Innovative Technology Summary Report

DOE/EM-0440

Pipe Explorer™ Surveying System

Industry Programs Crosscut and
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

Pipe Explorer™ Surveying System

OST Reference #74

Industry Programs Crosscut and
Deactivation and Decommissioning
Focus Area

Demonstrated at
Argonne National Laboratory-East
Argonne, Illinois

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if 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.

All published Innovative Technology Summary Reports are available on the OST Web site at http://OST.em.doe.gov under "Publications."

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SUMMARY

Technology Description

The US Department of Energy's (DOE) Chicago Operations Office and the DOE's Federal Energy Technology Center (FETC) developed a Large Scale Demonstration Project (LSDP) at the Chicago Pile-5 Research Reactor (CP-5) at Argonne National Laboratory-East (ANL). The objective of the LSDP is to demonstrate potentially beneficial decontamination and decommissioning (D&D) technologies in comparison with current baseline technologies.

The Pipe Explorer™ system was developed by Science & Engineering Associates, Inc. (SEA), Albuquerque, NM as a deployment method for transporting a variety of survey tools into pipes and ducts. Tools available for use with the system include alpha, beta and gamma radiation detectors; video cameras; and pipe locator beacons. Different versions of this technology have been demonstrated at three other sites; results of these demonstrations are provided in an earlier Innovative Technology Summary Report (See Appendix A, Ref. 1).

As part of a D&D project, characterization of radiological contamination inside piping systems is necessary before pipes can be recycled, remediated or disposed. This is usually done manually by surveying over the outside of the piping only, with limited effectiveness and risk of worker exposure. The pipe must be accessible to workers, and embedded pipes in concrete or in the ground would have to be excavated at high cost and risk of exposure to workers. The advantage of the Pipe Explorer is its ability to perform in-situ characterization of pipe internals.

The ANL CP-5 Research Reactor was chosen as the site to test the Pipe Explorer™ system in a nuclear facility setting. CP-5, one of the inactive DOE nuclear reactors undergoing D&D, provided an excellent proving ground for demonstrating the newly developed alpha detection capability of the system. Also, beta/gamma survey and video survey examination capabilities were demonstrated.

The Pipe Explorer™ system uses a pneumatically operated airtight tubular membrane to tow radiation detectors and video cameras into pipes. When pressurized, the membrane inverts into a pipe with adequate force to tow the characterization tools through the piping, providing a clean conduit through which the sensors can travel. To retrieve the membrane and tools, the process is reversed. The Pipe Explorer™ can thus be used to move a characterization tool forward and backward through a pipe as the tool's output and position are continuously recorded, providing detailed characterization of the location, visual appearance, and quantity of radioactive contamination in pipes. Two deployment systems are available on the Pipe Explorer™, an automated system and a manually operated system. Both were used during the demonstrations at CP-5.

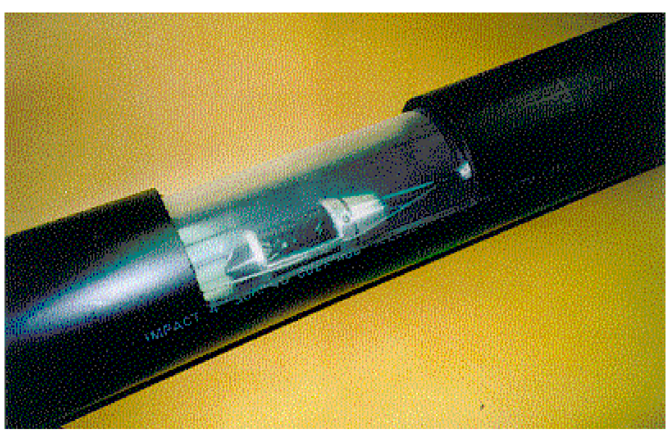

Figure 1. Detector Deployed Using Pipe Explorer Membrane

There are three comparative baseline technologies: 1) direct push method, which entails attaching a detector or video camera to the end of a conduit tape or push rod and shoving it through the pipe, 2) manual survey method, which involves excavating and dismantling the pipe, and manually surveying it, and 3) robotics method, which encompasses devices generally called pipe crawlers.

The Pipe Explorer™ offers several advantages over these technologies. They are:

- The membrane serves as a protection against contamination. Because the membrane is inside out upon retrieval, workers do not come in contact with contaminants, cross contamination is eliminated, and the detector and tether are protected from contamination by the membrane.
- The Pipe Explorer™ system deploys at faster speeds than the baseline technologies and can deploy past obstructions and elbows.
- The pipe or ductwork being characterized can remain in its original position, eliminating the risk of contamination when moving the pipe and the cost of dismantling or excavating the pipe or duct.
- The Pipe Explorer™ system can work pipe diameters between 2-40 inches.

Technology Status

Prior to being demonstrated on the Argonne site, the Pipe Explorer™ system had been demonstrated at three other sites: the Formerly Utilized Sites Remedial Action Program (FUSRAP) site in Adrian, MI, a DOE site in Albuquerque, NM and the Grand Junction Project Office in Colorado.

The Pipe Explorer™ demonstration at CP-5 was performed by C. D. Cremer, D. T. Kendrick and E. Cramer of SEA from July 15-23, 1996. D. B. Black of ANL served as Test Engineer. CP-5 facility personnel provided additional support and ANL health physics technicians. The Pipe Explorer™ was chosen to survey pipes in three areas of the CP-5 facility that lent themselves to this type of technology. The pipes used in the demonstration were fuel rod storage tubes (primarily to test alpha measurement capability), buried drain lines (primarily to test beta/gamma measurement and video survey capabilities), and vent lines (for beta/gamma measurements).

Key Results

The key results of the Pipe Explorer™ demonstration are as follows:

- The Pipe Explorer™ system was used to successfully survey for alpha contamination for the first time. These measurements were made in 3 fuel rod storage tubes at the CP-5 reactor. These were 11.5 feet long, 5-inch diameter stainless steel tubes set vertically, with the top of the tube at floor level.
- A video survey along 153 feet of a 4-inch drain line from a manhole was successfully conducted.
- A beta/gamma survey of a 4-inch drain line from a manhole was successfully conducted (137 feet surveyed with a Minimum Detectable Activity (MDA) of 4250 dpm/100 cm^2 and 53 feet surveyed with MDA of 1680 dpm/100 cm^2).

Although no survey data were obtained from the 12-inch vent lines, valuable experience was gained. This was the first Pipe Explorer™ survey conducted into a long, large diameter pipe that was plugged at the end. The issue of potentially producing airborne contamination as a result of displacing air in the pipe by the deploying membrane was addressed. The access pipe coupling design, which incorporated a HEPA filter to clean exhaust air prior to its release, was developed by SEA for this demonstration. This design will be applicable when similar circumstances are encountered at other facilities.

Due to a severe rain storm which dropped 2.89 inches of rain in a one-hour period (a total of 11.6 inches in a 24-hour period), the beta/gamma survey of the 4-inch drain line had to be halted at 53 feet. A beta/gamma survey of two 12-inch vent lines was deployed to 150 feet, but no reliable radiological data was obtained due to the storm, because the storm would have damaged the Pipe Explorer™ detectors and water would have damaged some of the Pipe Explorer™ electronics. Also, beta/gamma and video surveys of an 18-inch drain line were canceled due to the storm.

Contacts

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Licensing Information

No licensing or permitting activities were required to support this demonstration.

Web Site

The CP-5 LSDP Internet address is http://www.strategic-alliance.org.

SECTION 2

TECHNOLOGY DESCRIPTION

System Configuration and Operation

Overall Process Schematic

The Pipe Explorer™ system uses an airtight membrane configured so that when it is pressurized it inverts into a pipe. As it inverts, the pressure force on the end of the membrane is adequate to tow a detector around multiple elbows and through several hundred feet of piping. This technology provides both an effective transportation method for detectors and a clean conduit through which the detector can travel. Measurements are more reliable than detectors that are not in a contamination-free conduit, as these run the risk of causing erroneous readings by tracking removable contamination with the sensor.

The primary components of the Pipe Explorer™ technology are illustrated in Figure 2. An airtight membrane is initially spooled inside of a canister. The end of the membrane protruding from the canister is folded over and sealed around the canister outlet. When the canister is pressurized, the air pressure on the membrane causes it to be pulled from the spool. The membrane is spooled from the deployment canister, traveling inside (i.e., the clean surface) of the previously deployed membrane until it reaches the inversion point. The inversion point continually advances in the pipe as the membrane lays against the pipe wall. This continues until the membrane is completely spooled.

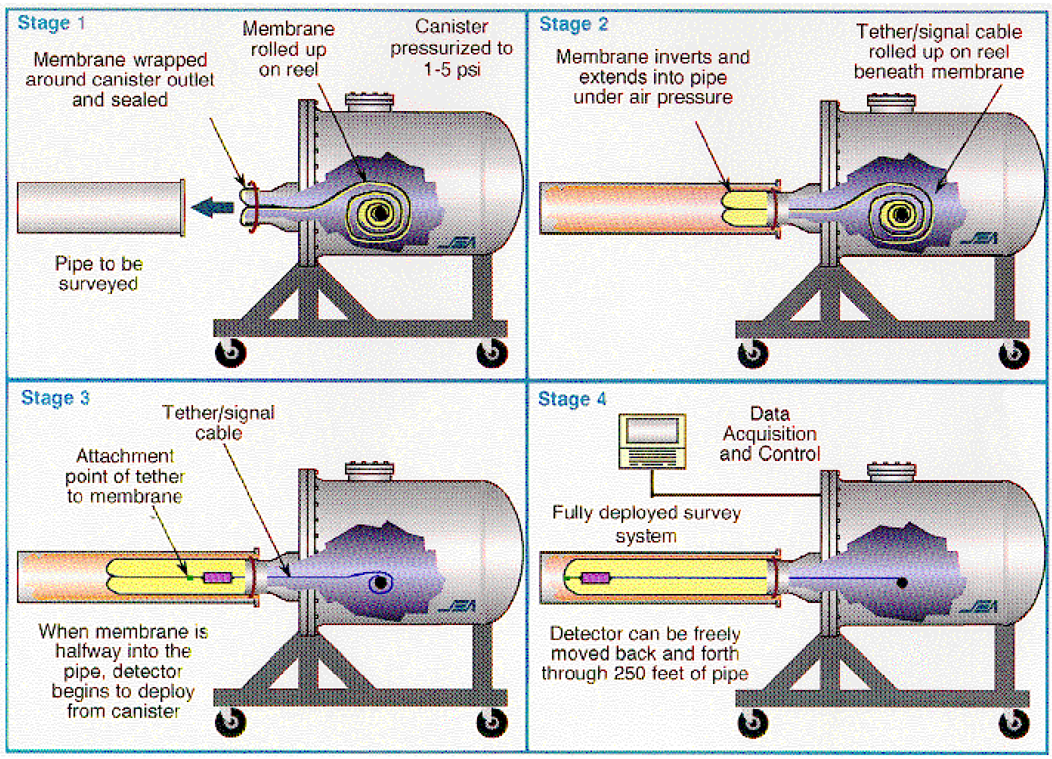

Figure 2. Deployment of the Pipe Explorer™ System

A characterization tool such as a radiation detector is attached to the end of the membrane and is towed into the pipe as the membrane continues to invert (see Figure 3). The detector cabling is also fed from the spool and towed into the pipe. To retrieve the system, the process is reversed, and the cabling, detector and membrane are wound back onto the spool. This enables the detector to be moved freely back and forth through a pipe while the radiological output and detector position are continuously recorded. As a result, the Pipe Explorer™ system provides comprehensive video surveys and detailed characterization of the location and abundance of radioactive contamination in pipes.

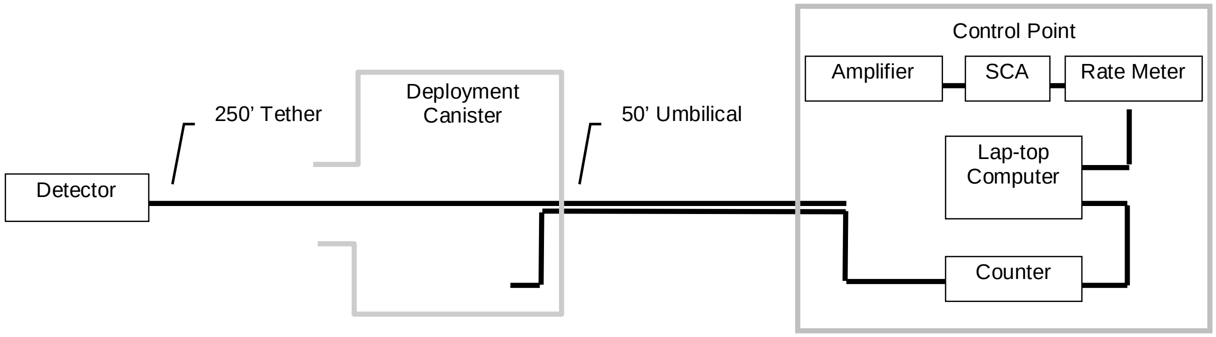

Figure 3. Block diagram of the measurement instrumentation

Pipe Explorer™ can be deployed via two different methods. The first is a fully automated system. The canister contains a motor and various control feedback sensors that limit operator interaction. A control panel is used in conjunction with the canister; it can be operated up to 50 feet away from the canister. A laptop computer logs data acquired with the automated system. The second deployment system is a manually operated canister. Membrane and sensor deployment is controlled through the use of a hand crank on the side of the canister. With this system, data are recorded manually as the detector is moved from point to point. Both deployment systems were used during the demonstration at CP-5.

To conduct alpha activity measurements, a scintillation material is incorporated into the membrane. When the scintillating membrane is deployed into a pipe, it is in close contact with the pipe wall. Alpha particles emitted by surface contamination on the pipe wall intersect the membrane, resulting in the emission of light pulses. The light pulses are detected by a photodetector towed down the pipe. This allows a direct measure of surface alpha activity as a function of distance in the pipe.

Three radioactive sources were used for calibration: a 0.1 μCi Sr/Y-90 source, a 1.0 μCi Cs-137 source, and a thorium lantern mantle encapsulated in plastic to use as an alpha check source. These sources were surveyed by ANL health physics technicians to ensure they were sealed and not leaking.

System Operation

Pipe Explorer™ is pneumatically operated, requiring a nominal level of air pressure (<10 psi), provided by a blower and standard air compressor. Standard 110-V, 20-amp electrical power and GFCI-protected extension cords were also required.

Personnel were required to wear safety shoes, hard hats, safety glasses with side shields, and dosimetry. Other personal protection equipment as specified in the Radiological Work Permit was worn. All personnel maintained OSHA HAZWOPER certification and were certified for Rad Worker II training. SEA personnel were also required to attend training unique to the ANL-E site (contractor site orientation and CP-5 building orientation).

The Pipe Explorer™ deployment system is specifically designed to prevent contamination of the tether, the towed devices, and the deployment canister. Secondary waste generated through the use of the technology consisted primarily of the used membrane material and PPE worn by the demonstrators. All waste was disposed as part of the normal radioactive waste from CP-5, and no mixed waste was generated.

SECTION 3

PERFORMANCE

Demonstration Plan

Scope. The primary purpose for using the Pipe Explorer^{TM} system at the Argonne CP-5 site was to demonstrate the alpha detection capability of the system. In addition, the beta/gamma survey capability of the system was to be used to determine if activity levels in pipes and drain lines at the site were below free release criteria. Furthermore, video surveys were to be completed in exterior drain lines to determine the integrity of the lines. These three types of surveys were to be carried out in three different areas of the site.

The first group of surveys was to be conducted from a manhole located in the yard area south of the reactor building's E-wing. Two lines were to be surveyed from a manhole. The first was a 4-inch drain line that runs east from the manhole for a distance of approximately 175 feet. The second was an 18-inch drain line coming into the manhole from the reactor building. Video surveys of the outside drain lines were to be conducted to determine the integrity of the lines. This included looking for signs of deterioration, areas of collapse, root intrusion, and debris buildup. In addition, beta/gamma surveys were to be conducted in both the 4-inch and 18-inch drain lines. A beta/gamma detector was to be deployed that had been calibrated for its response to both Cs-137 and Sr/Y-90 contaminants. The detector was to be deployed at a speed such that an MDA below 5000 dpm/100 cm^2 could be maintained at all times. In addition, an alpha survey of the 4-inch drain line was to be completed.

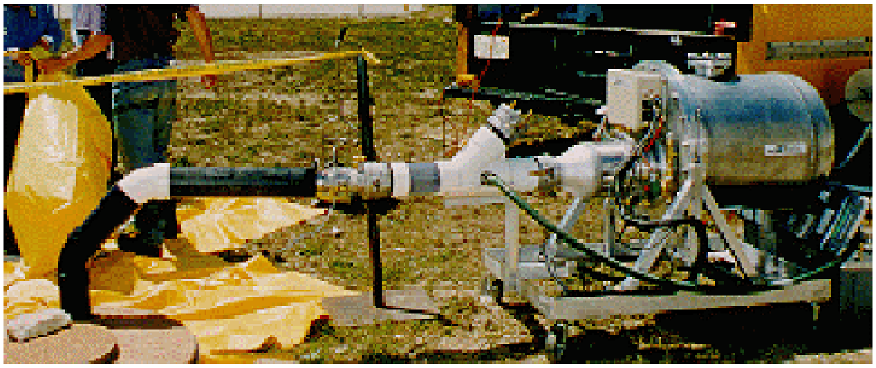

Figure 4. Pipe Explorer^{TM} System

The next area where surveys were to be conducted was inside the reactor building, where two 12-inch vent lines run from the reactor building to a ventilation annex located southeast of the reactor building's E-wing. These lines are approximately 155 feet long and are plugged at the end. Beta/gamma surveys were to be conducted in the two 12-inch vent lines. The detector was also to be calibrated for this measurement geometry where the detector response to Cs-137 and Sr/Y-90 was to be determined.

The final area to be surveyed as part of the demonstration was three fuel rod storage tubes located in the fuel storage area of the reactor building. These are 5-inch diameter stainless steel tubes encased in concrete that run to a depth of 11.5 feet. The Pipe Explorer^{TM} alpha detection system was to be used to complete these surveys. The detection system was to be calibrated with an Am-241 source (5.5 MeV) in a 5-inch pipe to determine the detection system response to contaminants emitting alpha particles of similar energies. The detection system was to be deployed at a speed such that an MDA below 20 dpm/100 cm^2 was maintained.

Deployment System. The Pipe Explorer^{TM} deployment system was described in Section 2 of this report. Briefly, the technology uses a pneumatically placed tubular membrane to transport characterization tools into pipes, drain lines and ducts. Two deployment systems are maintained, a fully automated system and a manually controlled system.

Sensors. The alpha measurement capability of the Pipe Explorer™ system is provided by a special scintillating membrane used in conjunction with a photodetector package towed through the pipe by the inverting membrane system (see Figure 5). A silver activated zinc-sulfide (ZnS[Ag]) scintillator is incorporated into the polyethylene membrane material resulting in a membrane that will produce scintillation light when struck by an alpha particle. This scintillation light is detected by a photodetector package using a bialkali-photomultiplier tube. Counting electronics connected to the photodetector are used to count the number of scintillation events registered by the scintillating membrane as a function of the detector position in the pipe, thereby providing a log of surface alpha activity versus depth in the pipe. The scintillator used in this configuration is virtually immune to both beta and gamma radiation, providing an accurate measure of the surface alpha activity in the pipe being measured.

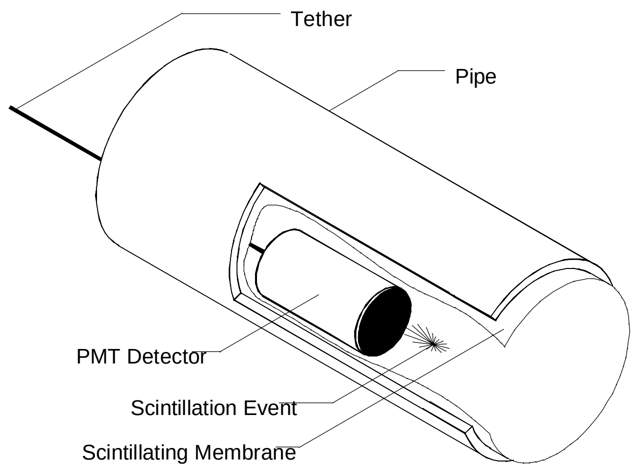

Figure 5. Sketch of Pipe Explorer™ Alpha Detector and Scintillating Membrane Deployed in a Pipe

The beta/gamma detector used with the Pipe Explorer™ system uses a coaxial design of a thin sleeve plastic scintillator wrapped around a light pipe. The light pipe is optically coupled to a compact photomultiplier tube (PMT) and preamplifier package. Output pulses from the detector are transmitted through the Pipe Explorer™ tether to a amplifier, single channel analyzer, and counter/timer. The design allows for a large detection window, while keeping a small overall package size. The window on the SEA detector is 1.95 inches long with a 1.24-inch diameter. The light-tight window on the detector is made from three layers of 0.5 mg/cm^2 aluminized Mylar material. In order to protect the window, a honeycomb shield is placed over the detector. The detector housing provides attachments for a cable to accommodate the tether. The housing also provides rounded edges on the front and back of the detector to facilitate going around corners and obstructions.

A compact black and white pinhole camera is used for video surveys with the system. The camera housing is designed to fit around long radius elbows in 2-inch diameter piping systems. To illuminate the pipe interior for the camera, three miniaturized 5-W incandescent bulbs are attached to the camera housing. The video camera can be used to locate areas of water inflow, objects within pipes and where T's come into pipes. In addition, the relative volume of sediment in the bottom of pipes and the occurrence of any significant features of the pipe can be determined with the video survey system.

Calibrations. Calibrations of the Pipe Explorer™ radiation detectors were performed specifically for the expected measurement conditions. The pipe size, pipe material, and isotope of interest were replicated as much as possible to ensure that attenuation and backscatter effects were accounted for during the calibration process. Calibration of the Pipe Explorer™ alpha measurement detectors in a 5-inch pipe followed the SEA Environmental Technologies Group Technical Procedure *Pipe Explorer™ Alpha Detector Calibration* using an NIST traceable Am-241 alpha source. Calibration of the beta/gamma detector was carried out following the SEA Environmental Technologies Group Technical Procedure *Pipe Explorer™ Beta Detector Calibration* using Cs-137 and Sr/Y-90 NIST traceable sources. The Cs-137 source was selected because this was the most likely isotope of concern. Sr/Y-90 is widely used for the calibration of beta-sensitive survey instruments and was included for data comparability.

Figure 6. Deploying the Pipe Explorer™ Membrane

Performance. The first day of the demonstration was devoted to site specific training and equipment set up. A video survey of the 4-inch diameter drain line was conducted on the second day. A total of 153 feet out of the 175 foot total length was surveyed. The survey showed that the pipe had no noticeable cracks or deterioration, but was approximately 25% blocked with debris. Operator error led to the first video run not being recorded on tape. Therefore, a second run was conducted where the pipe interior was video taped over a distance of 87 feet. The survey was stopped at this point due to a large (approximately 2-inch) freely moving debris that prevented the video camera from passing. Information gathered from the video survey led to the decision not to conduct an alpha survey in the 4-inch drain line. It was determined that debris in the pipe would create ambiguity in the survey data due to shielding of alpha particles. Further, the size of the debris in the pipe would not allow passage of the photomultiplier tube used with the alpha detection system.

On the third day, a beta/gamma survey was conducted on the same 4-inch drain line. Normal procedure is to rapidly deploy the detectors into the pipe and take rough readings during deployment to indicate hot spots, and to slowly retract the detectors to take more accurate readings as the membrane and detectors are pulled back toward the insertion point. The detector was deployed into the pipe at a relatively high deployment speed (averaged 5 ft/min). Data was recorded in 2-second intervals, resulting in an effective MDA of less than 5000 dpm/100 cm^2, where the MDA is calculated for Sr/Y-90 contamination. A slight elevation in the background activity was noted. It is suspected that the elevation in activity is due to naturally occurring radon in the soil gas. However, no definitive tests were conducted to verify this. After the detector had been deployed into the drain line approximately 140 feet, retrieval of the detector began for more detailed radiological measurements.

A 1 ft/min detector deployment rate with 10 second data acquisition intervals were used to achieve an MDA on the order of 2000 dpm/100 cm^2 (Sr/Y-90). Additionally, a 6-minute extended count was taken every 5 feet while retrieving the detector. These stationary measurements resulted in a MDA of about 300 dpm/100 cm^2 (Sr/Y-90). When the detector was 53 feet into the pipe, a rainstorm developed which dropped 2.89 inches of rain within a 1-hour period. A total of 11.6 inches of rain fell over the next 24 hours (Chicago's worst storm in 100 years). Due to the magnitude of the storm, the membrane and detector were hastily retrieved from the drain line, and the deployment canister had to be moved abruptly from the outside area. It is not clear if the rough handling of the system or the excessive moisture were to blame, but after the move the detector was damaged and the deployment system did not function properly. The next day the CP-5 facility was shut down, and the following two days were spent conducting field repairs of the system. By the sixth day all components of the system appeared to function properly, and the system was moved into the reactor area to conduct a beta/gamma survey of a 12-inch ventilation line. The detector was deployed approximately 150 feet into the pipe, and radiological data was taken as the detector was retrieved. However, residual moisture in the detector caused a transient noise problem. Due to the ambiguity of the resulting data, the survey was terminated. On the seventh day of the demonstration the Pipe Explorer alpha detection system was used to survey 3 fuel rod storage tubes identified as tubes #9, #29, and #30. Measurements were taken with the detector stationary while data was recorded over a 40-second interval, for a resulting MDA of less than 7 dpm/100 cm^2. Measurements were repeated every 0.3 feet. A notable elevation in the activity was found near the bottom of tube #30. Therefore a repeat survey of the tube was conducted and similar results were found.

In summary the Pipe Explorer™ demonstration at CP-5 was partially successful. The video and beta/gamma surveys were successfully demonstrated, but were not used in all of the targeted pipes due to damage to the system that occurred during the 100-year flood. The Pipe Explorer alpha detection system performed well with 3 fuel rod storage tubes were successfully surveyed. Table 1 lists all of the target surveys along with a summary of the surveys that were completed.

Table 1. Results of the CP-5 Pipe Explorer™ Technology Demonstration

Survey Description	Actual Survey Conducted
Video survey of 4-inch drain line from manhole south of CP-5 E-wing.	Video survey of 153 feet of the drain line.
Beta/gamma survey of 4-inch drain line from manhole south of CP-5 E-wing.	137 feet surveyed with MDA of 5000 dpm/100 cm^2. 53 feet surveyed with MDA of 2000 dpm/100 cm^2.
Video survey of 18-inch drain line from manhole south of CP-5 E-wing.	No survey conducted due to damaged deployment system.
Beta/gamma survey of 18-inch drain line from manhole south of CP-5 E-wing.	No survey conducted due to damaged deployment system.
Beta/gamma survey of two, 12-inch vent lines inside of CP-5 reactor building.	Detector deployed to 150 feet in one of the lines, but no reliable radiological data obtained due to damaged detector.
Alpha survey of fuel rod storage tubes.	Three fuel rod storage tubes successfully surveyed.

Survey Results

Alpha Measurements. The manually operated Pipe Explorer™ canister, mounted on a table, was used for the fuel tube alpha surveys. A short length of 4-inch PVC pipe, containing a long-radius 90° elbow, was used as a pre-pipe to connect the outlet of the canister to the opening of the fuel rod storage tube at the floor level. The measurements were conducted by deploying the scintillating membrane and photodetector to the bottom of the fuel rod storage tube. The depth encoder on the canister was then reset and a 40-second count was recorded. The photodetector was retrieved 0.3 foot, held at this depth, and another 40-second count recorded. This point-to-point measurement process continued until the entire tube length had been surveyed, as well as some of the pre-pipe length.

Because of the short total survey length (34.5 foot) and the non-standard pipe size (5-inch), existing 4-inch scintillating membrane stock was used to custom fabricate short lengths of membrane correctly sized for these 5-inch tubes. The length of the membrane used in each tube was determined by adding the tube length (11.5 feet) and the pre-pipe length (5.25 feet) so that the end of the membrane just reached the bottom of the tube at full deployment. At full deployment, the front of the photodetector is elevated from the bottom of the tube. However, the effective detection window of the photodetector extends approximately 40 cm. in front of the tube, so that detection for the full length of the fuel rod storage tube was obtained. The count time of 40 seconds was selected to provide an *a priori* MDA concentration well below the most conservative free release criteria found in the DOE Rad-Con Manual, 20 dpm/100 cm^2.

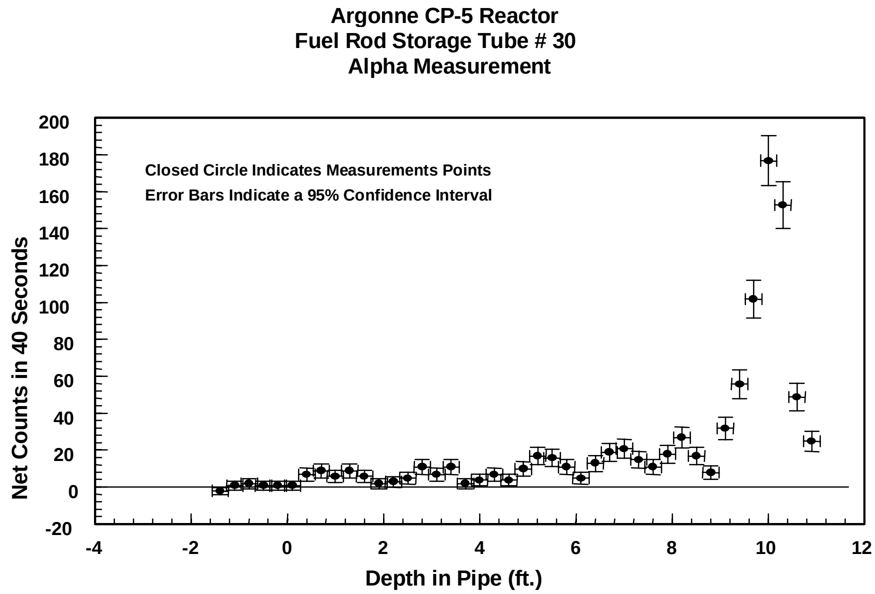

Figure 7. Results of Alpha Measurements in the CP-5 Fuel Rod Storage Tube #30
(Zero is the bottom of the pipe)

Beta/Gamma Measurements. Beta/gamma measurements were conducted in a 4-inch drain line located in the back yard of the CP-5 complex on July 16, 1996. Other beta/gamma surveys were planned but not completed due to equipment failures resulting from unusual weather conditions. The automated canister was employed for this survey. Access to the drain line was obtained through a manhole located at the upstream end of the 4-inch portion of the drain line. A short length of 4-inch PVC pipe, containing two 90-degree elbows, was used as a pre-pipe to connect the outlet of the canister to the pipe opening in the manhole. A standard 4-mil thick polyethylene membrane was used for these measurements. The detector employed for these measurements is a specialty beta/gamma detector, optimized for beta response. The signal from the beta/gamma detector is processed using industry standard NIM electronics consisting of a linear shaping amplifier, single-channel analyzer, and counter/timer module. Operating bias for the detector PMT is supplied by a high voltage supply. Settings for these components were chosen to optimize detector sensitivity against a low background count rate.

The average deployment rate for this survey was approximately 6.8 ft/min. The planned retrieval rate was to be 0.9 ft/min or slower, with static measurements of 6 min in duration taken every 10 feet. The calibration sources are used to determine the Minimum Detectable Activity (MDA) of the instruments. However, when the detector is moving the MDA has to be modified. This modified MDA for the continuous measurements at a detector rate of 0.9 ft/min were calculated at 2840 dpm/100 cm^2 using the Cs-137 calibration factor and 1680 dpm/100 cm^2 using the Sr/Y-90 calibration factor. The MDA for the static measurements were calculated at 439 and 259 dpm/100 cm^2 using the Cs-137 and Sr/Y-90 calibration factors respectively.

Due to severe weather conditions, the retrieval survey was not completed. Because of storm water accumulating in the drain line, the detector was retrieved at approximately 7 ft/min. Detector measurement data were recorded during this fast retrieval, but because of the high retrieval rate, the corresponding MDA is high, 8,840 and 5,200 dpm/100 cm^2 using the Cs-137 and Sr/Y-90 calibration factors respectively. Due to equipment damage as a result of the rainstorm, it was not possible to repeat the survey of the 4-inch drain line. After field repairs were made to the system, survey of one of the 12-inch ventilation lines was attempted. The line chosen was plugged at one end and a special adapter was fabricated. Unfortunately, residual moisture in the detector created a transient noise problem, making measurements unreliable. Therefore, the survey was terminated.

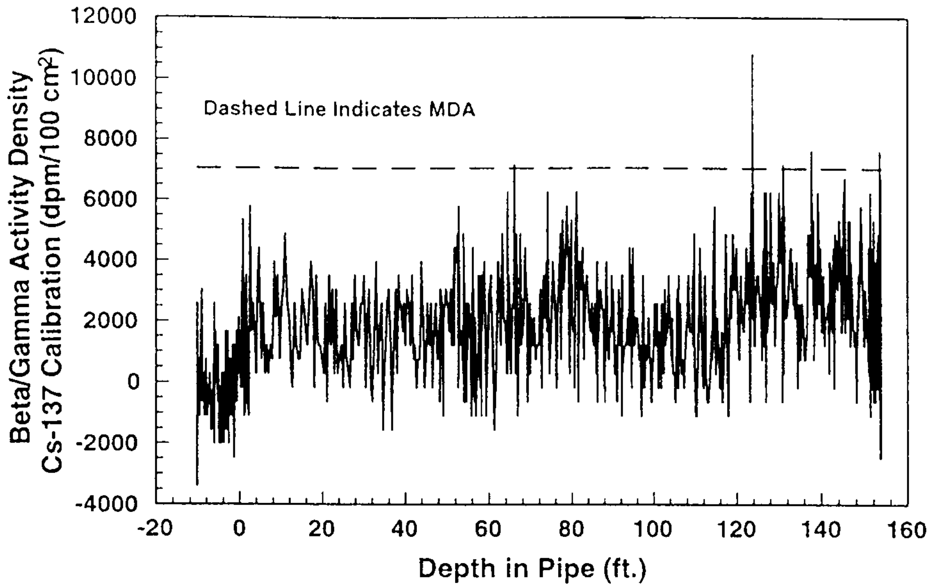

Figure 8. Survey data obtained during detector deployment using the Cs-137 calibration factor.

As Figure 8 shows, only five locations showed the possible existence of beta/gamma activity above detectable limits. The data with a negative depth is from the pre-pipe portion of the survey (the short length of 4-inch PVC pipe, containing two 90-degree elbows – see previous page). The count time represented is 2 seconds, with an average detector deployment rate of approximately 7 ft/min.

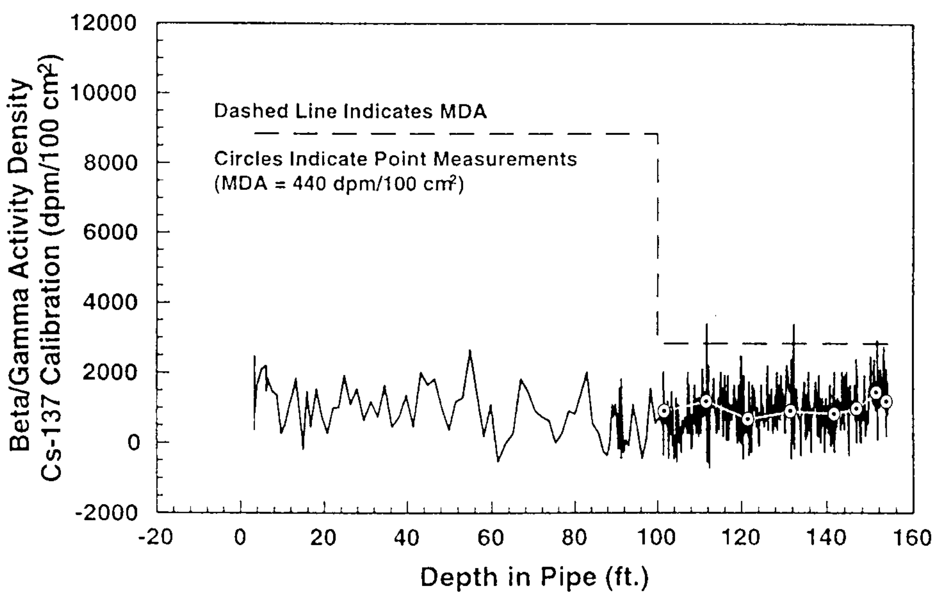

Figure 9. Survey results obtained during retrieval of the detector using the Cs-137 calibration factor.

The circles indicate the results of 6-minute static measurements. The high-density data on the right was obtained at a logging rate of approximately 0.9 ft/min. The low-density data on the left was obtained during rapid retrieval at approximately 7 ft/min. The count time for both zones was 10 sec.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVE TECHNOLOGIES

Technology Applicability

The Pipe Explorer™ technology is applicable as a survey tool for underground pipes containing either alpha or beta/gamma contamination. Most pipe materials can be surveyed, including steel, stainless steel, cast iron and vitreous clay. The most important factors affecting the suitability of pipe systems are obstructions and debris in the pipe, the continuity of the pipe, and the overall moisture content in the pipe. Drainpipes are particularly suited to the technology as they are typically fairly straight and uncomplicated systems and are often embedded, which increases the benefit of in-place management. The following are some advantages and limitations of the Pipe Explorer™ system.

Advantages

- The Pipe Explorer™ membrane prevents contact of measurement equipment with pipe surfaces while it reduces worker contact with contaminated materials
- Able to navigate around elbows and obstructions in pipes (up to 50% blockage)
- Relatively high deployment rate
- Contamination is not moved with the detector, eliminating the possibility of false readings
- Use of off-the-shelf detectors and other components simplifies repairs and increases up time.

Limitations

- Membranes add to expense and waste volume (however, waste volume for a typical 200-ft membrane is less than 0.5 ft^3).
- System is not steerable.
- Cannot be used in pipes with standing water.
- Significant debris in pipes will block the deployment of the membrane.
- Radiological measurements may be obscured by debris in the pipes.

Competing Technologies

Competing pipe characterization technologies involve sophisticated robotic devices designed as pipe crawlers. One technology demonstrated as part of the CP-5 LSDP is the Pipe Crawler, developed by Radiological Services, Inc. (RSI). The technology employs a family of manually advanced wheeled platforms (or crawlers) fitted with one or more arrays of thin GM detectors operated from an external power supply and data processing unit. Survey readings are taken in a step-wise fashion. Video camera and tape recording systems are used for video surveys of pipe interiors prior to and during radiological surveys. The Pipe Explorer™ and Pipe Crawler are applicable to roughly the same lengths (~ 200 ft.).

Advantages of the Pipe Explorer™:

- Superior access to alpha emitters than Pipe Crawler when scintillator is incorporated in the membrane.
- Membrane prevents detector from moving contamination, which could cause false readings.

- Membrane provides protection against possible contamination to workers and instrumentation.
- Pipe Explorer™ can move and survey more easily than Pipe Crawler in slippery pipes and up or down vertical pipes or ductwork.
- Greater range of pipe diameters (2-40 inches for the Pipe Explorer™ vs. 2-18 inches for the Pipe Crawler).

Limitations of the Pipe Explorer™:

- The detector deployment mechanism is more complex and harder to manipulate than the fiberglass rods used in Pipe Crawler
- Pipe must be vented to allow membrane to deploy
- Gamma detector geometry cannot be as precisely controlled as with Pipe Crawler

Additional competing pipe and duct characterization technologies not demonstrated at CP-5 include:

(1) Multisensor Inspection and Characterization Robot for Small Pipes (MICROSPI) developed by Lockheed Martin Astronautics

(2) Internal Duct Characterization System developed jointly by Idaho National Engineering Laboratory, Inuktun Services, Ltd., and Automation Systems Associated, Ltd. (the latter now located in British Columbia)

(3) Small Pipe Characterization System (SPCS) developed by Foster-Miller, Inc.

The baseline technology against which Pipe Explorer™ is being compared is excavation and disposal of embedded pipes as low-level waste. In-place management of pipe systems using Pipe Explorer™ in conjunction with decontamination has potential advantages over the baseline technology:

Pipe Explorer™:

- Allows in-place management of pipe systems
- Preserves options for pipe management, up to and including reuse, through characterization of pipe systems rather than dismantlement
- Is unobtrusive and non-disruptive to facility operations
- Produces minimal waste of its own, while when combined with decontamination produces far less waste than baseline technology
- Can be used where baseline technology is unfeasible, e.g., on upper floors within facilities
- Less costly

Patents/Commercialization/Sponsor

There is currently a patent pending on the Pipe Explorer™ technology.

SECTION 5

COST

Introduction

This cost analysis summarizes and evaluates the innovative technology and estimates the potential for savings relative to a baseline technology. The objective is provide decision makers with adequate data to enable them to make defensible decisions on the use of the innovative technology in future D&D work. This analysis strives to develop realistic estimates that represent actual 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 are eliminated or adjusted to make the estimates more realistic. These adjustments are allowed only when they will not distort the fundamental elements of the observed data (i.e. does not change the productivity rate, quantities, work elements, etc.) and eliminates only those activities which are atypical of normal D&D work. Descriptions contained in Appendix C of this analysis detail the changes to the observed data.

Methodology

This cost analysis compares an innovative Pipe Explorer™ technology used for performing radiological survey of pipe interior surfaces to a conventional baseline technology of dismantling and disposal of pipes. The Pipe Explorer™ technology has been demonstrated at the CP-5 facility ANL under controlled conditions with a vendor providing the service, their personnel and equipment, for which timed, measured, and quantified activities were recorded to determine achievable production rates.

Data collected during the demonstration included:

- Speed of deploying and retrieving the Pipe Explorer™ from the pipe;
- Frequency of stops during which counts are taken/recorded and the duration of the stop;
- Equipment and personnel used to perform the activity;
- Length, size, and material of the pipe, distance surveyed, and isotope surveyed for;
- Training courses required and taken (excluded from analysis).

The baseline dismantling and disposal technology was not demonstrated concurrently. Baseline information is extracted from existing budget or planning documentation for CP-5, and the labor, equipment, production rates, and site personnel at ANL provided productivity loss factors (PLF). Supplemental production rates and equipment costs were used from the R.S. Means cost data manuals, 1995 and 1997.

The following baseline documents were used as references:

- Decommissioning Cost Estimate for Full Decommissioning of the CP-5 Reactor Facility, prepared for Argonne National Laboratory by Nuclear Energy Services, Inc., June 1992;
- Activity Cost Estimate (ACE) backup sheets, dated 5/15/96, for CP-5 decommissioning;
- Current information from ANL personnel.

Since the baseline costs are not based on observed data, additional efforts are applied in setting up the baseline cost analysis to assure unbiased and appropriate production rates and crew costs. Specifically, a team consisting of members from the Strategic Alliance (ICF Kaiser, an ANL D&D technical specialist, and a test engineer for the demonstration) and the U.S. Army Corps of Engineers (USACE) reviewed the estimate assumptions to ensure a fair comparison.

The selected basic activities being analyzed come from the Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary (HTRW RA WBS), United States Army Corps of Engineers, 1996. The HTRW RA WBS was developed by an interagency group. Its use in this analysis provides consistency to established national standards.

Some costs are omitted to simplify and to facilitate comparison with costs for the individual sites. The ANL indirect expense rates for common support is omitted. However, as with all vendor-provided services, the procurement indirect expense (PIE) of 9.3 % is included. Overhead rates for each DOE site vary in magnitude and application. Decision-makers seeking site-specific costs can apply their site's rates to this analysis without having to first back-out ANL's rates, except the PIE. This omission does not sacrifice the cost savings accuracy, because overhead is applied to both the innovative and baseline technology costs. Engineering, quality assurance, administrative costs and taxes on services and materials are similarly omitted.

The standard labor rates established by ANL for estimating D&D work are used for work performed by local crafts. Rates for the vendor's services (labor and equipment) are used for the operation of the Pipe Explorer and includes the vendor's General and Administrative and overhead mark up costs. However, due to proprietary information, details were not provided by the vendor, but are derived using standard percentages along with the activities and overall costs provided by the vendor. An eight-hour work day with a five day week is used.

Summary of Cost Variable Conditions

The DOE complex presents a wide range of D&D work conditions because of the variety of functions and facilities. The working conditions for an individual job directly affect the manner in which D&D work is performed and, as a result, the costs for an individual job are unique. The innovative and baseline technology estimates presented in this analysis are based upon a specific set of conditions or work practices found at CP-5, and are presented in Table 2. This table is intended to help the technology user identify work differences that can result in cost differences.

Table 2. Summary of Cost Variable Conditions

Cost Variable	Pipe Explorer™ Technology	Baseline Technology
Scope of Work		
Quantity and Type of Material	175 feet (ft) of 4 inch buried clay drain pipe 45.2 ft of 5 inch stainless steel rod storage tubes, concrete encased (155 feet of 12 inch carbon steel pipe, ventilation line performed but not included in cost analysis)	175 lineal feet of 4 inch pipe 45.2 lineal feet of 5 inch concrete encased pipe
Location	Rod storage (inside) and drain lines (outside) of the reactor bldg.	Reactor building (bldg) area (same as demonstration)
Nature of Work	Mostly straight portions of pipe are surveyed and removal of end caps from 5 inch tubes requires a crane.	Floor thickness of 1 foot. Assume only low level radioactive contamination (no hazardous) so that there is no need to segregate sludge from pipe interior from the pipe (no need to try and reduce the volume of mixed waste). Drain line buried about 5-6 ft in soil requiring normal excavation.
Work Environment		
Level of contamination in the test areas	Demonstration area is not a radiation area. Any contamination that might be present is fixed. PPE was worn by the crew only when inserting the membrane or removing it.	Respiratory protection not required for concrete removal. Area previously decontaminated. Pipe removal requires protective clothing and respirators.

Level of contamination inside the pipes	2 pipes below release limits. 5 pipes near release limits. Remaining pipes were well above release limits.	Productivity loss factor (PLF) for pipe removal portions of work assumed to be 2.02 that would include protective clothing and respiratory protection. PLF for earthwork assumed to be 1.0
Work Performance		
Acquisition Means	Vendor provided service with mobilization of vendor equipment.	Local craft workers with rented equipment.
Compliance Requirements	100% and 25% of pipe surface area is surveyed (assumes coverage that NRC historically accepted is adequate for site and regulators)	
Equipment & Crew	1 detector with varying sizes of membranes for pipe sizes and crew of 2 vendor personnel plus 1 HPT (HPT support is a separate line item in the summary table)	Concrete work: Backhoe loader, concrete saw, decontamination technician, operator and HPT. Excavation work: Excavator, compactor, Front end loader, operator, oiler, decon worker/laborer, foreman and skilled craftsman
Production Rates	1. Automatic mode (typical for drain line) Deploy speed, 6.8 ft/min with survey count time, 2 seconds, stopping every 1 foot. Retrieval speed, 3.0 ft/min with count time of 10 seconds, stopping every 0.2 ft. All rates then based on total start to finish time divided by length of pipes. 2. Manual mode (typical for tubes) Deploy and retrieve at 1 ft/min, stop every 0.3 ft, count for 40 seconds. 3. Background count for 5 minutes at beginning of length (actual), but typical includes another 5 minutes upon completion.	1. Two cubic feet (CF) per hour for concrete saw cut. Four CF per hour for concrete block removal. Seven CF per hour for pipe removal. Rates for the concrete encasement work based on ANL, 1992. 2. Excavation: 200 cubic yards (CY) per day, 2 men & excavator; Backfill: 400 CY per day, 1.5 men, F.E. loader; Compaction: 375 CY/day, 1 man, power compactor; Pipe removal: 7 feet per day, 3 men, no power equipment.
Scale of Production		
Process Steps	1. Mobilize 2. Calibrate equipment 3. Remove pipe cap 4. Survey tube(s), manual 5. Move to new location, set up 6. Video pipe(s) 7. Survey pipe(s), automatic 8. Demob	1. Mobilize 2. Saw cut concrete along pipe length 3. Cross cut into blocks 4. Remove concrete blocks 5. Cut pipe and remove pipe and soil 6. Segregate contaminated soil (this occurs as it is removed) 7. Disposal of waste 8. Excavate trench (outside drain line) 9. Remove drain line 10. Backfill and compact 11. Restore (minor landscaping) 12. Demob
End Condition	Pipe determined to meet free release criteria remains in place (pipe not meeting release requirements will require further action)	Pipe and concrete removed (open trench remains)

Potential Savings and Cost Conclusions

For the conditions and assumptions of this demonstration, a very small quantity of pipe surveyed, the innovative technology cost $3,531 over the baseline alternative, and a summary comparison is shown in Figure 10.

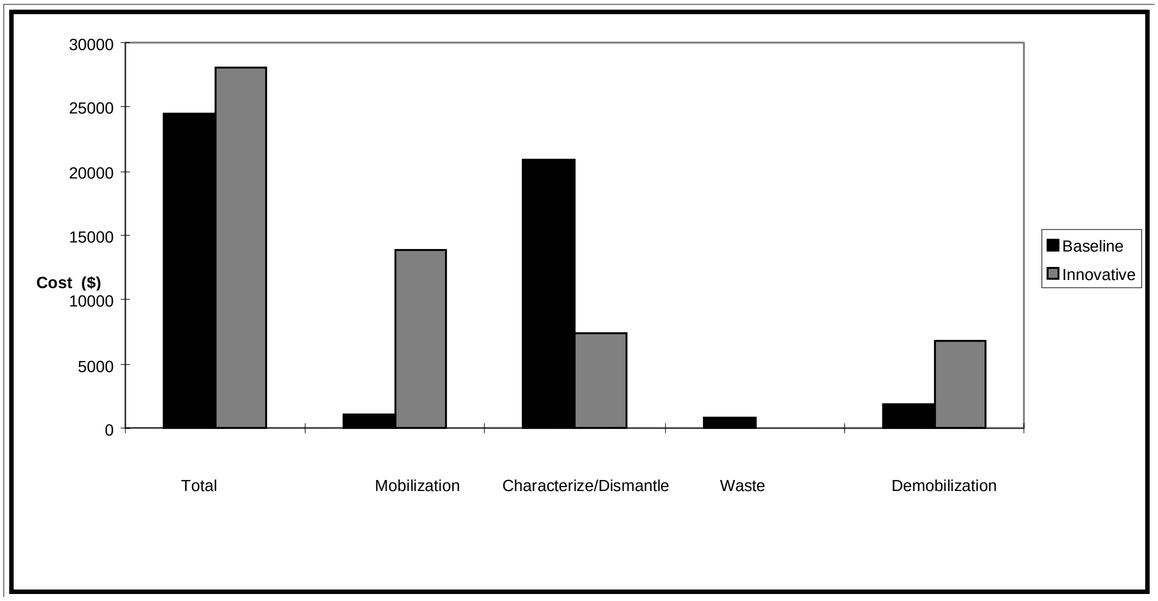

Figure 10. Technology Cost Comparison

The innovative costs are dominated by the mobilization costs. In general, for small jobs such as this demonstration the innovative technology is more expensive than the baseline, and for large jobs the innovative is less expensive than the baseline. Cost comparisons between the baseline and innovative technologies are highly dependent on site-specific features, including the medium in which the pipe is embedded (sand, concrete, etc.) and the depth to which the pipes are buried. The number and type of radioisotopes are also site-specific characteristics that factor significantly into the cost analysis. For the particulars of this demonstration, the innovative and baseline costs would be about equal for jobs that are a slightly larger in scope than this demonstration. The most prominent cost influences are the size of the job and the ability to free release the pipe following the Pipe Explorer™ survey. In situations where a surveyed pipe fails the free release requirements, decontamination and or dismantlement and disposal of the pipe will be required, saving nothing and actually costing more.

Approximately 70% of the Pipe Explorer™ cost in this demonstration are for mobilization and demobilization. That is due mainly to using the service of a vendor from afar on such a small scope of characterization work. These costs remain relatively constant despite the number of pipes surveyed. Those facilities with larger characterization scope (pipe survey quantities) will distribute the semi-fixed mobilization and demobilization over a larger cost base. Figure 11 is a comparison of costs for the innovative and baseline technologies extrapolated from the demonstrated 45 feet of pipe removal (for pipe imbedded in concrete) to a hypothetical 200 feet. The extrapolation is included in the analysis to provide an estimate of costs for jobs in the range of normal D&D work. It also demonstrates the relative effect of job size on mobilization and demobilization costs as well as displaying a cross over threshold where cost for the baseline technology exceeds costs for the innovative technology. The extrapolation is based only on pipe imbedded in concrete (the demonstration costs for pipes below ground are not considered). An extrapolation for pipe below ground is unnecessary, because the baseline technology's cost advantage is so large for that situation that there is no cross over in preference with changes in job size).

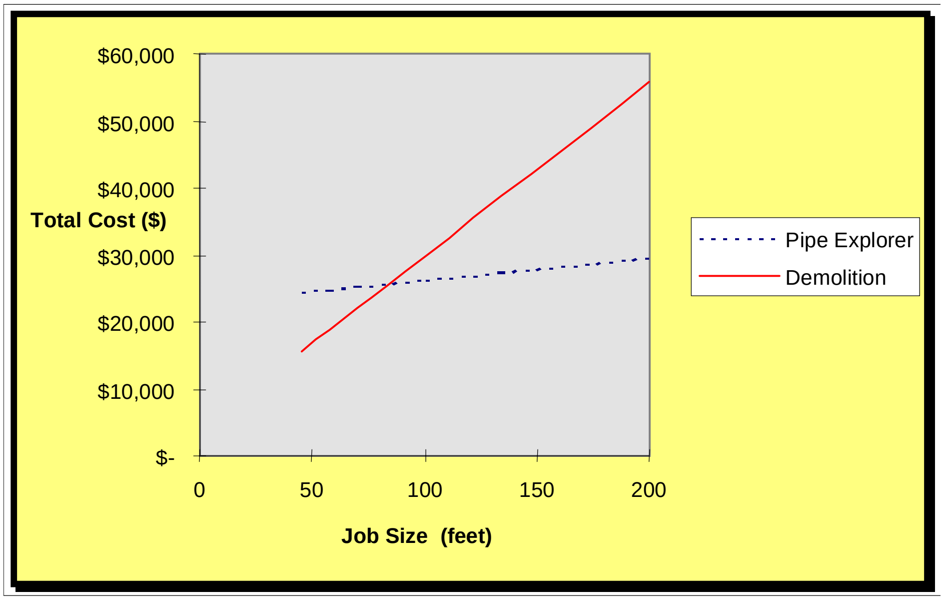

Figure 11. Extrapolation of Technology Costs

As shown in Figure 11, if the work involved a quantity of pipe greater than approximately 90 feet, then the innovative technology would be more cost effective than the baseline.

Calibration is a large cost factor for the innovative technology. This cost is included under mobilization activities for this estimate. The vendor's experience is 10 person hours per individual calibration required by the customer, which depends on the size, material, and number of pipes and the isotopes expected. Using an approximate hourly cost for this vendor, material and radioisotopes found at this demonstration, and equipment and labor at $180 per 2-person crew hour, the 4 sets (of 2) calibrations in this demonstration are worth $7200. Calibration costs are highly dependant on site-specific factors including the number and types of radioisotopes, survey type, background levels, number of different pipe diameters and geometries to be analyzed, etc. These factors cannot be generalized, and individual projects must estimate overall calibration costs based on specific project criteria. SEA has developed an automated calibration system for the Pipe Explorer™. This is expected to reduce the overall cost associated with calibration.

Establishing background radiation levels may be necessary where well documented survey results are required. The cost for establishing background is included in this analysis at 5 minutes at the start of survey per pipe. It is a small cost factor, not affecting the potential savings.

The baseline total cost is sensitive for several parameters. Concrete slab thickness and width of the trench are significant cost drivers, because changes in these dimensions result in changes to the concrete cutting production rate, removal quantity, and waste disposal quantity. Unknown underground hazards, not on the drawings or records, can significantly affect the cost of digging up old pipes. Additionally, the assumptions for the type of contamination are important factors in the total cost. If hazardous waste is present in addition to the radioactive contamination, then efforts to scrape the sludge from the pipe interior may be required (so that the pipe can be disposed of as low level radioactive waste rather than mixed waste). The waste assumptions in this analysis are greater than can be expected in many situations, and the potential savings from the Pipe Explorer™ will often be larger than reported in this analysis.

Different size vehicles and instruments are not required as pipe sizes and configurations being surveyed change. That is an advantage of this Pipe Explorer™ technology over some other innovative technologies. One only has to use a new length of the proper diameter membrane with a small cost of $0.03 per foot.

The scope of pipes and sizes being characterized will vary with the specific needs of the site. While the vendor does not provide the details of that consumable cost, the cost is relatively small and inconsequential.

Because of the impact site specific conditions have on total costs, a decision maker should tailor this analysis for his site by substituting the expected quantities, mobilization distance, etc. into Table C-1, Appendix C.

SECTION 6

REGULATORY/POLICY ISSUES

Regulatory Considerations

The regulatory/permitting issues related to the use of the Pipe Explorer™ technology at the ANL CP-5 Research Reactor consisted of the following safety and health regulations:

- 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
  - —1926.102 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)

These are the same regulations that govern the baseline technology, excavation.

Disposal requirements/criteria include the following Department of Transportation (DOT) and DOE requirements:

- 49CFR Subchapter C Hazardous Materials Regulation
  - —171 General Information, Regulations, and Definitions
  - —172 Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements
  - —173 Shippers - General Requirements for Shipments and Packagings
  - —174 Carriage by Rail
  - —177 Carriage by Public Highway
  - —178 Specifications for Packaging

- 10CFR 71 Packaging and Transportation of Radioactive Material

If the waste is determined to be hazardous solid waste, the following Environmental Protection Agency (EPA) requirement should be considered:

40 CFR Subchapter 1 Solid Waste

The following are the waste form requirements/criteria specified by disposal facilities used by ANL. Disposal of Pipe Explorer™ membranes would have to follow these criteria.

- *Hanford Site Solid Waste Acceptance Criteria*: WHC-EP-0063-4
- *Barnwell Waste Management Facility Site Disposal Criteria*: S20-AD-010
- *Waste Acceptance Criteria for the Waste Isolation Pilot Plant*: WIPP-DOE-069

Safety, Risks, Benefits, and Community Reaction

The Pipe Explorer™ technology is generally quite safe to operate. Identified hazards include industrial hazards typical of working with electrical powered instrumentation, physical hazards associated with pipe systems and confined spaces, and radiological hazards associated with contamination inside piping systems.

The Pipe Explorer™ technology used as a surveying technique eliminates the unnecessary steps of excavation, dismantlement, and disposal of uncontaminated piping, and risks to workers associated with excavation, heavy equipment usage, and possible exposure to radioactive piping are minimized. The use of the Pipe Explorer™ technology rather than the baseline technology would have little impact on community safety, environmental, or socioeconomic issues. Any such impacts would be mostly favorable relative to the baseline technology due to reduced disruption of the affected facility, reduced physical hazards, reduced noise and dust emissions and reduced waste hauling and disposal.

SECTION 7

LESSONS LEARNED

Implementation Considerations

Several implementation considerations have been identified with regards to the Pipe Explorer™ technology:

- A clean portion of an embedded or buried pipe must be available for determining background.
- Pipe sizes need to be confirmed in the field (if possible) as facility drawings may be inaccurate or misleading.
- Contractor needs to have spare detectors and other key components available in case of breakdowns or damage in the field.
- Pipes containing debris cannot be surveyed for alpha.
- Both alpha and beta/gamma measurements may be affected by presence of radon gas. Pipes may require purging prior to survey. Purging may not be an available option because of possible contamination spread or piping configuration.
- Vertical or slick pipes present no problems.
- Pipes cannot contain standing water.
- Pipe surfaces should be fairly smooth and free of sharp edges.
- Best suited for initial characterization of pipes.

Technology Limitations and Needs for Future Development

A limiting factor to the deployment of this technology is inadequate knowledge of piping configuration. Unvented pipes, large obstructions, moisture in pipes, and incongruent pipe diameters at joints can all cause problems in surveys. Additionally, during the demonstration, damage to both the detector and the deployment system occurred due to water damage and possible rough handling. Development could focus on developing a system more resistant to adverse conditions.

Technology Selection Considerations

- Best suited for initial characterization of pipes.
- Pipes must be vented to allow the expansion of the membrane.
- Pipes should be free of large objects that could prevent the deploying of the membrane.
- Best suited for detection of alpha emitters, and is very good with beta/gamma emitters.

The feasibility of decontaminating pipes to below release standards should be determined prior to pursuing a management option involving free release based on surveys. It should first be determined whether or not it is possible to decontaminate pipes to below release standards before submitting the results of pipe characterization as the basis for the free release of the pipe. Otherwise, excavation and dismantlement of the pipes may be required regardless of the results of the characterization survey.

Appendix A

REFERENCES

(1) Pipe Explorer™ System Innovative Technology Summary Report, demonstrated at FUSRAP, Adrian, Michigan, and U.S. Department of Energy, Albuquerque, New Mexico, and Grand Junction, Colorado, April 1996.

(2) Test Plan for the Demonstration of the Pipe Explorer™ System at CP-5, July 1996.

(3) Cremer, C. David, D. T. Kendrick and Eric Cramer, Results of Pipe Explorer™ Surveys at the Argonne National Laboratory CP-5 Reactor Large Scale D&D Project, September 6, 1996.

(4) Kendrick, D. T., Pipe Explorer™ Alpha Detector Calibration, Science & Engineering Associates, Inc. Environmental Technologies Group Technical Procedure, July 8, 1996.

(5) Kendrick, D. T., Pipe Explorer™ Beta Detector Calibration, Science & Engineering Associates, Inc. Environmental Technologies Group Technical Procedure, January 1996.

(6) Radiological Control Manual, U.S. Department of Energy, DOE/EH-0256T, June 1992.

(7) AIF, 1986 Guidelines for Producing Commercial Nuclear Power Plant decommissioning Cost Estimates, May 1986, National Environmental Studies Project of the Atomic Industrial Forum, Inc., 7101 Wisconsin Avenue, Bethesda, MD 20814-4891.

(8) ANL, 1992 Decommissioning Cost Estimate for Placing the CP-5 Reactor Facility into Safe Storage (SAFSTOR), April 1992, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439-4841.

(9) Strategic Alliance for Environmental Restoration, 1997 Technology Technical Data Report for the Pipe Explorer Demonstration, 1997, Argonne National Laboratory, Technology Development Division, 9700 South Cass Avenue, Argonne, IL, 60439-4841.

(10) USACE, 1996 Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary 1996, Headquarters United States Army Corps of Engineers, 20 Massachusetts Avenue, N.W., Washington, DC, 20314-1000.

(11) R.S. Means Mechanical Cost Data, 20th Edition, 1997, Section 027, line 172, sub 5000. Piping, Drainage and sewage.

(12) R.S. Means Site work and Landscape Cost Data, 14th Edition, 1995,
Section 022, line 254, sub 0110. Excavating trench
Section 022, line 254, sub 3020. Backfill trench
Section 022, line 226, sub 7220. Compaction
Section 029, line 308, sub 2400 Seeding

(13) Strategic Alliance for Environmental Restoration, CP-5 Large-Scale Demonstration Project, *Technology Summary Sheet for the Demonstration of* Pipe Explorer™ Surveying System, Argonne National Laboratory, January 1998.

Appendix B

ACRONYMS AND ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
ANL	Argonne National Laboratory
BF	Backfill
CC	cut concrete (an activity)
CF	cubic feet (foot)
CFM	cubic feet per minute
CY	cubic yards
D&D	Decontamination and Decommissioning
Decon	Decontamination
Demob	Demobilization
DOE	Department Of Energy
Equip (Eq)	Equipment
FCCM	Facilities Capital Cost Of Money
FETC	Federal Energy Technology Center
H&S	Health and Safety
HR	Hour
HTRW	Hazardous, Toxic, Radioactive Waste
LF	lineal feet (Foot)
LLW	Low Level Waste
LS	lump sum
Min	Minute
Mob	Mobilization
NESP	National Environmental Studies Project
NRC	Nuclear Regulatory Commission
PLF	Productivity loss factor
PPE	personnel protective equipment
Qty (Qnty)	Quantity
RA	Remedial Action
RB	remove (concrete) blocks (an activity)
RSP	remove soil and pipe (an activity)
SAFSTOR	Safe Storage
SF	square feet (foot)
UCF	unit cost factor
UOM	unit of measure
USACE	U.S. Army Corps Of Engineers
WBS	Work Breakdown Structure
WPI	Waste Policy Institute

Appendix C

TECHNOLOGY COST COMPARISON

This Appendix contains definitions of cost elements, descriptions of assumptions and computations of unit costs that are used in the cost analysis.

Innovative Technology - Pipe Explorer™

MOBILIZATION

Transport Personnel and Equipment

Definition: Transport of vendor's personnel and equipment from Albuquerque, NM to site via van and using crew members as drivers.

Assumption: The one-way distance is 1350 miles. The duration assumes 500 miles per day, driving 10-hour days with 2 overnights. Per Diem is applicable.

Unload Equipment

Definition: Unloading the vendor's equipment includes time required for crew to unpack equipment from the van and move the equipment to a staging area for radiological survey.

Assumptions: One-half hour is required for unloading the equipment. This is based on an overall observed times from the first day of the demonstration.

Note: The first day, 8 hours, included four activities, times for which have been allocated as follows: Unload equipment, ½ hour; survey equipment, ½ hour; setup equipment, part of the characterization work breakdown below, ½ hour; and site specific training requirements, 6.5 hours.

Survey Equipment

Definition: This cost element provides for radiological survey of the equipment by a site HPT to assure that contaminated equipment is not brought on-site. Costs include crew stand-by time plus HPT labor.

Assumptions: The allocated time is ½ hour as noted above.

Training

Definition: Site and Health & Safety related training required for subcontractor personnel.

Assumptions: 6.5 hours required for training. This is based on observed time from demonstration.

CHARACTERIZATION

Set-Up Equipment (initial arrival)

Definition: This cost element includes time to lay out the equipment and prepare for the task work.

Assumptions: Set-up is assumed to be ½ hour based upon the allocation in the earlier note.

Calibration

Definition: This cost element covers the labor and materials for calibrating the detector devices to known sources and for the expected conditions to be encountered. Specifically, for each isotope, pipe size, and pipe material, a calibration is conducted.

Assumptions: Per the demonstration results, eight (8) calibrations are made, 2 different expected isotopes (usually according to the customers requirements) for the 4 pipe sizes and 2 elements scheduled for the test. The observed time, from vendor experience and information, is 80 hours. This is done to meet requirements for this demonstration, as it would be for a typical D&D scenario, at the vendor's facility prior to mobilization to the site. Costs were part of the charges for the services rendered. However, because the demonstration was terminated due to inclement weather, only 6 of the 8 criteria are needed, making 60 hours the time for calibration.

Establish Background

Definition: The background radiation level is established for each pipe size. Cost will vary depending upon the number of pipe sizes.

Assumptions: Based on vendors experience, establishing background requires 5 minutes using their equipment upon entering and again on exiting the pipe being surveyed. The reason for both readings is to ensure consistency and confidence. During the demonstration, necessitated by the inclement weather, the count was not taken upon exiting. Estimate assumes only one 5-minute count. Additionally, many of the situations requiring characterization will not require a level of accuracy that will require determining background. Consequently, the number of background counts that will be required for an individual job will vary from zero (if no background is required) to twice the number of pipes being surveyed.

Access Pipe

Definition: This cost element accounts for the time and equipment required to open the pipe by removing a plug, cap, etc.

Assumptions: During the demonstration of this technology, a crane was used to gain access to the rod storage area piping which had been capped with 500 pound plugs for heath and safety reasons. Individual situations where this technology may be used will have various plugs, clean out plug, drain strainer, valve or other pipe closures that will require effort to gain access to the pipe. Each site's situation will have a different cost.

Video Pipeline

Definition: Prior to survey, a camera is used to observe the pipe interior.

Assumption: Normally, a video survey is made of each pipe to be surveyed. Due to inclement weather, a video was only completed on one line and included in this estimate. Each site will have estimate the quantity for this activity based on their site-specific conditions.

Pipe Characterization

Definition: This cost element accounts for the time required to move the sensor through the pipeline and record the radiation count.

Assumption: The time required for movement through the pipeline was very consistent for each of the automatic and manual equipment configuration. For the automatic, the deployment speed was 6.8 feet per minute with essentially constant counts being recorded. The retrieval rate, as observed, was not per the standard procedures and therefore disregarded. A more normalized retrieval rate, provided by the vendor, of 3 ft/min is included in this analysis, again with continuous counts. For the manual equipment used on the 3 rod storage tubes, the deployment and retrieval rate was 1 ft/min for both, stopping every 0.3 feet and taking a 40 second count.

Scope:	One 4” drain line	Video
	One 4” drain line (same)	Beta - Gamma
	Three 5” rod storage tubes	Alpha
	One 5” rod storage tube	Alpha, Redone for clarity and used in analysis
	One 12” vent line	Failure and disregarded.

Set-Up and Move to Adjacent Pipe (between pipes at one location)

Definition: From a single location, an activity is necessary once the equipment has been retrieved from a pipe, to prepare for the next pipe, be it the same or a different size or length. This cost element consists of discarding the just used membrane from the deployment canister, cutting a new length of the proper size membrane for the next diameter and length pipe, installing it on the deployment canister and apparatus, and switching out the pre-pipe length attachment from the completed pipe to one that fits the next pipe.

Assumptions: Based on vendor experience and the demonstration, but not specifically timed, this takes about 1 hour.

Set-Up and Move to Remote Pipe (to a new location)

Definition: Once all pipes accessible from one location are completed, another activity is relocating to other parts of the building or area sufficiently remote from the current location that the equipment must be packed for moving. This cost element includes loading the Pipe Explorer and associated equipment into the van, moving the van, and re-positioning the equipment for the next set of pipe characterizations.

Assumptions: Based on vendor experience and the demonstration, but not specifically timed, this takes about 2 hour and includes the time to set up for the first pipe in the new location. This activity is also used when setting up at the first location on site.

Performance Check

Definition: This cost element accounts for performing a check of the instrument and system using a calibrated source to assure that any variation in performance is identified (at the end of the day) and includes the cost of the crew standing by during this time.

Assumptions: This activity is not applicable to this demonstration.

HPT Support

Definition: This activity provides for radiological oversight as well as radiological surveys.

Assumption: Used as an escort full time.

Productivity Loss

Definition: Losses from productive work occurring during the course of the work due to personal protective equipment (PPE) changes, ALARA, height of reach inefficiencies, etc.

- Assumption: A productivity loss factor (PLF) is a factor which multiplies the work time to account for the necessary activities which do not directly accomplish the work (i.e. work breaks) or to account for conditions which result in decreases in production rates (i.e. heat stress, etc.). Since the non-productive activities in the demonstration are atypical of normal D&D work, most of these activities have been screened out of this analysis. In an effort to restore the costs to a more realistic estimate of typical D&D work, a PLF from the baseline is used to make the innovative analysis comparable with the baseline estimate (from ANL documentation, which is based upon AIF, 1986) and is 1.10 based on the following factors:

Base	1.00
+Height	0
+Radiation/ALARA	0
+Protective Clothing	0 (no productivity reduction observed)
= Subtotal	1.00
X	
Respiratory Protection	1.00
=Subtotal	1.00
X	
Breaks	1.10
=Total	1.10

H&S/Project Meetings

Definition: This cost element provides for safety meeting and project planning meetings during the work.

Assumptions: The estimate assumes one 15 minute safety meeting per day based on typical practice at ANL, which is not accounted for in the PLF.

PPE Cost Per Day

Definition: This cost element provides for the personal protective clothing used during the work activity.

Equipment	Quantity in Box	Cost Per Box	Cost Each	No. of Reuses	Cost Each Time Used	No. Used Per Day	Cost Per Day
Respirator			1,933	200	10	1	10.00
Resp. Cartridges			9.25	1	9.25	2	18.50
Booties	200	50.00	0.25	1	0.25	4	1.00
Tyvek	25	85.00	3.4	1	3.4	4	13.60
Gloves (inner)	12	2.00	0.17	1	0.17	8	1.36
Gloves (outer pair)			7.45	10	0.75	1	0.75
Glove(cotton Liner)	100	14.15	0.14	1	0.14	8	1.12
Total							46.33

The PPE costs are predominantly from the ANL activity cost estimates for 1996 (costs for outer gloves, glove liners, and respirator cartridges are from commercial catalogs).

Assumption: 4 changes per day per person (typical for ANL D&D work).

<u>DEMOBILIZATION</u>

Survey Equipment and Decontaminate

Definition: This cost element covers the radiological survey of the equipment by a site HPT to assure that contaminated equipment does not leave the site. Labor and equipment for both the HPT and the crew standing by is included.

Assumptions: One-half hour is included for survey based on observed time from demonstration.

Pack Equipment

Definition: Loading the vendor's equipment includes time required for crew to pack equipment in the van.

Assumptions: One-half hour is required for loading, based on demonstration times.

Personnel and Equipment Transport

Definition: Transport of vendor's personnel and equipment to Albuquerque, NM via the vendor's van.

Assumption: This activity is the reverse of and equal to the mobilization activity.

PPE Cost

Definition: The decontamination and survey of vendor equipment will have some requirement for PPE by the crew and HPT conducting the decon work. This is assumed to be similar to the previously defined PPE cost element.

Cost Analysis

Innovative Technology - Pipe Explorer™

Costs for demonstration of the Pipe Explorer™ innovative technology are based on operating the device at one buried pipe location outside next to the reactor building and at the rod storage area inside the reactor building. The Pipe Explorer™ technology consists of mobilization and calibrations, site-specific training, set-up, establishing background counts, removing any caps or obstructions to the pipeline entrance and/or setting up an adaptation to the pipe, video taping the pipeline interior, radiological survey of the pipeline interior, moving and set-up on the next pipe, and demobilization. The projection of demonstration costs to reflect a more realistic cost for that scope of work includes a number of assumptions that make that projection possible. These assumptions are shown below:

- Survey of pipe consists of one pass through the pipe, generally at a rapid speed taking counts during deployment and at a slower retrieval speed stopping periodically for longer count periods. The time requirements associated with multiple passes through the pipe to check survey repeatability are ignored as an untypical D&D work situations, except for one tube. Both the deployment and retrieval procedures are specifically designed to meet the criteria of the Nuclear Regulatory Commission (NRC*),* of covering approximately 25% of the pipe interior surface. This technology has the capability of moving slowly enough to cover 100%, exceeding the 25% coverage rate.

- Surveys of pipes using less than one-minute count times are included which exceeds the currently accepted standard. An alternate count time of 6 minutes was performed on one pipe. Since this count is atypical of real work, it was not considered in the cost analysis.

- Characterization results for surveys, which failed due to storm conditions, are not used. However, the times to deploy and retrieve are utilized to figure production rates. The fact that the characterization data was invalid doesn't nullify the production rate for costing purposes.

- Excluded are two days of lost time spent repairing the equipment damaged in the storm, which is atypical of a normal D&D work. That situation could very likely be experienced at any site, at any time. The contractor / vendor providing the service generally would remain at the site, and an appropriate charge would be incurred. In this case the vendor had to get his equipment working in order to finish the job.
- The 1.5 hours for morning safety meetings (15 minutes each of 6 workdays) are included.

- The time required to convert one diameter and length membrane to fit another pipe size and length is included in this analysis as a "set-up, move adjacent" and or "move remote".

- Work will be performed as a vendor provided service because this equipment is not available to purchase for use by sites.

- Full time Health Physics Technician (HPT) support is included.

- A productivity loss factor (PLF) is a factor which multiplies the work time to account for the necessary activities which do not directly accomplish the work (i.e. work breaks) or the conditions which result in decreases in production rates (i.e. heat stress, etc.). Since the non-productive activities in the demonstration are atypical of normal D&D work, most of these activities have been screened out of this analysis. In an effort to restore the costs to a more realistic estimate of typical D&D work, a PLF from the baseline is used to increase the hours to more closely reflect the baseline estimate (from ANL documentation and the ANL data is based upon AIF, 1986). It is 1.10 as described in the preceding Activity Dictionary.

- A procurement indirect expense of 9.3% is added to the vendor hourly rates (both his owned equipment and labor) to account for the ANL charge to the project for administration of the procurement contract.

The cost for personal protective equipment (PPE) used is based upon typical practice and equipment at ANL (4 pairs of PPE used per day per person). Since this is an assumed rate rather than an observed quantity, the cost is computed based on the total duration of work in the controlled area plus the time required for decontamination of the equipment at the completion of the work.

The activities, quantities, production rates and costs observed during the demonstration are shown in Table C-1 Innovative Technology Cost Summary Table.

Table C-1 Innovative Technology Summary Cost

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor HRS	Labor Rate	Equipment HRS	Equipment Rate	Other	Total UC	Total Quantity (TQ)	Unit of Measure	Total Cost (TC) note	Comments
MOBILIZATION (mob) (WBS 331.01)								**Subtotal**	**$ 13,852**	
Transport Personnel & Equip	23	$ 195	23	$ 85	$ -	$ 6,430	1.0	Lump Sum (LS)	$ 6,430	Albuquerque, NM. to Chicago (Department of Transportation restrictions approx. 500 miles & 10 hr per day), vendor crew of 2 w/ 8 hr charge & per diem (consistent for remainder of table)
Calibration	5	$ 195	5	$ -		$ 973	6	Each	$ 5,837	Used 6 of planned 8 due 2surveys deleted.
Unload Equipment (Equip)	0.5	$ 195	0.5	$ 85		$ 140	1	Each	$ 140	
Survey-In Equip						$ -	1	Each	$ 181	
'Vendor Crew Stand-By	0.5	$ 195	0.5	$ 85		$ 140				Vendor Labor & Equipment rates
HPT Support	0.5	$ 56		$ -	$ 13	$ 41				ANL's Health Physics Technician (HPT) labor and 1/4 cubic foot (CF) of Low Level waste disposal for swipes @ $52.78/cf
Training	6.5	$ 195	0	$ 85		$ 1,265	1	Day	$ 1,265	3 Site specific training requirementrs (6.5 hr)
PIPE CHARACTERIZATION (WBS 331.17)								**Subtotal**	**$ 7,389**	
Set-Up: At site initially	0.5	$ 195	0.5	$ 85		$ 140	1	Day	$ 140	
Establish Background	0.083	$ 195	0.083	$ 85		$ 23	6	pipes	$ 140	5 minutes each for 6 pipes. Normal would have included another 5 min. upon exit also.
Access Pipeline							1	location	$ 449	Lift 1- 500 pound cap off rod storage pipe area
Vendor Stand-By	1.25	$ 195	1.25	$ 85		$ 349				
Lift Cap off Pipe	1.25	$ 40	1.25	$ 40		$ 100	4	pipes		ANL crane operator and overhead crane
Survey pipe lines										
Video Pipeline (4") (drain)	0.006	$ 195	0.006	$ 85		$ 2	175	Feet	$ 284	Normally, video each. Did 1 at demo due flood.
Pipe Survey-4" drain, for Beta/Gamma (B/G)	0.022	$ 195	0.022	$ 85		$ 6	175	Feet	$ 1,062	Deployed into pipe at 6.8 ft/min, retrieved at 3 ft/min,continuous counts, 10 second grouping.
Pipe Survey-12" (vent)		$ 195		$ 85		$ -	-	Feet	$ -	Failed, so disregarded. Not typical
Rod storage tubes (5")	0.081	$ 195	0.081	$ 85		$ 23	45	Feet	$ 1,029	3 tube, 1 done twice= 4 @11.3 ft considered.
Set-Up & Move to Adjacent	1	$ 195	1	$ 85		$ 280	4	Moves	$ 1,118	1 hr to disconnect & hookup for next pipe
Set-Up & Move to Remote	2	$ 195	2	$ 85		$ 559	2	Each	$ 1,118	Initial & Move from inside building to outside
HPT Support	1	$ 56				$ 56	17.7	hours	$ 994	HPT presence during performance of work
Productivity Loss Factor(PLF)	1.77	$ 195	1.775	$ 85		$ 496	1	Each	$ 496	Duration in controlled area X 10% (PLF=1.10)
H&S/Project Meetings	0.25	$ 195	0.25	$ 85		$ 70	6	day	$ 419	15 min/day safety meeting (typical for ANL)
PPE					$ 46	$ 46	3	Pair	$ 139	Assumed cost per person per day of $46.33
DEMOBILIZATION (demob) (WBS 331.21)								**Subtotal**	**$ 6,765**	
Survey Equip. & Decon						$ -	1	Each	$ 181	
'Vendor Crew Stand-By	0.5	$ 195	0.5	$ 85		$ 140				Vendor Labor & Equipment rates
HPT Support	0.5	$ 56			$ 13	$ 41				Same as Mobilization, HPT Support
Pack Equipment	0.5	$ 195	0.5	$ 85		$ 140	1	Each	$ 140	
Personnel & Equip. Transp.	23	$ 195	23	$ 85	$ -	$ 6,430	1.0	LS	$ 6,430	Reverse of Mob, back to Albuquerque
Productivity Loss Factor	0.05	$ 195	0.05	$ 85		$ 14	1	Each	$ 14	Applied to Decontamination & Survey of Equip

Note: TC = UC * TQ

TOTAL: $ 28,006

Activity Dictionary

Baseline Technology - Dismantlement & Disposal

MOBILIZATION

Transport and Unload Equipment (from local)

This cost element represents the cost of transporting the equipment from a local equipment rental firm to the local site. The costs include loading the equipment on a truck for transport, transport costs, unloading and stand by for equipment being rented. The equipment being transported for cutting the concrete, using a concrete saw alternative, includes a concrete saw, a backhoe loader, and miscellaneous equipment. The cost to transport equipment is shown below:

Crew Element	Unit Rate ($/hr)	Quantity	Total ($)
Labor			
Truck Driver	49.67	4 hr	149.01
Total Labor			**$ 149.01**
Equipment (rental)			
Concrete Saw (baseline estimate) Backhoe Loader (baseline est.) Flat Bed Truck rental (3 ton, Means 1997)): Miscellaneous	17.13 60.78 19.00 5.00	3 hr 3 hr 4 hr 3 hr	51.39 182.34 76.00 15.00
Total: Equipment	**$ 101.91**		**$ 324.73**
Total Labor & Equipment (used as Other):			**$ 473.74**

Survey-In Equipment

Definition: This cost element consists of surveying by an HPT and the rental cost of the equipment for the duration of the survey.

Assumptions: Assumes the equipment is dropped off at a staging area and then waits for an HPT to come by at some later time to survey the equipment.

Crew Element	Unit Rate ($/hr)	Quantity	Total ($)
Labor			
HPT	56.00	1 hr	56.00
Total	**$ 56.00**		**$ 56.00**
Equipment (rental)			
Concrete Saw (baseline estimate) Backhoe Loader (baseline est.) Miscellaneous	17.13 60.78 5.00	4 hr 4 hr 4 hr	68.52 243.12 20.00
Total	**$ 82.91**		**$ 331.64**
Other Costs			
Waste Disposal for Swipes	52.78 $/cf	1/4 cf	13.20
Total:	**$ 52.78**		**$ 13.20**

DISMANTLEMENT

Concrete Cutting

Definition: This cost element provides for saw cutting the floor that overlies the piping.

Assumptions: This analysis assumes the floor is cut using a diamond saw which makes two parallel cuts which are approximately 1 foot to 18 inches apart and then cross cuts are made at intervals of approximately 18 inches. The production rate of 2 ft/hr per lineal foot of trench length is based on rates from the 1992 baseline (ANL 1992).

Concrete Block Removal

Definition: This cost provides for the removal of the block of concrete that is cut from the floor.

Assumptions: The block is assumed to be removed using a backhoe loader. The equipment and production rate of 4 ft/hr is based on the 1992 baseline (ANL, 1992).

Remove Pipe & Contaminated Soil

Definition: Once the concrete has been removed, then the piping and any contaminated soil is removed.

Assumption; It is assumed that the production rate is 7 ft/hr based on the 1992 baseline (ANL,1992).

HPT Support

This cost element is the same as the cost element for the innovative technology.

Productivity Loss Factor

Definition: Losses for donning and removing PPEs, etc. are accounted for in this cost element.

Assumption: Productivity loss (associated with changing of PPE, etc.) is assumed to be the same as used in the baseline estimate (ANL, 1992) and is 1.10 for concrete removal activities and 2.02 for earthwork and pipe removal activities calculated as follows.

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	Concrete Removal	Earthwork		Pipe Removal
Base	1.00	1.00		1.00
+Height	0	0		0
+Radiation/ALARA	0	0		0.20
+Protective Clothing	0	0		0.15
= Subtotal	1.00	1.00	=Subtotal	1.35
X			X	
Resp Prot	1.00	1.00		1.36
=Subtotal	1.00	1.00	=Subtotal	1.84
X			X	
Breaks	1.10	1.10		1.10
=Total	1.10	1.10	=Total	2.02

H&S/Project Meetings

Definition: This cost element is similar to the cost element for the innovative technology.

Assumption: The PPE costs are predominantly from the ANL activity cost estimates for 1996 (costs for outer gloves, glove liners, and respirator cartridges are from commercial catalogs). D&D work at ANL typically requires 4 changes per day per person.

DEMOBILIZATION

Decon and Survey Equipment

This cost element consists of surveying by an HPT and the rental cost of the equipment for the duration of the survey.

Crew Element	Unit Rate ($/hr)	Quantity	Total ($)
Labor			
HPT	56.00	8 hr	448.00
Total	**$ 56.00**		**$ 448.00**
Equipment (rental)			
Concrete Saw (baseline estimate) Backhoe Loader (baseline est.) Miscellaneous	17.13 60.78 5.00	8 hr 8 hr 8 hr	137.04 486.24 40.00
Total	**$ 82.91**		**663.28**
Other Costs			
LL Waste Disposal	52.78 $/cf	1 cf	52.78
Total:			52.78

Productivity Loss

Definition: The decontamination and survey of rented equipment will have some productivity loss. This analysis assumes a PLF consistent with the 1992 baseline (ANL, 1992) of 1.10.

PPE Cost

Definition: The decontamination and survey of rented equipment will have some requirement for PPE by the HPT conducting the decon work. This is assumed to be similar to the previously defined PPE cost element.

<u>WASTE DISPOSAL</u>

Clean Waste (Concrete)

Definition: This cost element provides for disposal of the concrete blocks cut from the floor.

Assumption: The blocks are assumed to be free of contamination (a common assumption for this type of work) so that they can be disposed of as clean waste. Rate of $0.14/cf for packaging, transport and disposal are from ANL 1996 activity cost estimates. The 1992 baseline documentation (ANL, 1992) does not provide for any swell of the concrete waste (assumes that blocks are neatly stacked).

Waste Disposal (Solid-Low Level Radioactive Waste)

Definition: This cost element provides for the disposal of the contaminated soil and the pipe.

Assumption: The contamination is assumed to be low level radioactive waste and the disposal cost is $53/cf based on rates from ANL 1996 activity cost estimates. The 1992 baseline documentation (ANL, 1992) assumes a 150% swell factor and 0.05 cf/ft of contaminated soil.

Cost Analysis

The work is assumed to consist of:

- mobilization of the rented equipment,
- removal of overlying concrete,
- removal of piping both from under concrete and in earth requiring excavation, backfill, and compaction,
- survey of concrete to allow disposal as clean waste,
- packaging of waste,
- demobilization of equipment, and

- disposal of waste

The costs for the dismantlement and disposal alternative are based upon production rate and crew cost assumptions developed from historic experience. It assumes the pipe to be removed is buried in earth with three different surface preparations. The "typical" candidate for using the Pipe Explorer technology is the horizontal drainpipe which is overlain by a slab. The baseline for this "typical" type of candidate pipe is concrete removal and disposal of the pipe. The concrete removal scenario is not representative of the D&D work required for the fuel rod storage tubes but is used in this cost analysis because it represents a typical approach to D&D work for the types of pipes that would normally be candidates for the Pipe Explorer technology. The assumptions for the baseline are shown below:

- Work is performed using rented equipment and local crafts
- Trench excavation consists of five feet of cover, width of 18 inches at bottom and 2 v:1h slope
- Production rates
    - Two cubic feet per hour for concrete saw cut
    - Four cubic feet per hour for concrete block removal
    - Seven cubic feet per hour for pipe removal
    - Excavation, 200 cy/day; Backfill, 400 cy/day; Compaction, 375 cy/day; pipe removal, 132.5 lf/day.
- Pipe waste volume is 150% of the actual pipe volume due to bulking and contaminated soil volume is 0.05 cubic feet per foot (based on ANL, 1992)
- Concrete waste volume is not adjusted for bulking (assumes concrete blocks are stacked to preclude voids) (ANL, 1992)
- Soil is not contaminated
- Productivity loss, associated with changing of PPE, etc., is assumed to be the same as used in the baseline estimate (ANL,1992) and is 1.10 for concrete removal activities and 2.02 for pipe removal activities

	Concrete Removal		Pipe Removal
Base	1.00		1.00
+Height	0		0
+Radiological/ALARA	0		0.20
+Protective Clothing	0		0.15
= Subtotal	1.00	=Subtotal	1.35
X		X	
Respiratory Protection	1.00		1.36
=Subtotal	1.00	=Subtotal	1.84
X		X	
Breaks	1.10		1.10
=Total	1.10	=Total	2.02

- Safety meetings each morning for 15 minutes
- HPT support is full time and provides for safety oversight as well as radiological surveys for segregation of the concrete, soil, and pipe waste

The costs for dismantlement and disposal will vary from the costs and assumptions used in this analysis due to the site-specific conditions. Conditions that will influence cost significantly are depth of concrete overlying the pipe (lower production rate and greater volume), type of pipe, and disposal costs.

The activities, quantities, production rates and costs observed during the demonstration are shown in Table C-2 Baseline Technology Cost Summary Table.

Table C-2 Baseline Technology Cost Summary

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor Hour	Labor Rate	Equipment Hour	Equipment Rate	Other	Total UC	Total Quantity (TQ)	Unit of Measure	Total Cost (TC) note	Comments
Mobilization (mob) (WBS 331.01)								**Subtotal**	**$ 1,024**	
Transport & Unload Equipment	0	$ -	0	$ -	$ 474	$ 474	1	Each	$ 474	Transport equip. from local rental , includes 4 hours truck hauling, teamster and stand by for saw and backhoe for 3 hours
Survey-In Equipment (Equip.)						$ -	1	Each	$ 401	Stand by cost for saw and backhoe for 4 hours
Equipment Stand By	0	$ -	4	$ 82.91		$ 332				ANL's Health Physics Technician (HPT)
HPT Support	1	$ 56.00		$ -	$ 13	$ 69				1/4 cubic foot (CF) of low level (LL) waste (LLW) disposal for swipes @ $52.78/cf
Mobilize for Excavation/BF	1.5	$ 79.70			$ 30	$ 150	1	Each	$ 150	2 people, 1.5 hr, $79.70/crew, pipe removal
Dismantlement (WBS 331.17)								**Subtotal**	**$ 20,866**	
Remove Concrete Encased Pipe	0	$ -	0	$ -		$ -	45	Feet	$ -	Production rate(PR) designated for activities:
Cut Concrete(CC),remove blocks(RB) & soil and pipes (RSP)	0.893	$ 73.45	0.893	$ 82.91		$ 140	45	Feet	$ 6,310	CC=2 feet/hour(ft/hr); RB=4 ft/hr; and RSP=7 ft/hr. 3- 11.3 ft tubes. 3 activities duration is 0.893/sf. HPT support & PLF applicable.
Productivity Loss (Concrete)	3.39	$ 73.45	3.39	$ 82.91		$ 530	1	Each	$ 530	Work duration in controlled area X 10% Productivity Loss Factor (PLF)=1.10
Productivity Loss (Pipe)	6.586	$ 73.45	6.586	$ 82.91		$ 1,030	1	Each	$ 1,030	Duration in controlled area X 102% (PLF=2.02); yard pipe PLF is different
Set-Up & Move Remote	1	$ 73.45	1	$ 82.91		$ 156	1	Each	$ 156	
Excavate (yard pipe)	0.04	$ 79.70	0.04	$ 76.86		$ 6.26	164	cubic yd(CY)	$ 1,027	PR=200cy/day,2 man crew, excavator,
Backfill (BF)	0.020	$ 56.65	0.02	$ 41.00		$ 1.95	180.4	CY	$ 352	PR=400cy/day,1.5 man crew, 10% bulking
Compact	0.021	$ 33.60	0.021	$ 10.85		$ 0.93	180.4	CY	$ 168	PR=375cy/day,1 laborer w/compactor
Remove pipe/Landscape (yard)	0.286	$114.00	0.286		$ 0.37	$ 32.97	175	Feet	$ 5,770	PR=7ft/hr,3 man crew (with PLF=2.0)
HPT Support	41.36	$ 56.00	0	$ -		$ 2,316	1	Each	$ 2,316	HPT presence during performance of work
H&S/Project Meetings	0.25	$ 73.45	0.25	$ 82.91		$ 39	18	Days	$ 704	15 minutes/day health and safety (H&S) meeting (typical ANL)
Personal Protection Equip.	0	$ -	0	$ -	$ 139	$ 139	18	Days	$ 2,502	$46.33/person/day for 3 persons for 18 days
Demobilization (demob) (WBS 331.21)								**Subtotal**	**$ 1,815**	
Demob Excavation Equip.	1.5	$79.70	1.5			$ 120	1	lump sum	$ 120	On the excavation, BF, & pipe removal equip.
Decon and Survey Equip.						$ -	1	Each	$ 1,164	Stand by during decontamination (decon.)
Equipment Stand By	0	$ -	8	$ 82.91		$ 663				ANL's HPT labor rate & 1 cubic feet of LLW
HPT Support	8	$ 56.00			$ 53	$ 501				disposal for cleaning @ $52.78/cf for 1 cf
Productivity Loss Factor	0.08	$ 56.00	0.08	$ 82.91		$ 11	1	Each	$ 11	Productivity Loss Factor of 1.10 for decon
Personal Protection Equip.	0	$ -	0	$ -	$ 46	$ 46	1	Day	$ 46	$46.33/person/day for 1 persons for 1 day
Load and Transport Equip.	0	$ -	0	$ -	$ 474	$ 474	1	Each	$ 474	Same as Mobilization, Transport & Load Eq
Waste Disposal (WBS 331.18)								**Subtotal**	**$ 770**	
Clean Waste (Concrete)					$ 0.14	$ 0.14	68	Cubic Ft	$ 10	$0.14/cf unit rate for ANL clean waste disposal
Waste Disposal (Solid LL)					$52.78	$ 52.78	14.4	Cubic Ft	$ 760	Assume 150% bulking for 5 inch pipe and .05 cubic feet/foot contaminated soil at $52.78/cf unit rate for ANL LLW disposal
Note: TC = UC * TQ								**TOTAL:**	**$ 24,475**	