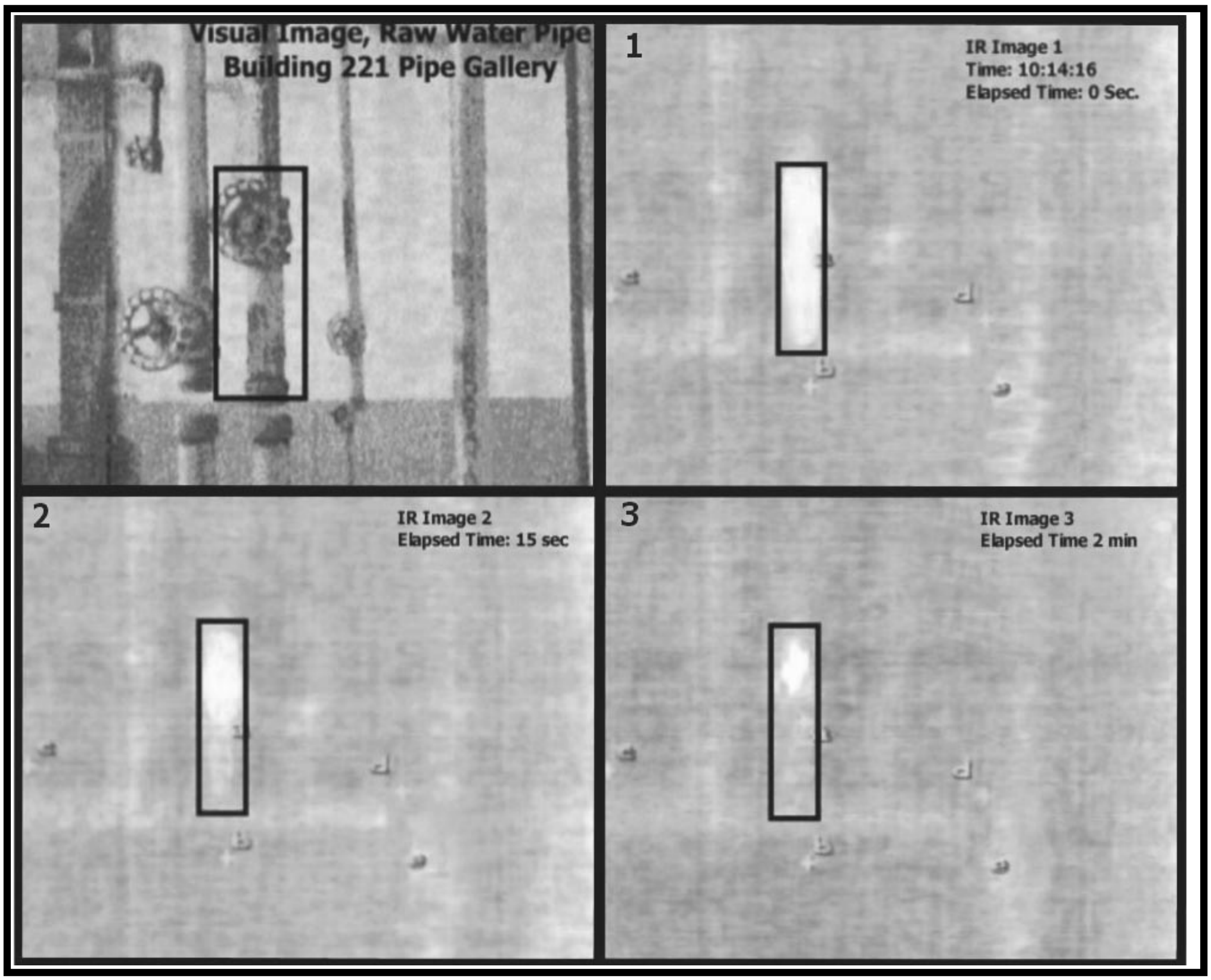



**Figure 8 Thermograph Showing Rapid Cooling of Target Area**

As in the case of tanks and vessels, a trained Thermographer can often determine the condition of piping systems based upon the rate of changes of the temperature contours that are observed in the Infrared Camera viewing window. Also, as in the case of tanks, a timed sequence of infrared images of a piping system will often display changing temperature contours that point to possible liquids, corrosion, sludges or other abnormalities within the pipe. Figure 8 at the bottom of the previous page presents an example of this is in the visual and the sequence of infrared images. External heat was applied for 15 seconds to the area highlighted in these images. As the reader will note, the temperature in the lower portion of the highlighted box decreased very rapidly compared to the upper portion. This rapid change resulted from the existence of an efficient heat sink in this area. It is known that there was a liquid and other corrosive sledge in this area.

**Baseline Procedures**

The current method for determining the existence of liquids or other foreign materials in tanks, vessels or piping assemblies is to conduct a visual inspection. Following is listed the steps that are required to conduct such an inspection in a radiologically hazardous environment:

- **Develop work package** – This activity would include personnel from engineering, radiological controls, planners, safety and supervision. A Radiation Work Procedures (RWP's) would be developed along with a detailed work plan.
- **Build scaffolding around the tank or vessel** – This work would include the time and labor required to: perform a pre-job survey of the tank by Radiation Control Technicians (RCT's), erecting scaffolding by riggers supported by Nuclear Chemical Operators (NCO's).
- **Remove flanges and or other access devices** – This work would include the physical removal of the access entry devices by a pipe fitter.
- **Measure vapor or gas that may emanate from the vessel** – An industrial hygiene technician would be required to check the vapor space.
- **Perform visual inspection, physically check for liquid levels** – Visual inspection of the inside of the vessel using a dip stick method would be conducted by a RCT and a NCO.
- **Replace flanges or other entry access devices** – Pipe fitter would be required to reinstall the flanges or other access devices.
- **Remove scaffolding** – Riggers would remove the scaffolding.

**Note**: The baseline procedure for piping assemblies is similar to that for tanks and vessels above. A work package must be prepared and a pre-job survey would be conducted. A hot-tap is inserted in a pipe to determine if liquids are present.

The visual inspection would require 1Pipe-fitter, 2 Radiation Control Technicians, 2 Nuclear Chemical Operators, an Industrial Hygiene Technician, 3 Riggers, planners, schedulers and supervisors.

The safety and hazard problems associated with the inspection would include, unsafe air space in the equipment, potential contact with unknown liquids, fall hazards associated with the scaffolding, heat stress from physical exertion and additional radiation doses to workers due to exposure of the tank or vessel.

## ■ Results

Over 500 infrared images were captured and analyzed. These included sample targets in Building 336 and the selected targets in the pipe gallery and canyon deck of the 221-U Facility. With the exception of two targets the NLLDT systems was able, after posttest analysis, to determine if liquids or other foreign materials were present in the surveyed tanks, vessels or pipes. The NLLDT system demonstrated the ability:

- To detect liquids or other foreign materials in tanks, vessels or piping assemblies.
- To operate in a radiologically contaminated environment and to perform the demonstrations in such a way as to avoid contamination
- To operate at temperatures between 0°C and 45°C
- To store and download electronic data to an available PC computer system and to conduct post-test analysis

In addition the NLLDT System demonstrated that it:

- Is well suited to reducing the exposure of operating personnel to radiological hazards
- Does not produce environmentally hazardous waste
- Can be decontaminated using standard cleanup procedures
- Requires fewer personnel and lower costs to conduct a survey than the Baseline methods

The following table summarizes the results of the individual test conducted in the 221-U Facility. The location in the appendix of the visual images of the surveyed objects is referenced in the table.

**Table 2 NLLDT System Survey Results**

| Test | Description | Result |
|---|---|---|
| 21 | Special Tank Vessel, (Image 6 page 24) | Vessel is empty |
| 23 | Pipe Configuration (Image 1 page 24) | Pipes are empty |
| 24 | The Strontium Nitrate Line(Image 10 pg. 24) | Pipe is empty |
| 25 | Caustic Pipe (Image 5 page 24) | Possible accumulation of solids inside the pipe |
| 26 | Raw Water Pipe (Image 9 page 24) | Pipe is empty |
| 27 | Down Drain Pipe | Pipe is empty |
| 28 | Pipe Assembly (Image 8 page 24) | Detected presence of liquid or sludge |
| 30 | Pipe and Valve Assembly (Image 7 pg. 24) | Empty |
| 31 | Centrifuge, (Image 3 page 25) | Undetermined due to visqueen wrapping |
| 40 | Left side double SS Tank (Image 8 pg. 25) | Empty |
| 41 | Right side double SS Tank (Image 8 pg. 25) | Empty |
| 42 | Debris Tank (Image 10, 11, 12 p25) | Liquid, Sludge Detected |
| 43 | Wooden Box (Image 9 pg. 25) | Film of Liquid, Oil Detected at the bottom |
| 46 | Purex Heat Exchanger (Image 4 pg. 25) | Internal Structure or liquid detected |
| 47 | Waste CASIC Tank, Cell 18 Dry Storage (Image 7 pg. 25) | Empty |
| 48 | High Rad Tank, Cell 36 (Image 2 pg. 25) | Tank is Empty |

## ■ Comparison of the NLLDT System to the Baseline

There is a major difference in productivity and safety between the NLLDT System and the Baseline procedures related to the detection of liquids in tanks, vessels and piping assemblies. The baseline visual inspection involves direct contact by personnel with the objects to be inspected. Not only is the contact direct but the exposure time can be for a significant duration potentially increasing the radiation doses to the operators and technicians. NLLDT provides a non-contact, passive, capability to detect liquids that results in conducting surveys with far fewer personnel and with far less exposure to the hazardous conditions.

The following table summarizes the performance and operation of the NLLDT System compared to the baseline technology.

**Table 3 Summary of Performance and Operation**

| Feature | NLLDT System | Baseline |
|---|---|---|
| Work Package Preparation[1] | Use existing work package | 100 hours |
| Average Setup Time per Survey[2] | 30 minutes | 7.9 hours |
| Visual - Physical Inspection | 30 minutes | 24 hours |
| Safety – Radiation Exposure | Very Much Less | Potentially Large |
| Waste Generation | Very Little | Moderate |
| Applicability | Wide Range of Applicability | NA |
| Training | Much Less | Skill or Craft |
| Ease of operation | Requires Some Training | Complex |
| Cost of PPE[3] | Some | Very Much Greater |
| Report Preparation | Same | Same |
| Data Interpretation | More Complex | NA |
| Report Archiving | Electronic Format | Hard Copy, Microfilming |
| Durability[4] | See Note 4 | NA |

Notes:

1. NLLDT surveys can be conducted under existing work control documents
2. Setup includes radiation surveys. The times are based on an average for 15 tanks. It was assumed the two of the tanks required scaffolding. Scaffolding would not be required for NLLDT.
3. PPE is required for each entry, Baseline requires many more personnel and entries
4. The NLLDT System uses infrared imaging cameras and computers to conduct analysis. Care must be taken not to damage the various components.

The DOE complex presents a wide range of D&D work and conditions. Because of the variety of functions and facilities, the working conditions for a specific job directly affect the manner in which D&D work is performed. The NLLDT and baseline procedures discussed in this report are based on a specific set of conditions or work practices present at the Hanford Site.

# TECHNOLOGY APPLICABILITY AND ALTERNATIVE TECHNOLOGIES

## ■ Competing Technologies

In addition to the baseline, there are a number of other technologies that might be successful in locating liquid in stainless steel tanks and pipes.

Radiography is an example of a technology that should prove successful in this application. Radiography processes, however, can be expensive and may be difficult to implement in the confined spatial environment specified in the Canyon Disposition Initiative.

It is also possible that various Acoustical Technologies could detect liquid in tanks and piping. Acoustical systems may be less adaptable to the required conditions. They also require an active component that may contribute to increasing the radiation environmental hazards.

## ■ Technology Applicability

Infrared Thermography is a mature and stable technology used widely in many industrial applications. It can be inexpensively applied to the problem of detecting liquids in tanks and piping using non-intrusive and passive procedures. Infrared Imaging Cameras are compact, rugged and portable and can be adapted to remote operations by incorporating simple modifications to the IR equipment and existing remote operation systems.

## ■ Patents/Commercialization/Sponsor

No issues related to patents, commercialization, or sponsorship are pending. Infrared Imaging Technology is a commercially available technology.

SECTION 5

# COST

## ■ Methodology

This cost analysis compares the costs of the NLLDT System and baseline procedures and presents information that will assist D&D planners in decisions about the use of the NLLDT in future D&D work. This analysis strives to develop a cost structure that represent D&D work within the DOE Complex. However, this is a limited representation of actual cost because the analysis uses only data observed during the demonstration. Some of the observed costs will include refinements to make the estimates more realistic, such as elimination of cost factors only applicable to the demonstration program. These are allowed only when they will not distort the fundamental elements of the observed data (e.g., do not change the productivity rate, quantities, and work elements, etc.) and eliminate only those activities that are atypical of normal D&D work.

## ■ Cost Analysis

This cost analysis for the NLLDT System is based upon data collected during the demonstration and includes duration of activities, work crew composition, equipment used in the performance of the work, and supplies used. The ER Contractor provided the work description, labor categories and time required to conduct the Baseline procedures. For the purpose of developing comparable costs, it was assumed that 15 target vessels and 16 piping assemblies were to be surveyed, all located in a radiologically hazardous environment. Two of the vessels required that scaffolding be constructed to conduct the surveys. Work units packages were defined by the ER Contractor to conduct the baseline procedure. Work unit task times to complete were calculated as the average based of the target vessels and piping assemblies. Those activities and costs that are for performance benchmarking (not a normal part D&D work) or that result from the demonstration nature of the contract are not included in this analysis.

Costs for the NLLDT are based on the use of one Thermographer, one Infrared Technician and a Radiological Control Technician with an average production rate of four target vessels or sixteen piping assemblies surveys per day. Monitoring for radiological contamination is included in this cost comparison. The ER Contractor prepared the description and cost elements for the baseline procedure. Tabulated cost for the NLLDT and the baseline are presented in the Tables in Appendix C, pages 29, 30, 31, and 32 respectively.

The baseline procedure as described by the ER Contractor involved the mechanical opening of vessels that were to be surveyed for the existence of liquids. The costs for that baseline procedure are based upon recent historical data supplied by the ER Contractor. Since the baseline cost estimate is not based on observed data, extra effort is applied in setting up the cost analysis to assure unbiased and appropriate work rates and costs.

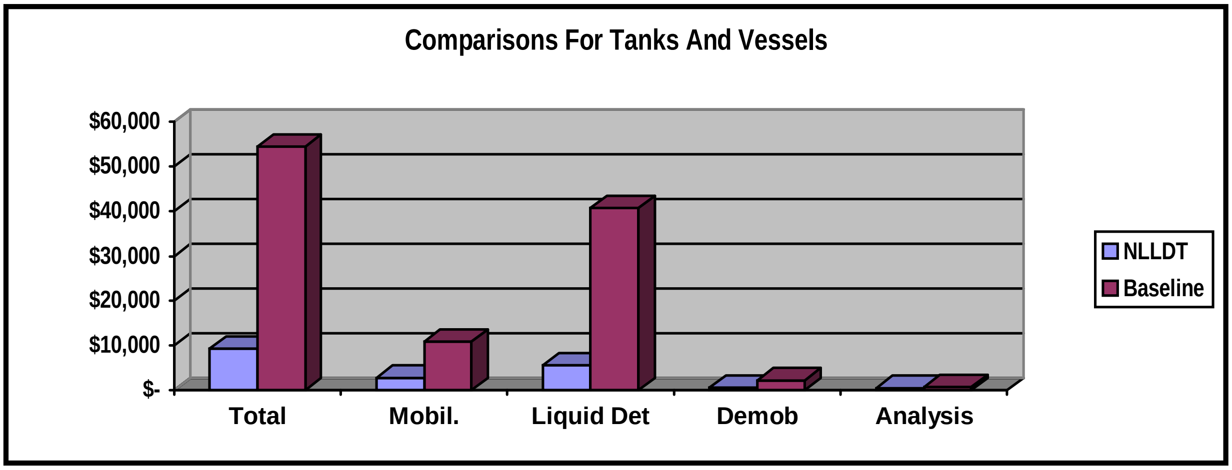
An average labor rate of $60.00 per hour was used to determine the total cost per tank.

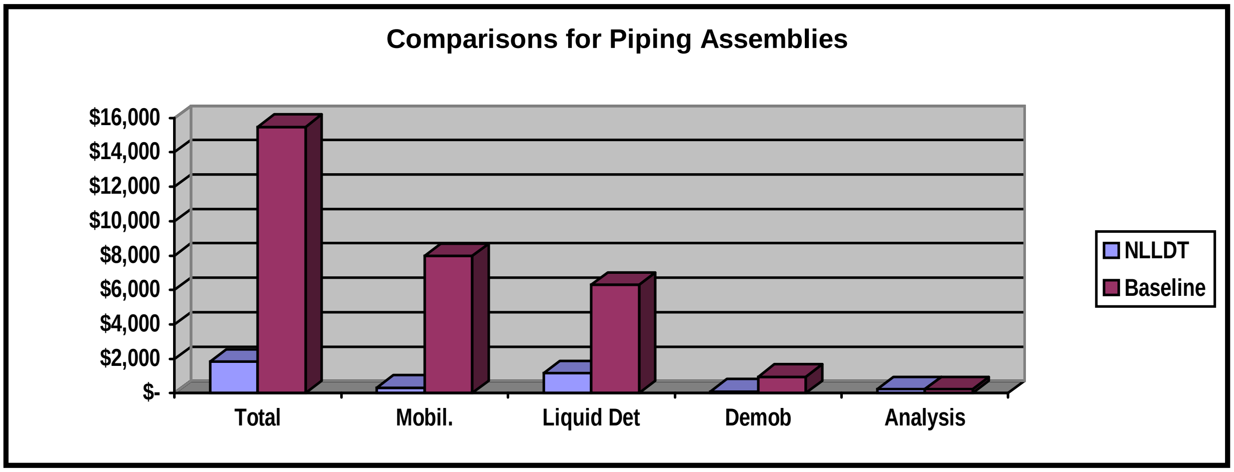
The cost estimates for both the baseline and the innovative technology follow the *Hazardous, Toxic and Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary* (USACE, 1996) for collecting costs into cost elements for reporting.

## ■ Cost Conclusions

For the conditions and assumptions of this demonstration, the NLLDT System successfully completed the surveys of the target tanks, vessels and piping assemblies at:

- Substantially (7 to 10 times) less cost than baseline procedure
- Much less time to conduct surveys which results in
- Far less exposure of personnel to the contamination hazards than would be expected from the baseline procedure.




## Figure 9 Cost Analysis Comparison Summaries

Figure 9 above presents a summary of the elements of the analysis and indicates a nearly 7 to 1 ratio (Baseline to NLLDT) in the overall (Tanks and Piping Assemblies) survey costs. The comparison is based on the demonstration for the NLLDT and historical data provided for the Baseline Procedures. Much of the difference results from the increase in productivity realized for the NLLDT System and the affect this has on the number of days that would be worked. The much longer time required for the baseline procedure to complete the Work Package, conduct the radiation survey and where necessary to erect the scaffolding has a major impact on the out come of the analysis. The support elements for the baseline are substantial. This is due to workers operating in a closer proximity to the contaminated areas, which requires more time for donning/doffing PPE, and more time required for RCT and industrial hygienist support.

Other than the baseline procedure needed to prepare a detailed work package the main difference in productivity is the time and number of craftsman required to physically open the tanks, vessels and piping assemblies and the caution required in surveying for gases/vapors before a physical (dipstick) or (hot-tap) measurement is made to determine the presence of liquids. Not included in this analysis are the additional Baseline Costs that would result from actually detecting or locating liquids when manually opening tanks or applying the hot-tap to a piping assembly. According to the information supplies by the ER Contractor this would result in a substantial increase in the Baseline Project costs.

Based on the assumption used in this analysis and the productivity results from the NLLDT demonstration it is projected that the operating cost of the system is approximately $1800 per day.

In conclusion, the overall savings associated with the use of the NLLDT System will depend on site-specific conditions and work requirements. For example, if access to target vessels and tanks is visually obstructed more time will be required to conduct the survey. If target piping assemblies are located in areas that are difficult to view, i.e. in the ceilings or overhead, application of external heat, when required, will be more complicated.

# SECTION 6

# REGULATORY/POLICY ISSUES

## ■ Regulatory Considerations

The regulatory/permitting issues related to the use of the NLLDT System at the Hanford Facility are governed by the following DOE Orders and safety and health regulations:

- DOE Orders

—DOE 5400.5 Radiation Protection of the Pubic and the Environment
—DOE 5480.11 Radiation Protection for Occupational Workers
—DOE 5820.2A Radioactive Waste Management

- Occupational Safety and Health Administration (OSHA) 29 CFR 1926

—1926.300 to 1926.307 Tools-Hand and Power
—1926.400 to 1926.449 Electrical - Definitions
—1926.28 Personal Protective Equipment
—1926.52 Occupational Noise Exposure
—1926.53 Ionizing Radiation
—1926.55 Gases, Vapors, Fumes, Dusts and Mists
—1926.102 Eye and Face Protection
—1926.103 Respiratory Protection

- OSHA 29 CFR 1910

—1910.211 to 1910.219 Machinery and Machine Guarding
—1910.241 to 1910.244 Hand and Portable Powered Tools and Other Hand-Held Equipment.
—1910.301 to 1910.399 Electrical - Definitions
—1910.95 Occupational Noise Exposure
—1910.132 General Requirements (Personal Protective Equipment)
—1910.133 Eye and Face Protection
—1910.134 Respiratory Protection
—1910.147 The Control of Hazardous Energy (Lockout/Tagout)

In addition to these regulations, the baseline technology would be subject to numerous OSHA regulations covering demolition, excavation, and operation of heavy equipment. The waste form requirements for low-level wastes from either technology, as specified by disposal facilities used by the DOE, include:

- *Hanford Site Solid Waste Acceptance Criteria:* WHC-EP-0063-4

## ■ Safety, Risks, Benefits, and Community Reaction

The Infrared Based Liquid Level Detection System is safe to operate. Hazards are those typical of working in industrial environments with electrically powered equipment. Physical hazards associated with working in confined spaces associated with tanks, vessels or piping assemblies are also present. The physical exertion required to move the NLLDT System from target to target, while working in protective clothing is moderate.

The use of the NLLDT System to detect liquids in vessels eliminates the need to physically open and inspect these vessels. Risks to workers associated with gaining access to these type objects and the possible exposure to radioactive or contaminated materials can nearly be eliminated.

The use of the NLLDT rather than the baseline procedure would have little impact on the community safety, environment, or socioeconomic issues. Any possible impacts would be favorable relative to the baseline procedure due to the reduced physical hazards and radiological exposure

# SECTION 7

# LESSONS LEARNED

## ■ Implementation Considerations

- Where ambient temperature conditions vary substantially (20 to 30°F) over the course of a day external heating should not have to be implemented to directly measure liquid levels in tanks and vessels. Where temperatures do not vary more than a few degrees during the day, an external heating strategy should be established to produce the most favorable results.
- The signature database should analyzed for comparison to the type of targets expected in the production surveys.
- When surveying piping assemblies' care should be taken to position the NLLDT System so as to reduce reflections.
- The NLLDT System will lose sensitivity when totally covered with plastic sheeting. Therefore, extra care is required when operating the system in contaminated areas.
- Close coordination of visual and infrared images will improve the post-test analysis of objects that are surveyed.

## ■ Technology Limitations and Needs for Future Development

- Where daily temperature variations are small, a target heating strategy must be employed to produce temperature variations. When operating in contaminated areas a technology (i.e. laser) that permits the remote application of heat would reduce the radiological exposure of personnel.
- Piping assemblies represent a special problem in direct liquid level detection. Usually successful detection of liquids will require a post-test analysis of a carefully planned sequence of infrared images.

## ■ Technology Selection Considerations

- The NLLDT System is suitable for DOE nuclear facility D&D sites or any other sites that must be surveyed to facilitate property transfer or release.
- The technology is useful for site characterization in support of D&D engineering design and during and subsequent to D&D activities.
- Use of the technology inherently reduces the exposure of personnel to radiological hazards

## APPENDIX A

## REFERENCES


*Canyon Disposition Initiative Demonstration of "Non-Intrusive Liquid Level Detection Technology"* Test Plan, May 28, 1999

*Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary*, U. S. Army Corps of Engineers, Washington, D. C., 1996

*Transactions in Measurement and Control, Volume 1, 2nd Edition, Non Contact Temperature Measurement. 1998*

Office of Management and Budget Circular No. A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*.

29 CFR Part 1910, "General Industry Occupational Safety and Health Standards," *Code of Federal Regulations, as amended*.

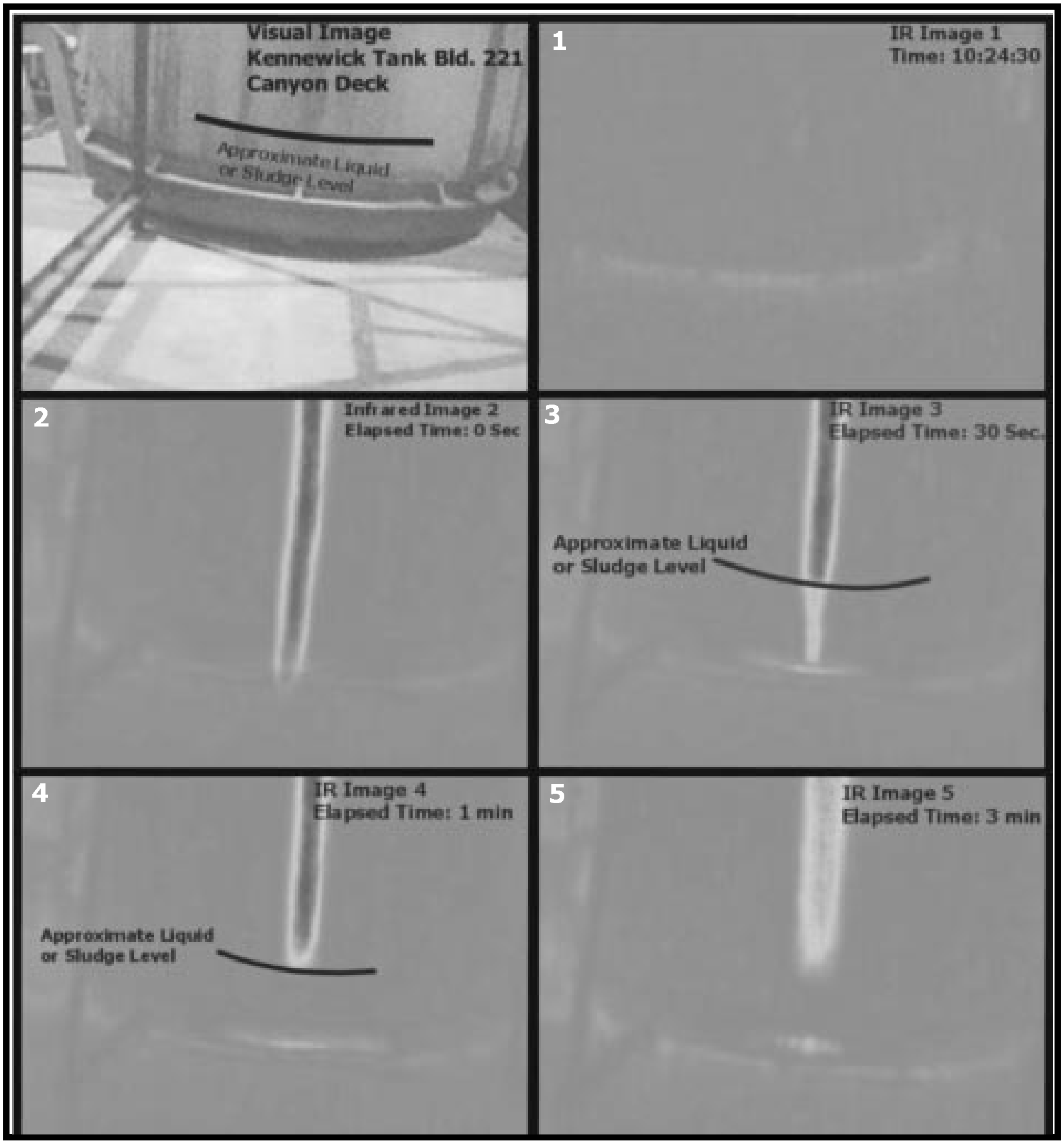
10 CFR Part 835, "Occupational Radiation Protection," *Code of Federal Regulations, as amended*

APPENDIX B

## Visual And Infrared Images

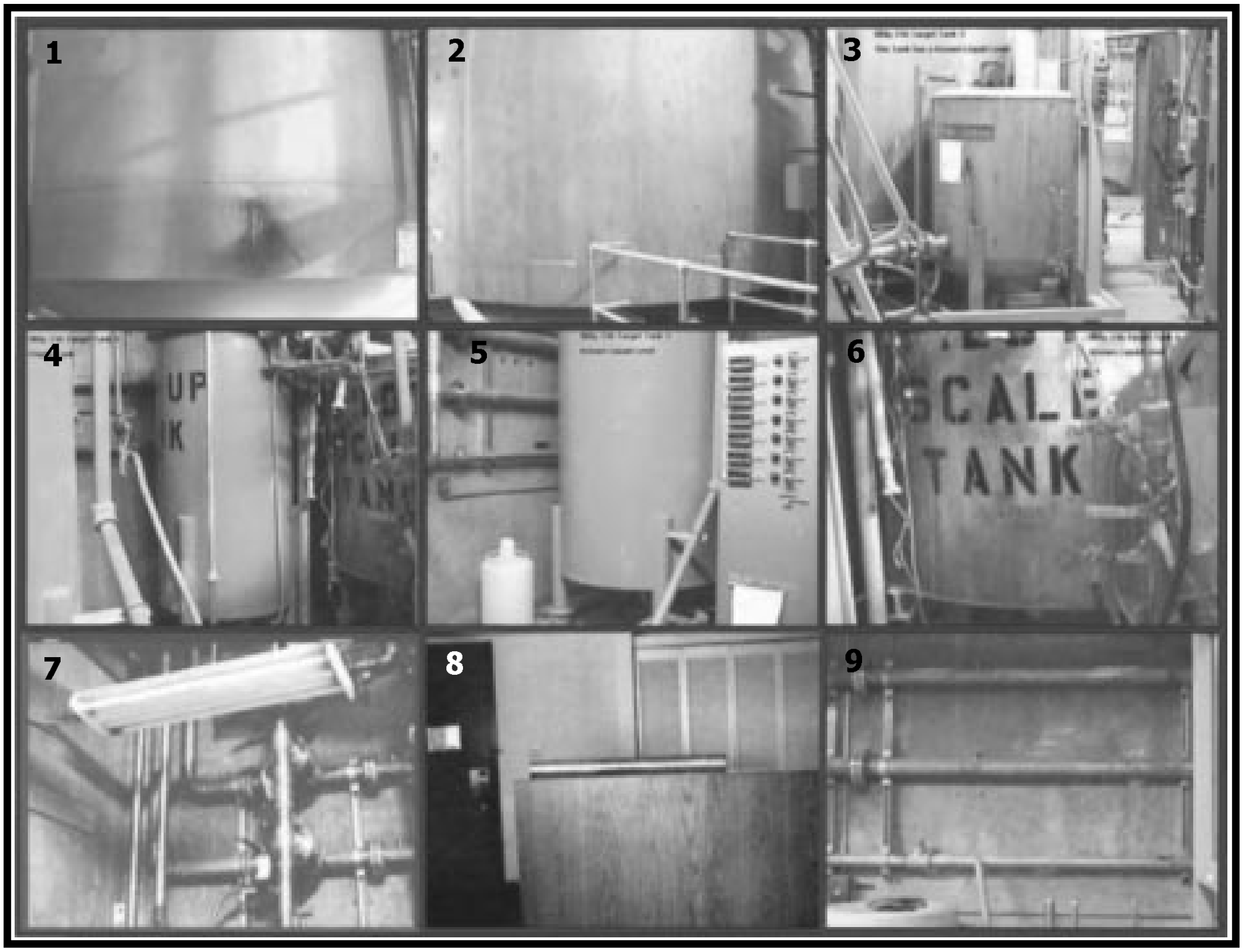
### ■ Example Liquid Level Detection

The Kennewick Tank in 221-U Facility is an example of liquid level detection using NLLDT. An external heating strip was applied for 15 seconds. Infrared images were captured in 15 second intervals. The heat sink properties of the liquid and sludge are clearly visible. The detection level indicated in the figure was verified.



## ■ Infrared Signature Target Vessels and Pipes

The following visual images are the targets used for developing Infrared Signature Data. It was intended that these images would provide data to compare to signatures captured in 221-U Facility..

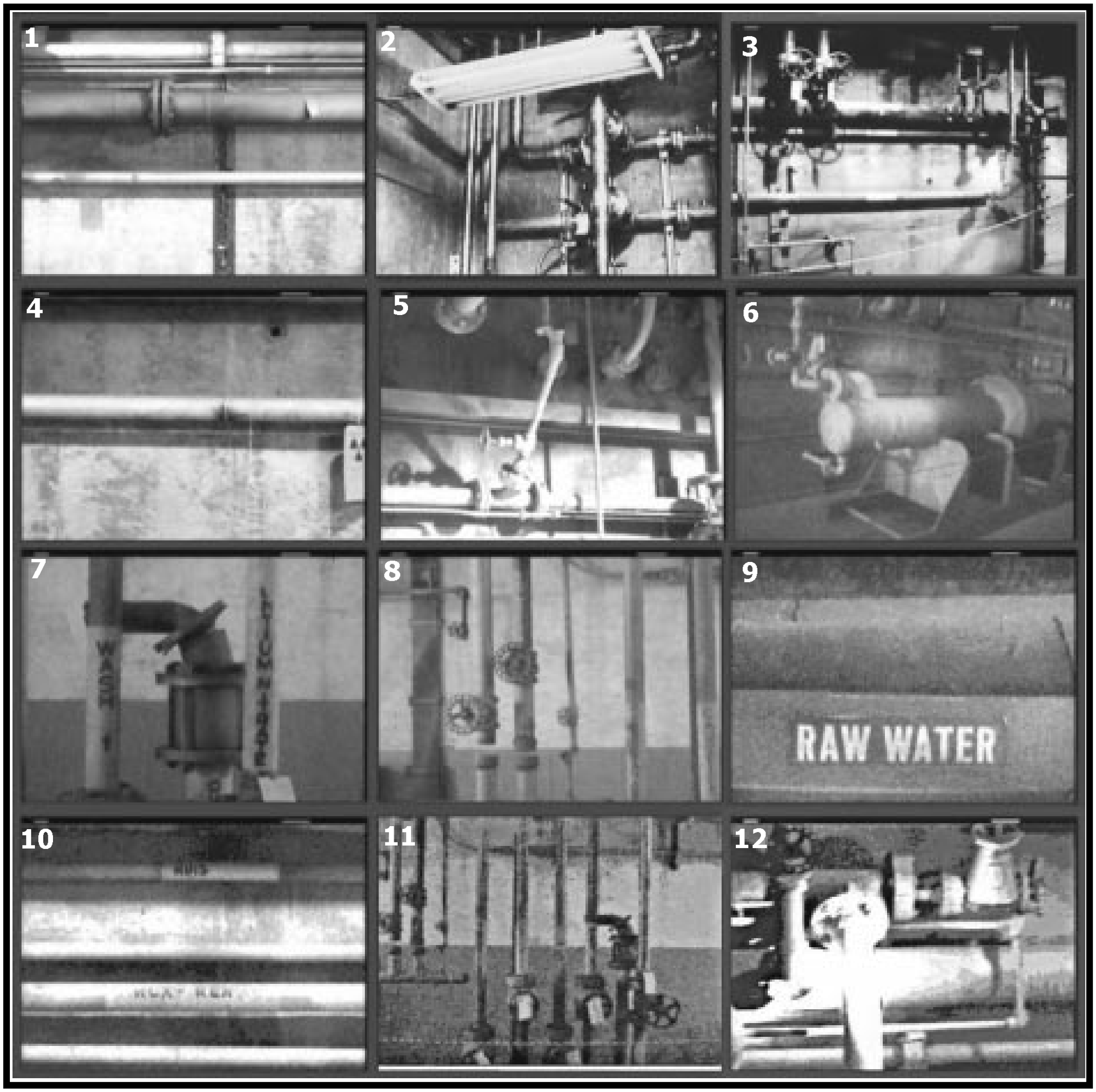



**Following is a description and location of the above images:**

1. **Stainless Steel Tank, main floor**
2. **Stainless Steel Tank, main floor**
3. **Stainless Steel Tank, basement level**
4. **Painted SS Tank, basement level**
5. **Painted SS Tank, basement level**
6. **Unpainted SS, basement level**
7. **Pipe Elbow, basement level, Galvanized**
8. **SS pipe used for calibration**
9. **Pipe assembly, top 2 pipes are 3 ½ " SS, bottom pipe is 2 ½ " Galvanized**

## ■ Pipe Gallery 221-U Facility

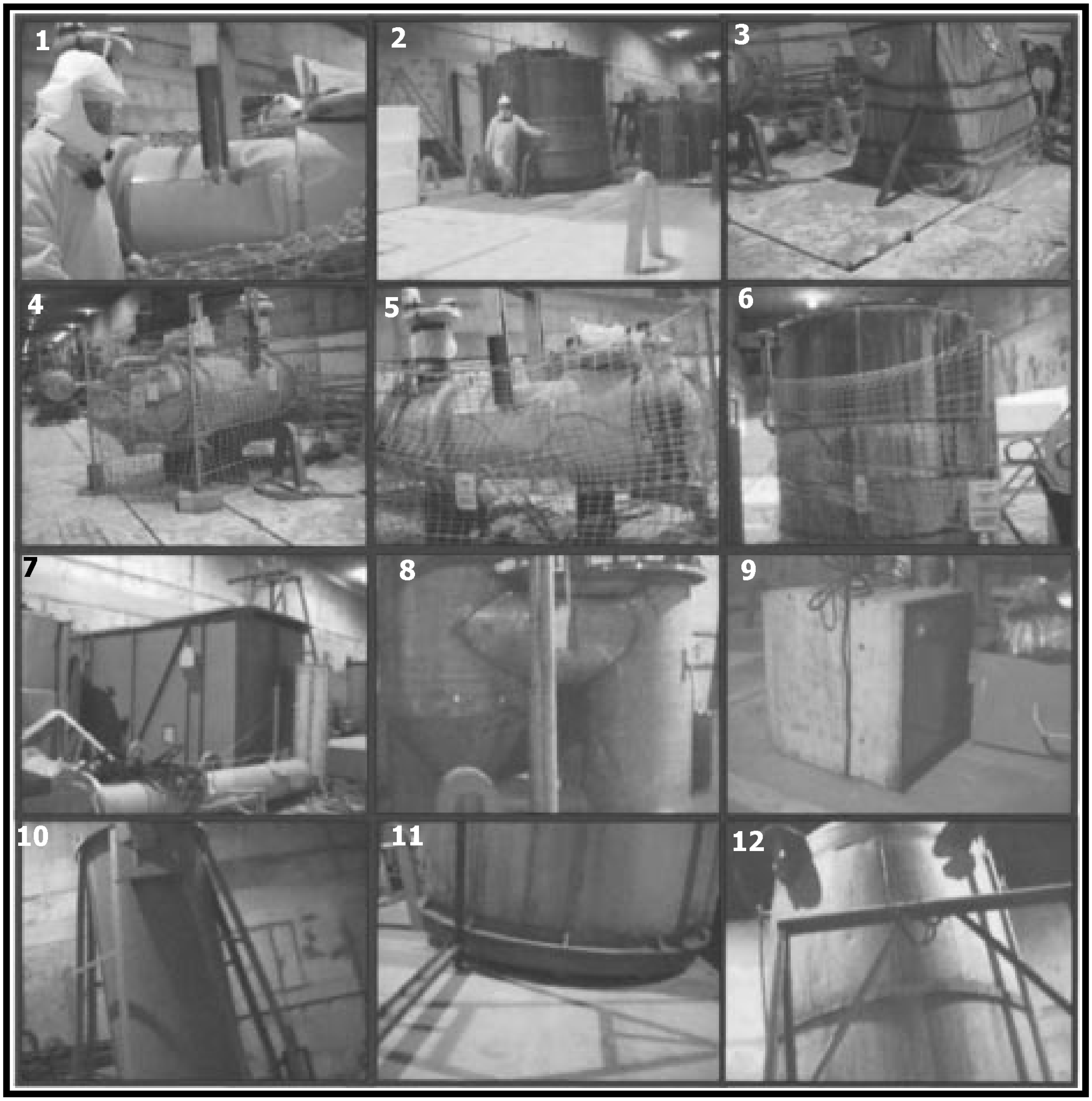
Following are visual images of the piping assemblies located in the 221-U Facility.




Following is listed the description and location of the above visual images:

1. Pipe Arrangement, 10' West Door 13
2. Valve and Pipe Assembly
3. Pipe Arrangement, 30' East Door 17
4. Single Pipe 25' West Door 15
5. Valve and Pipe Assembly, 42' West of Door 5
6. Tank/Vessel near Door 17
7. Elbow and Pipe Assembly
8. Valve and Pipe Assembly.
9. Raw Water Pipe, 90' East Door 15
10. Strontium Nitrate Line, 35' Feet West Door 9
11. Valve and Pipe Assembly, 4 Pipe Test
12. Pipe Elbow, 50' West Door 13, NaOH Leak.

## ■ 221-U Facility Target Objects




Following table contains a description and location of the target vessels and tank (shown above) selected by the Environmental Restoration Contractor for the NLLDT Demonstration:

| | |
|---|---|
| 1. High Radiation Wrapped Tank, Cell Number 6 Purex Centrifuge and Purex Heat Exchanger | 7. Waste CASIC Tank, Cell Number 18 Used for dry storage |
| 2. High Radiation Tank Cell 36 | 8. Double Tank Configuration |
| 3. Heat Exchanger and Centrifuge, Wrapped in Visqueen | 9. Wooden Box on Window Ledge. |
| 4. Heat Exchanger, High Radiation Protective Netting | 10. Debris Vessel, Stainless Steel |
| 5. Second View Heat Exchanger | 11. Lower Portion of Debris Vessel |
| 6. Large Tank with High Radiation Netting | 12. Debris Vessel, Stainless Steel |

# APPENDIX C

## Technology Cost Comparison

This Appendix contains definitions of cost elements, descriptions of assumptions, and computation of unit cost that are used in the cost analysis. The test plan *Canyon Disposition Initiative Demonstration of "Non-Intrusive Liquid Level Detection Technology"* was utilized as a model for the activity structure. The definitions used in this analysis are based on the work breakdown structure (WBS) for mobilization, characterization, demobilization, data assembly, and documentation as presented in the Reference *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary*, U. S. Army Corps of Engineers, Washington, D. C., 1996. Where applicable methodology and cost factors were developed utilizing information contained in the referenced ITSR documents.

Costs for the NLLDT are based on the use of one Thermographer, one Infrared Technician and a Radiological Control Technician with an average production rate of four target surveys per day. Monitoring for radiological contamination is included in this cost comparison. Those cost that are directly related to the technology demonstration and would not be incurred in routine production surveys; have not been included in this analysis. The ER Contractor prepared the description and cost elements for the baseline procedure. Tabulated cost for the NLLDT and the baseline are presented in the tables on pages 29,30 31 and 32 respectively.

## ■ Improved Technology – NLLDT System

**Mobilization (WBS 331.01**

**<u>Development of Infrared Signature Database:</u>** This cost element includes all of the activities associated with preparing an Infrared Signature Data Base. This is a one-time charge, the cost are pro-rated across all production tanks and vessels to be surveyed. It is assumed that six samples will be captured to develop the database. This will require four hours by a Thermographer and an Infrared Technician.

**<u>Transportation of Equipment to the Work Area:</u>** This cost element provides for transporting equipment from its' storage location on the site to the area where the surveys are to be conducted. In the demonstration example the survey site was the 221-U Facility. It was assumed that this would be done one time each production day.

**<u>Daily Equipment Setup:</u>** This cost element includes checking all components of the NLLDT System for proper operation. This also includes that battery packs are fully charged, extra batteries are available and that communication devices are in working order. This is done one time each day.

**<u>Wrap NLLDT System Components:</u>** On a daily basis, when the production surveys are to be conducted in a contaminated area, all NLLDT components are required to be wrapped with a plastic cover. This procedure is taken to prevent contamination of the equipment which, if it occurred could result in its' being discarded.

**Liquid Level Detection Demonstration (WBS 331.1**

**<u>Safety Meetings, Daily and Weekly:</u>** This cost element includes daily as well as weekly safety meeting for the entire crew at the U-221 Facility (Weekly) and specific daily safety meetings for the individuals involved in the production survey. For the purpose of maintaining the format of the cost summary, the weekly meeting time was divided by five and added to the time for the daily meetings.

**<u>Donning PPE:</u>** This cost item includes the time for each individual to fully suit-up as well as material cost for the PPE. The time spent for donning and doffing each day is based on observed times during the technology demonstration and from information supplied by the ERC. The material costs for daily PPE for one worker at the Hanford Site are shown in the table 4 located at the top of the next page.

**Infrared Survey of Target Vessels and Tanks:** A Thermographer and an Infrared Technician accompanied by a Radiological Control Technician are required to conduct the survey of the target vessels. Included in this cost element is the setup time (location) of the equipment for each survey, the time to capture visual images, the time, if required to apply external heating and the time to capture a sequence of infrared images.

**Table 4 Daily PPE Costs**

| Equipment | Cost Each Time Used $ | Number Used Per Day | Cost Per Day $ |
|---|---|---|---|
| Air Purifying System | 20.00 | 1 ea | 40.00 |
| Face Shield | 1.28 | 1 ea | 1.28 |
| Boots | 0.62 | 2 pr | 1.24 |
| Coveralls | 5.00 | 2 ea | 10.00 |
| Double Coveralls | | | 0.56 |
| Hood | 2.00 | 2 ea | 4.00 |
| Gloves (inner) | 0.14 | 2 pr | 0.28 |
| Gloves (outer) | 1.30 | 2 pr | 2.60 |
| Gloves (liner) | 0.29 | 2 pr | 0.58 |
| Rubber overshoes | 1.38 | 2 pr | 2.76 |

**Repositioning the NLLDT System:** This cost element includes moving the NLLDT System to new location after completing a survey of a target vessel. The number to times that it was required to move the system during a given day varied depending upon other work at the D&D site. For purposes of simplification and to be consistent with the baseline procedure, the number of moves per day is based on an average and was estimated to be four moves.

**Demobilization (WBS 331.21**

**Disassemble Equipment and Air Hoses and Decontaminate Equipment:** This activity includes unwrapping, disassembling, and decontamination the NLLDT equipment.

**Exit Radiologically Contaminated Area:** This activity includes doffing all PPE and personnel survey to check for contamination.

**Data Analysis & Documentation (WBS 331.17)**

**Prepare Daily Reports from Captured Infrared Images:** This activity includes downloading data collected from both the visual and infrared cameras to either a lap-top or office computer. These electronic files are used to prepare reports. This is measured as a daily activity.

**Other Cost Analysis Considerations**

This analysis is based on the survey and inspection of 15 tanks, vessels or piping assemblies. Based on the demonstration program four targets per day can be surveyed. This would include the usual lunch and work breaks; the time to pack up the equipment, leave the job site and return to the office and prepare the daily reports. Calculation of cost for the NLLDT System are based of these production assumptions in order to fairly judge it against the baseline procedure and to establish a basis by which other DOE sites can judge the technology. Thus table C-1 distills the deployment and implementation from an activity that took approximately six weeks to five fully productive days.

The Hanford Site indirect expenses for common support and materials are omitted from this analysis. Overhead rates for each DOE site are likely to vary in magnitude and application method. This omissions does not sacrifice the cost saving accuracy because is applied to both the baseline procedure and the NLLDT.

## ■ Baseline Procedure

**Mobilization (WBS 331.01)**

**Develop Work Package:** This activity includes many types of personnel engineering, radiological controls, planners, safety and supervision. The time would include development of Radiation Work Procedures (RWP's), a detailed work plan, scheduling and planning time, and all review and approval signatures.

**Radiation Survey of Vessels to be Inspected:** RCT's conduct Radiation Survey of tanks and vessels.

**Transportation of tools and equipment to work area:** This cost element provides for moving all tools, equipment and materials to the work where the visual inspection is to take place.

**Liquid Level Determination Procedure:**

**Safety Meeting, Daily and Weekly:** This activity involves everyone who works around or in the contaminated area where the visual inspections are to be performed. The pre-work briefing and safety meeting are required to be conducted every day and once a week. In calculating cost, the time for the weekly meeting is divided by 5 and added to the daily meeting times.

**Donning PPE:** This cost item includes the time for each individual to fully suit-up as well as the material cost for the PPE.

**When required build scaffolding around tanks:** This would include the time required to perform a pre-job survey of the tank be Radiation Control Technicians (RCT's), erect scaffolding by the riggers, support by Nuclear Chemical Operators (NCO's) and the time to exit the facility.

**Remove flanges:** This task involves the physical removal of the top flange of the tank or vessel by a pipe fitter and the reinstallation of the flange, if required, at the completion of the inspection.

**Measure of Vapor/Gas – Visual inspection:** This task involves a check of the vapor space in the tank or vessel by an Industrial Hygiene Technician (IHT) and a visual inspection of the inside of the tank, by the insertion of a dip stick to measure liquid level by an RCT and an NCO. The time required to enter and exit the facility is also included.

**Demobilization (WBS 331.21)**

**Removal of scaffolding:** This work includes the removal of the scaffolding from around the tank, its storage in the hazardous area and the time to exit and enter the facility

**Exit Radiologically Contaminated Area:** This activity includes doffing all PPE and personnel survey to check for contamination.

**Preparation of Inspection Report**

**Assemble a Report from the Inspection Results:** This cost activity includes logging all of the hand-recorded data into a lap-top or office computer for analysis and report generation.

**Other Cost Considerations**

The ER Contractor based the manual inspection procedure on the survey of 15 targets with an average production rate of four targets per day. It is assumed that three entries per target would be required in addition to the work package. Assume that 10% of the equipment would require scaffolding.

An average labor rate of $60.00 per hour was used to determine the total cost per tank.

## APPENDIX C Cost Summary for NLLDT

| Work Breakdown Structure (WBS) | Unit Cost | | | | | | Total Quanity (TQ) | Unit of Measure | Total Cost (TC) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | Labor | | Equipment | | Other | Total Unit Cost | | | | |
| | Hours | Rate | Hours | Rate | | | | | | |
| **MOBILIZATION (WBS 331.01** | | | | | | | **Subtotal:** | | **$2,700.00** | |
| Development of Infrared Signature Database | 16.0 | $ 60.00 | 16.0 | $ 40.00 | | $ 1,600.00 | | Hours | $ 1,600.00 | Time and equipment used to survey 6 targets. Time also to prepare signature report |
| Transportation of Equipment to the Work Area | 1.0 | $ 60.00 | 0.5 | $ 40.00 | | $ 80.00 | 4 | Days | $ 320.00 | Time to take the equipment from a storage area to the survey site |
| Daily Equipment Setup | 0.75 | $ 60.00 | 1.50 | $ 40.00 | | $ 105.00 | 4 | Days | $ 420.00 | Initial setup of the equipment 45 minutes |
| Wrap NLLDT System Components | 1.0 | $ 60.00 | 0.75 | $ 40.00 | | $ 90.00 | 4 | Days | $ 360.00 | Includes 30 minute for an RCT |
| **LIQUID LEVEL DETECTION DEMONSTRATION (WBS 331.1)** | | | | | | | **Subtotal:** | | **$5,590.00** | |
| Safety Meeting, Daily and Weekly | 0.50 | $ 60.00 | | | | $ 30.00 | 4 | Days | $ 120.00 | Based on Hanford Site Requirement to have one weekly meeting and a daily job review |
| Don & Doff PPE | 1.50 | $ 60.00 | | | $160.00 | $ 90.00 | 4 | Days | $ 520.00 | Time included to RCT assistance |
| Infrared Survey of Target Tanks and Vessels | 3.00 | $ 60.00 | 1.00 | $ 40.00 | | $ 220.00 | 15 | each | $ 3,300.00 | One RCT included to assist the Thermographer |
| Repositing the NLLDT System | 1.50 | $ 60.00 | 0.50 | $ 40.00 | | $ 110.00 | 15 | each | $ 1,650.00 | Based on an average of 4 moves per day |
| **DEMOBILIZATION (WBS 331.21** | | | | | | | **Subtotal:** | | **$560.00** | |
| Disassemble and Decontaminate Equipment | 1.00 | $ 60.00 | 0.25 | $ 40.00 | | $ 70.00 | 4.0 | Days | $ 280.00 | Equipment standby and time for an RCT to survey materials |
| Exit Radiologically Contaminated Area | 1.00 | $ 60.00 | 0.25 | $ 40.00 | | $ 70.00 | 4.0 | Days | $ 280.00 | |
| **DATA ANALYSIS & DOCUMENTATION (WBS 331.17)** | | | | | | | **Subtotal** | | **$480.00** | |
| Prepare Daily Reports from Captured Infrared Images | 2 | $ 60.00 | | | | $ 120.00 | 4.0 | days | $ 480.00 | Time to prepare summary and final reports |
| | | | | | | | **TOTAL** | | **$9,330.00** | Daily cost $1866.00; $622 each |

## APPENDIX C Cost Summary NLLDT for Piping Assemblies

| Work Breakdown Structure (WBS) | Unit Cost | | | | | | Total Quanity (TQ) | Unit of Measure | Total Cost (TC) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | Labor | | Equipment | | Other | Total Unit Cost | | | | |
| | Hours | Rate | Hours | Rate | | | | | | |
| **MOBILIZATION (WBS 331.01** | | | | | | | **Subtotal:** | | **$332.50** | |
| Transportation of Equipment to the Work Area | 1.0 | $ 60.00 | 0.5 | $ 40.00 | | $ 80.00 | 1.5 | Hours | $ 120.00 | Time to take the equipment from a storage area to the survey site |
| Daily Equipment Setup | 0.75 | $ 60.00 | 0.75 | $ 40.00 | | $ 75.00 | 1.5 | Days | $ 112.50 | Initial setup of the equipment 45 minutes |
| Wrap NLLDT System Components | 1.0 | $ 60.00 | 1.00 | $ 40.00 | | $ 100.00 | 1.0 | Days | $ 100.00 | Includes 30 minute for an RCT |
| **LIQUID LEVEL DETECTION DEMONSTRATION (WBS 331.1)** | | | | | | | **Subtotal:** | | **$1,170.00** | |
| Safety Meeting, Daily and Weekly | 1.50 | $ 60.00 | | | | $ 90.00 | 1.5 | Hours | $ 135.00 | |
| Don & Doff PPE | 1.50 | $ 60.00 | | | $100.00 | $ 90.00 | 1.5 | Hours | $ 235.00 | Time included for RCT assistance |
| Infrared Survey of Target Tanks and Vessels | 0.25 | $ 60.00 | 0.25 | $ 40.00 | | $ 25.00 | 16 | each | $ 400.00 | One RCT included to assist the Thermographer |
| Repositing the NLLDT System | 0.25 | $ 60.00 | 0.25 | $ 40.00 | | $ 25.00 | 16 | each | $ 400.00 | |
| **DEMOBILIZATION (WBS 331.21** | | | | | | | **Subtotal:** | | **$105.00** | |
| Disassemble and Decontaminate Equipment | 1.00 | $ 60.00 | | | | $ 60.00 | 1.0 | Hours | $ 60.00 | Equipment standby and time for an RCT to survey materials |
| Exit Radiologically Contaminated Area | 0.50 | $ 60.00 | | | | $ 30.00 | 1.5 | Hours | $ 45.00 | |
| **DATA ANALYSIS & DOCUMENTATION (WBS 331.17)** | | | | | | | **Subtotal** | | **$240.00** | |
| Prepare Daily Reports from Captured Infrared Images | 4 | $ 60.00 | | | | $ 240.00 | 1.0 | days | $ 240.00 | Time to prepare summary and final reports |
| | | | | | | | **TOTAL** | | **$1,847.50** | $115 each |

| APPENDIX C Cost Summary for Baseline Procedure | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Work Breakdown Structure (WBS)** | **Unit Cost** | | | | | | **Total Quanity (TQ)** | **Unit of Measure** | **Total Cost (TC)** | **Comments** |
| | **Labor** | | **Equipment** | | **Other** | **Total Unit Cost** | | | | |
| | **Hours** | **Rate** | **Hours** | **Rate** | | | | | | |
| **MOBILIZATION (WBS 331.01** | | | | | | | | **Subtotal:** | **$10,840.00** | |
| Develop Wlork Package | 100.0 | $ 60.00 | | - | | $ 6,000.00 | | Hours | $ 6,000.00 | Requires personnel from Engineering, Radiologcal Control, etc. |
| Radiation Survey of Tanks and Vessels to be inspected | 4.0 | $ 60.00 | | | | $ 240.00 | 15 | Each | $ 3,600.00 | Time to conduct Pre-Job Surveys by RTC's of all tanks and vessels to be inspected |
| Transportation of tools and equipment to work area | 1.0 | $ 60.00 | | - | $ 1,000.00 | $ 60.00 | 4 | Days | $ 1,240.00 | The $1000 is for miscellanous equipment |
| **LIQUID LEVEL DETECTION DEMONSTRATION (WBS 331.1)** | | | | | | | | **Subtotal:** | **$40,640.00** | |
| Safety Meeting, Daily and Weekly | 0.50 | $ 60.00 | | | | $ 30.00 | 4 | Days | $ 120.00 | |
| Don & Doff PPE | 1.50 | $ 60.00 | | | $ 500.00 | $ 90.00 | 28 | Entries | $ 16,520.00 | One time cost of PPE is $500 per entry |
| Where Required Build Scaffolding Around Tanks and Vessels | 20.00 | $ 60.00 | | | | $ 1,200.00 | 2 | Each | $ 2,400.00 | Scaffolds are erected by Riggers |
| Remove Where Required flanges | 10.00 | $ 60.00 | | | | $ 600.00 | 15 | Each | $ 9,000.00 | Pipe Fitters remove where required all flanges |
| Measure Vapor/Gas - Conduct Visual Inspection | 14.00 | $ 60.00 | | | | $ 840.00 | 15 | Each | $ 12,600.00 | Nuclear Chemical Operators measure for vapors and gases. |
| **DEMOBILIZATION (WBS 331.21** | | | | | | | | **Subtotal:** | **$2,220.00** | |
| Remove Scaffolding where required | 14.00 | $ 60.00 | | | | $ 840.00 | 2.0 | Each | $ 1,680.00 | |
| Exit Radiologically Contaminated Area | 1.50 | $ 60.00 | | | | $ 90.00 | 6.0 | Days | $ 540.00 | Time for RCT to survey all personnel and equipment |
| **DATA ANALYSIS & DOCUMENTATION (WBS 331.17)** | | | | | | | | **Subtotal** | **$720.00** | |
| Prepare Daily Hardcopy Reports | 2 | $ 60.00 | | | | $ 120.00 | 6.0 | days | $ 720.00 | |
| | | | | | | | | **TOTAL** | **$54,420.00** | Cost Per Day $10,884.00 |

## APPENDIX C Cost Summary, Baseline Procedure for Pipes

| Work Breakdown Structure (WBS) | Unit Cost | | | | | | Total Quanity (TQ) | Unit of Measure | Total Cost (TC) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | Labor | | Equipment | | Other | Total Unit Cost | | | | |
| | Hours | Rate | Hours | Rate | | | | | | |
| **MOBILIZATION (WBS 331.01** | | | | | | | **Subtotal:** | | **$7,980.00** | |
| Develop Wlork Package | 100.0 | $ 60.00 | | - | | $ 6,000.00 | | Hours | $ 6,000.00 | Requires personnel from Engineering, Radiologcal Control, etc. |
| Radiation Survey of Piping Assemblies to be inspected | 2.0 | $ 60.00 | | | | $ 120.00 | 16 | Each | $ 1,920.00 | Time to conduct Pre-Job Surveys by RTC's of Area to be inspected. Assume 16 Targets |
| Transportation of tools and equipment to work area | 1.0 | $ 60.00 | | - | | $ 60.00 | 1 | Hours | $ 60.00 | |
| **LIQUID LEVEL DETECTION DEMONSTRATION (WBS 331.1)** | | | | | | | **Subtotal:** | | **$6,300.00** | |
| Safety Meeting, Daily and Weekly | 1.00 | $ 60.00 | | | | $ 60.00 | 1 | Hours | $ 60.00 | |
| Don & Doff PPE | 1.00 | $ 60.00 | | | $ 100.00 | $ 60.00 | 8 | Entries | $ 1,280.00 | One time cost of PPE is $100 per entry |
| Install Hot-Tap and determine if Liquid Exists | 1.00 | $ 60.00 | | | $ 250.00 | $ 60.00 | 16 | Each | $ 4,960.00 | Requires 1 RCT, 1 NCO and 1 Pipefitter |
| **DEMOBILIZATION (WBS 331.21** | | | | | | | **Subtotal:** | | **$960.00** | |
| Breakdown and Survey the Work Area, Exit Area | 1.00 | $ 60.00 | | | | $ 60.00 | 16.0 | Each | $ 960.00 | |
| **DATA ANALYSIS & DOCUMENTATION (WBS 331.17)** | | | | | | | **Subtotal** | | **$240.00** | |
| Prepare Daily Hardcopy Reports | 4 | $ 60.00 | | | | $ 240.00 | 1.0 | Hours | $ 240.00 | |
| | | | | | | | **TOTAL** | | **$15,480.00** | Cost Per Day $3,096 |

APPENDIX D

# ACRONYMS AND ABBREVIATIONS

| Acronym | Description |
|---|---|
| ALARA | As Low As Reasonable Achievable |
| BHI | Bechtel Hanford, Inc. |
| CFR | Code of Federal Regulations |
| D&D | Decontamination and decommissioning |
| DDFA | Deactivation and Decommissioning Focus Area |
| DOD | Department of Defense |
| DOE | Department of Energy |
| DOE-RL | U. S. Department of Energy, Richland Operations Office |
| EPA | Environmental Protection Agency |
| ERC | Environmental Restoration Contractor |
| FETA | Federal Energy Technology Center |
| NLLDT | Liquid Level Detection Technology |
| LSDP | Large-Scale Demonstration Project |
| NCT | Nuclear, Chemical Technician |
| NRC | Nuclear Regulatory Commission |
| OSHA | Occupational Safety and Health Administration |
| PAPR | Powered Air Purifying Respirators |
| PPE | Personnel Protective Equipment |
| RCT | Radiological Control Technician |
| USACE | United States Army Corps of Engineers |
| WBS | Work Breakdown Structure |