Cost/Performance Report
Ultrasonic Liquid Level Detection Technology

SUMMARY

Information on standing liquid in vessels or piping is needed for planning decommissioning activities. The Ultrasonic Liquid Level Detection System uses ultrasonic/acoustic wave transmission through solids and liquids to determine liquid levels. A *pulse-echo* technique is used that employs a single sensor.

The Ultrasonic Liquid Level Detection System was deployed in the 221-U Facility at the Hanford Site during fiscal year 2000. The results of the ultrasound examinations were identical to the results obtained using traditional methods and/or an infrared liquid level detection method. Analysis of the costs associated with the Ultrasonic Liquid Level Detection System indicates significant savings compared to baseline. Cost savings are realized due to significant reductions in work scope planning, engineering, and operations costs. In addition, personnel exposure to potentially hazardous conditions is significantly reduced using the Ultrasonic Liquid Level Detection technology.

Deployment of the Ultrasonic Liquid Level Detection System was accomplished through the support of the Deactivation and Decommissioning Focus Area, which is managed by the National Energy Technology Laboratory. This work was conducted as part of the 221-U Facility characterization in support of the Canyon Disposition Initiative Project. Characterization information is being obtained to support a Record of Decision for the 221-U Facility, which will establish regulatory and technical precedence for future disposition of the other chemical processing facilities (canyons).

INNOVATIVE TECHNOLOGY DESCRIPTION

The Ultrasonic Liquid Level Detection System was designed and manufactured by Pacific Northwest National Laboratory. The technology uses ultrasonic transducer (UT) pulse-echo-based instruments with custom electronics designed for the manual detection of freestanding liquid in drums, tanks, and pipes. The Ultrasonic Liquid Level Detection System provides the capability for real-time, simple “yes/no” electronic detection/determination of standing liquid.

The ability for liquids (e.g., water) to couple and support acoustic waves is the principle used to determine liquid levels. A gel is used to couple the acoustic wave from the piezoelectric-based sensor into the wall of the vessel to be tested. The metal wall has acoustic impedance similar to that of the gel. This acoustic impedance combined with low attenuation conducts the acoustic wave to the other side of the wall. If the tank contains water or a liquid with similar acoustic impedance, then the inner wall wave will be transmitted at the interface and coupled

into the liquid. The liquid will support the wave transmission across the tank diameter to the far side, where some of the wave will be reflected back across the liquid. This reflected wave is coupled back into the near wall where it is detected as an “echo” by the same sensor that launched the wave.

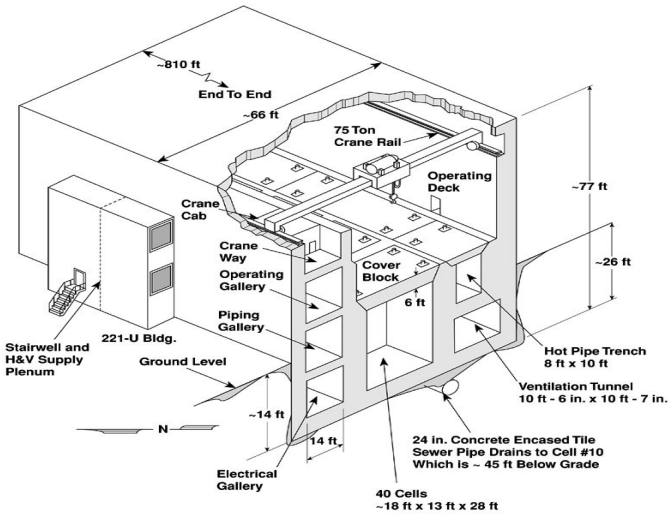
In a scanning mode, the sensor is physically moved along an inspection axis. If the liquid level transitions to air, then the return echo disappears; this location is the fill-level line. The instrument will denote this point by lighting the “no liquid detected” light-emitting diode (LED) and turning off the “liquid detected” LED. Solids, such as sludges, are very attenuative and produce the same apparent result as air; therefore, this instrument is restricted to items that contain liquids.

Two similar devices comprise the Ultrasonic Liquid Level Detection System: a barrel/tank tester and a pipe tester. The barrel/tank tester model uses a 1-MHz transducer and is intended for use on single-walled steel vessels with diameters rangingfrom at least 0.3 to 3 m (1 to 10 ft). The pipe tester uses 5-MHz transducer and is intended for use on pipe diameters of 10 to 25 cm (4 to 10 in.). Both units use a high-voltage (385 V) excitation pulse source to launch the ultrasonic pulse. The width of the high-voltage pulse is tailored to the transducer frequency. The units are powered by a separate 12-V battery pack and will operate for at least 4 hours. An accompanying AC charger is available for overnight recharging of the battery pack.

DEPLOYMENT SITE INFORMATION

The 221-U Facility is a multi-story building, approximately 246.9 m (810 ft) in length. The building and equipment were originally designed to support the production of plutonium; however, the facility was never used for this purpose. After construction, the 211-U Facility was remodeled and used for the recovery of uranium from tank farm wastes. The foundation, walls, and roof are constructed of reinforced concrete. The building is divided into two main portions, the canyon and the galleries, by a concrete wall running the full length of the building. The length of the building is divided into 20 sections, at approximately 12.2-m (40-ft) intervals. The cells on the canyon deck and the cells beneath the canyon deck are currently being used to store contaminated process equipment. All cell piping, except process transfer lines, was brought to the pipe gallery, terminating in connections on the wall. From here, connections were made to the weigh tanks and control boards located in the operating gallery.

221-U Canyon Building Section



DEPLOYMENT DESCRIPTION

Deployment of the Ultrasonic Liquid Level Detection System was performed in concert with normal and routine operations activities and in accordance with existing generic work procedures and authorizations at the 221-U Facility.

The Ultrasonic Liquid Level Detection System was deployed to examine selected tanks and vessels located on the 221-U Facility canyon deck. This technology was also deployed to examine piping sections in the operating gallery. Results of the deployment were comparable and consistent with results from other forms of examination, including traditional methods (e.g., visual inspection, boroscopic visual inspection, dipsticks, hot taps, and low-point drain) and an emerging technology (i.e., infrared liquid level detection) deployed on the same tanks, vessels, and piping sections.

Two instruments based on similar operating principles were deployed as part of this technology demonstration:

- The barrel/tank tester, which is optimized for use on large-diameter tanks or vessels
- The pipe tester, which is optimized for smaller diameter piping.

Regularly assigned operations and maintenance personnel received onsite instruction in the operation of the ultrasonic barrel/tank and pipe testers. The designer and manufacturer of the ultrasonic testers conducted an orientation and training. Training consisted of a 15-minute briefing and a demonstration of the instruments in a nonradiologically controlled area. The test fixture consisted of a standard 208-L (55-gal) drum partially filled with water. Operation of the testers proved to be so simple that additional written instructions or procedures were not deemed necessary.

Equipment selected for examination was known to be generally free of substantial volumes of freestanding liquid. The goal of the liquid level detection efforts was to identify residual or entrapped liquids. Disassembly of equipment, breaching of piping connections, opening and subsequent closure of inspection ports, or physical penetration of sealed systems and equipment (as described in the baseline description below) was not required. Actual deployment of the Ultrasonic Liquid Level Detection System was performed at or near the canyon deck level, therefore, the erection and subsequent removal of scaffolding was not necessary.

Entry into the canyon deck area was accomplished in a routine manner and within normal radiological monitoring and survey requirements. Liquid level detection consisted of approaching the target equipment, applying a small amount of acoustic coupling gel to the target surface, and passing the instrument sensor over the target surfaces to determine the existence of a liquid/air interface. Following application of the Ultrasonic Liquid Level Detection System sensors to the target equipment, radiological survey and smear collection were performed by normally assigned radiological control technicians (RCTs). These surveys and smear collections were significantly less rigorous and extensive than those required for performance of the baseline liquid level detection methods. This level of participation by the RCTs is within the normal entry and generic work requirement parameters.

All of the targets selected as subjects for the Ultrasonic Liquid Level Detection System deployment had been previously examined using traditional methods and/or an infrared liquid level detection method. Selected targets included the following:

- <u>Piping sections</u>
  - 228-mm (9-in.) schedule 40 carbon steel
  - 101-mm (4-in.) schedule 40 stainless steel
  - 50-mm (2-in.) schedule 40 stainless steel (six locations)
  - 25-mm (1-in.) schedule 40 stainless steel
- <u>Tanks/vessels</u>
  - Four tanks/vessels were examined (material of construction is stainless steel rolled plate, 0.64 cm [0.25 in.] and 1.3 cm [0.5 in.] in thickness).

BASELINE DESCRIPTION

Direct visual inspection, boroscopic visual inspection, and dipsticks are the traditional baseline technologies for determining the presence or absence of freestanding liquids in equipment and piping. The equipment subject to examination for the presence of freestanding liquid falls into two general categories: tanks or vessels, and piping sections.

Tanks

Tanks, vessels, and other equipment installed as part of facility processes are typically constructed or equipped with removable piping connections, inspection ports, covers, manholes, etc. The baseline method to determine the liquid level within a tank located on the canyon deck includes, but is not limited to, the following steps:

- Develop work instruction package -- This effort includes many different types of personnel, including, but not limited to, engineering, radiological controls, planning and scheduling, safety, operations, and crafts supervision. Work package preparation includes radiation work permits, a detailed work plan, scheduling and planning, material identification and procurement, and a comprehensive review and approval process.

- Erect scaffolding around the tank **--** Scaffolding is required to accommodate personnel access to the top of the tank or vessel in order to open ports, or to perform equipment penetrations, for the introduction of traditional level measurement instrumentation or to perform visual inspections. This effort includes, but is not limited to, pre-job-surveys of the subject equipment by RCTs, erecting scaffolding by riggers, support by nuclear chemical operators (NCOs), and the time and materials required for entry to and exit from the canyon deck. The work would require three riggers, two RTCs, and two NCOs.

  It is important to note that equipment selected for examination is generally free of substantial volumes of freestanding liquid. The goal of liquid level detection efforts is to identify residual or entrapped liquids. For this reason, erecting scaffolding is essentially for personnel protection and safety during the performance of mechanical access to the interior of equipment under examination.

- Open port or perform penetration of the equipment -- This effort includes, but is not limited to, physically removing the top flange, opening any available access port, or preparing and installing a new equipment penetration.

- Perform vapor/gas measurements and radiological survey **--** In concert with opening of an existing access port or installing a new penetration, a check of the tank or vessel internal atmosphere/gas space must be performed. Work of this nature requires services provided by an industrial hygiene technician and a RCT.

- Perform liquid level detection using traditional baseline methods **--** A visual inspection is made inside the equipment and a dipstick is inserted (or other method) to measure the liquid level.

- Close port or seal penetration **--** This effort includes, but is not limited to, the physically replacing the top flange, closing of an existing access port, or closing/sealing a new equipment penetration.

- Remove scaffolding **--** This effort includes, but is not limited to, the removal of scaffolding and or fall protection from around the tank, disassembly, staging, storage on the canyon deck, and the time and materials required for entry to and exit from the canyon deck. This activity typically requires three riggers, two RCTs, and two NCOs.

Piping Sections

The baseline liquid detection in pipes is accomplished by finding low points and opening existing valves or tapping the pipe for insertion of sampling apparatus. Baseline level detection technology and application is similar to that associated with tanks and vessels.

The baseline method to determine if liquid is present within the pipe includes, but is not limited to, the following.

- Develop work package **--** Similar scope and resources as described for tanks and vessels.

- Prepare work area **--** This effort includes, but is not limited to, the pre-job survey of the pipe by RCTs and the establishment of a temporary contamination control zone by NCOs. This effort requires one RTC and one NCO.

- Hot tap pipe/verify liquid presence **--** This effort includes, but is not limited to, physical installation of the hot tap and the determination of liquid presence by opening the hot tap valve. This effort requires one RCT, one NCO, and one pipefitter.

- Clean up work area -- This effort requires one RCT and one NCO.

COST COMPARISON

Tables 1 and 2 present cost breakdowns for the baseline and Ultrasonic Liquid Level Detection System. The cost analysis is based on multiple separate and diverse equipment targets. The differential in costs must be expected to change depending on requirements for the erection of scaffolding and/or fall protection. To amortize the high scaffolding/fall protection costs, reducing the number of targets to be examined would not provide a realistic cost comparison. In the example presented, only a portion of the targets examined were deemed to require erection and disassembly of scaffolding/fall protection.

It should also be noted that the efforts required to prepare a job-specific work instruction are not directly proportional to the number of equipment targets to be examined. To provide some reduction of the baseline costs via economy of scale, multiple equipment targets were used in this example. As noted previously, the efforts required for job-specific work instructions associated with the Ultrasonic Liquid Level Detection System are minimal and generic. Therefore, the cost values shown in the example are conservative, regardless of job scope.

Capital cost for the Ultrasonic Liquid Level Detection System instruments are not shown in Tables 1 and 2. Although initial development costs of the devices used in this technology deployment demonstration were significant, acquisition costs of similar devices used in a production or routine operations mode are much less. Estimated costs for similar instruments is estimated at $6,000 to $8,000 per unit. These instruments are nonexpendable with a long useful life. Amortizing this modest capital cost over instrument lifetime is not a significant contributor to overall cost.

The cost comparison does not include basic costs that are common to both methods (e.g., routine work planning and radiation surveys). As shown in Table 1, the cost estimates for evaluating 15 pieces of equipment are $54,800 using baseline methods and $3,200 using the Ultrasonic Liquid Level Detection System. The cost estimates for evaluating 16 pieces of piping are $16,400 using baseline methods and $900 using the Ultrasonic Liquid Detection System. This demonstrated cost reduction factors of approximately 17 to 18, depending on the application.

Note: Deployment of the Ultrasonic Liquid Level Detection System was performed in the operating gallery. The costs developed in Tables 1 and 2 are based on conduct of operations in this area, which has less stringent entry requirements smaller costs for attendant personal protective equipment than the canyon deck area. Application of the ultrasonic technology to the canyon deck area will result in an increase in savings due to the smaller personnel and work time requirements.

Table 1. Liquid Detection in Tanks/Vessels
Cost Comparison Development.

Baseline	
Assumption: 15 pieces of equipment; 2 pieces require scaffolding; one work package to cover entire work scope	
Baseline work package preparation	100 m-hrs
Setup and radiation survey for two tanks requiring scaffolding (28 m-hrs each)	56 m-hrs
Radiation survey of remaining 13 tanks (4 m-hrs each)	52 m-hrs
Visual inspection/physical measurement of 15 tanks (24 m-hrs each)	360 m-hrs
Breakdown of equipment for two tanks (24 m-hrs each)	48 m-hrs
Total time for 15 pieces of equipment	**616 m-hrs**
Labor (at an average rate of $66.00 per hour)	$40,600
Miscellaneous equipment	$1,000
Personal protective equipment (based on $400 per entry)	$13,200
Total Cost	**$54,800**
Ultrasonic Liquid Detection Level System	
Assumption: Eight tanks per entry	
Addition to existing work package	2 m-hrs
Training	2 m-hrs
Perform ultrasonic imaging of tanks	32 m-hrs
Total time for 15 pieces of equipment	**36 m-hrs**
Labor (at an average rate of $66.00 per hour)	$2,400
Personal protective equipment	$800
Total Cost	**$3,200**
Net difference for 15 pieces of equipment	**$51,600**

Note: Basic costs that would be common to both methods are not included.

Table 2. Liquid Detection in Piping Sections Cost Comparison Development.

Baseline	
Assumption: 16 pieces of piping; common work package for entire work scope	
Work package preparation	100 m-hrs
Setup of work area and radiation survey per pipe (2 m-hrs each)	32 m-hrs
Installation of hot tap and liquid verification per pipe (1 m-hr each)	16 m-hrs
Breakdown and survey of work area (1 m-hr each)	16 m-hrs
Total time for 16 pipe sections	**164 m-hrs**
Labor (at an average rate of $66.00 per hour)	$10,800
Miscellaneous equipment ($250 per hot tap)	$4,000
Personal protective equipment (assume $100 per entry)	$1,600
Total Cost	**$16,400**
Ultrasonic Liquid Detection Level System	
Addition to existing work package	2 m-hrs
Training	2 m-hrs
Perform ultrasonic imaging (16 per shift)	8 m-hrs
Total time for 16 pipe sections	**12 m-hrs**
Labor (at an average rate of $66.00 per hour)	$800
Personal protective equipment	$100
Total Cost	**$900**
Net difference for 16 pieces of pipe	**$15,500**

Note: Basic costs that would be common to both methods are not included.

SUMMARY OF BENEFITS

Safety and Health

The use of the Ultrasonic Liquid Level Detection System to detect liquids in vessels and pipes eliminates the need to physically open or perform intrusive penetration of equipment stored or installed in a facility. Workers must still come in direct contact with the vessel or pipe being examined. Potential risks to workers, which are reduced using this technology, include the following:

- Exposure to unknown or unsafe air space in the equipment under examination
- Contact with unknown materials (contents)
- Exposure to potentially pressurized piping or equipment
- Fall hazards associated with working from scaffolding
- Heat stress concerns from much greater physical exertion
- Radiological exposures dose to personnel due to closer proximity and extended contact with the equipment subject to examination.

Scheduling and Time Management

Use of the Ultrasonic Liquid Level Detection System methods requires significantly less planning and may typically be accomplished using existing routine work procedures. Regularly assigned facility personnel are capable of performing liquid level examination without the need for extensive support from specially skilled technicians.

Direct Cost Savings

Depending on the type of equipment to be examined, cost reduction factors of 17 to 18 may be realized using Ultrasonic Liquid Level Detection System technology versus traditional baseline methods described herein.

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