Cost/Performance Report
Drain Line Characterization Robot

Photo 1. Drain Line Characterization Robot in Mockup.

Photo 2. Interior of 221-U Facility Drain Line.

SUMMARY

The Drain Line Characterization Robot is a tracked robotic vehicle with onboard video and radiation monitoring instrumentation. The robot was deployed to safely and economically inspect, characterize, and collect samples from 800 ft of subterranean piping in the Hanford Site's 221-U Facility (Photos 1 and 2). The remote capabilities of the Drain Line Characterization Robot greatly reduced actual and potential radiological dose to operations personnel. No practicable alternate methods to obtain similar characterization data have been identified.

The *Sampling and Analysis Plan for 221-U Facility*, DOE/RL-97-68 (herein after referred to as the [SAP]), defines the objectives for examination of the 221-U Facility drain line. In accordance with the SAP, necessary characterization data included the following:

- Visual record for assessment of the structural integrity of the pipe and where liquid may be draining from
- Scale or sludge sample to obtain the isotopic distribution and inventory of radiological and nonradiological contaminants of potential concern, and a radiological survey of the pipe (using gamma energy analysis) to correlate with the isotopic distribution obtained from the scale/sludge sample.

Phase 1 of the characterization involved assessment of the as-built configuration of the drain line outfalls into cell 10. Initial visual examination and evaluation were needed for the design and development of suitable methods to satisfy the SAP requirements.

Data collected using the overview video system (OVS) satisfied the Phase I objectives by providing information necessary for design of systems and equipment for more complete characterization of the drain line.

The Drain Line Characterization Robot was designed and constructed by Pacific Northwest National Laboratory. Deployment of the Drain Line Characterization Robot was accomplished through the support of the Deactivation and Decommissioning Focus Area, which is managed by the National Energy Technology Laboratory. This work was conducted as part of the 221-U Facility characterization in support of the Canyon Disposition Initiative Project. Characterization information is being obtained to support a Record of Decision for the 221-U Facility. The Record of Decision will establish regulatory and technical precedence for future disposition of the other Hanford Site chemical processing facilities (also known as canyons).

INNOVATIVE TECHNOLOGY DESCRIPTION

Robot Description

The tracked robotic vehicle is constructed with sharply tapering ends (front and rear) to aid in navigating obstructions. Vehicle power, control, and data are carried over a 0.5-in.-diameter cable bundle (tether) that is pulled by the vehicle. The tether terminates at the rear of the vehicle via electrical connectors. A robust strain relief is used to provide the physical interface between the vehicle and tether and to mechanically isolate electrical connectors.

An adjustable iris/focus pan-tilt-zoom camera and two variable intensity headlights are mounted at the vehicle's midplane. The vehicle is equipped with a MGP DMC 100 gross gamma sensor. Data are transmitted to the control station and are superimposed on the video image from the primary camera.

A secondary camera and microphone with digitized radio frequency (RF) output are also provided. The secondary camera and microphone are not necessary for operation of the Drain Line Characterization Robot. The RF instruments were deployed for evaluation purposes.

The vehicle is operated via a control station that was staged in the operating gallery. Data presented for operation and recording at the control station include video images from the primary on-vehicle camera, an overview camera on the deployment platform, gross gamma radiation dose, and video/sound from the RF instruments. The vehicle track's motion control is via a self-centering, return-to-zero, bi-directional joystick. One joystick is used for each of the two independently operated tracks. Controls for the tether-management friction cable drive are also provided at the control station.

The control station provides operator interfaces for each of the three cameras. Video signals for the cameras are recorded at the control station.

Deployment System Description

The deployment system involves two major elements: a deployment platform (which is lowered via overhead crane to the drain line outfalls) and a separate cable management system (which was located on the canyon deck).

<u>**Deployment Platform**</u>

The deployment platform is designed to be manipulated and lowered by the facility's overhead bridge crane into cell 10 to the level of the drain line outfalls. The deployment platform and vehicle-mounted cameras provide additional visual cues for positioning the platform (Photo 3).

The major components of the deployment platform include the following:

- Deployment frame
- Vehicle support tray with cable wiper
- Cable drive with distance encoder
- Idler pulley
- Overview camera
- RF camera receiver.

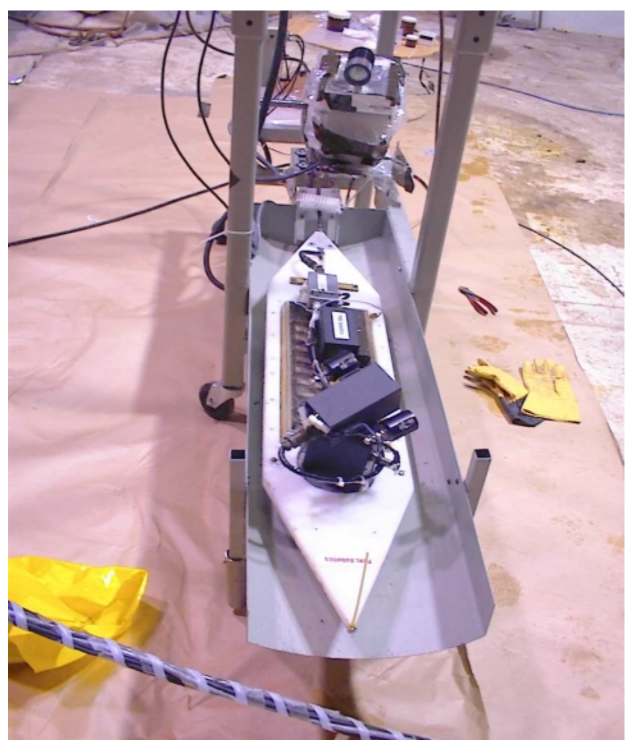


Photo 3. Robot Vehicle on Deployment Platform.

Deployment Frame. The deployment frame is constructed of 2-in.-square carbon-steel tube in accordance with *Hanford Hoisting and Rigging Manual* (DOE-RL-92-36) requirements for lifting devices. The basic frame weighs approximately 200 lb and is rated to lift an additional 600 lb. The estimated weight of the vehicle and other components supported on the frame is 200 to 300 lb. The frame pick-point is adjustable in two directions for center compensation at the time of lift. Casters are installed in the legs to facilitate movement of the platform within the building. The height of the frame is adjustable, from approximately 65 in. to 83 in., via sliding tube-on-tube construction and quick-release ball lock pins. Overall dimensions of the deployment frame enable it to be passed through the 20-in.-wide canyon deck access door.

Vehicle Support Tray. The vehicle rests in a sheet metal tray that is bolted to the lower portion of the frame (see photo 3). The tray is curved to match the inside radius of the drain line. Legs on each side of the tray act as stops against the bottom edge of the outfall pipe. A cable wiper is mounted between the tray and the cable drive unit to reduce contamination on the cable, protect the cable drive unit from debris, and collect samples from material adhering to the returning cable.

Cable Drive Unit. The cable drive unit is a commercially available (Zetec™) assembly with a direct-current (DC) motor/gearbox driving four rubber wheels that clamp onto the tether in forward or reverse directions via an adjustable speed control and a distance encoder. Coordination of vehicle and cable drive speed is performed manually by monitoring cable slack at the deployment platform and by the vehicle-mounted motor speed controller. The cable drive unit is capable of retrieving the vehicle in the event of vehicle drive failure.

Idler Pulley. An idler pulley is installed at the level of the vehicle to guide the tether from horizontal to vertical orientation. A pulley guide keeps the tether engaged with the pulley if tension is lost in the tether.

Overview Camera. The overview camera provides a view of the vehicle as it enters and exits the outfalls and allows continuous monitoring of the tether drive unit as the vehicle travels down the pipe. The camera can also assist in positioning the deployment platform with the crane. The overview camera has pan, tilt, and zoom capabilities.

RF Camera Receiver. The RF camera receiver is mounted on the deployment platform to provide the best possible reception.

Cable Management System

The cable management system is used to deploy and retrieve the tether as it travels up to 600 ft down the drain line. In addition to the tether, a bundle of several ancillary cables terminates at the deployment frame.

The cable management system uses a counter-weighted frame at the deck-level to deploy and retrieve the tether. The frame supports a cable storage bin, a cable drive motor, and a weighted idler that hangs down into cell 10 to provide constant tension and a variable length section of "take-up" cable. A visual measurement device on the frame indicates how far the idler has traveled. Two operating personnel are required to operate the cable management system. One operator uses a cable-handling pole to control the tether as it enters and exits the storage bin. The second operator monitors cable length in the "take-up" section and operates the cable drive motor.

Major components of the cable management system include the following:

- Framework
- Cable storage bin
- Cable drive
- Hanging weighted idler
- Take-up measurement device.

Framework. The framework is 18 in. wide to accommodate the 20-in. access door and has casters for transport and positioning. The upper portion is removable (using ball-lock pins). Part of the frame cantilevers out over cell 10 so the tether freely hangs directly over the deployment platform. The framework is counter-weighted to tolerate at least 100 lb of deployed tether/idler weight.

™ Zetec, Inc., is located in Issaquah, Washington.

Cable Storage Bin. A specially built cable storage bin accommodates staging of the tether in a figure-eight pattern (Photo 4). The bin is oval in shape, 54 in. long, and has a 12-in. radius at each end. Two 18-in.-diameter cylinders are placed at the center of the radius at each end. The figure-eight pattern prevents the cable from twisting during deployment and retrieval. Because of its size, the bin must be assembled on the deck.

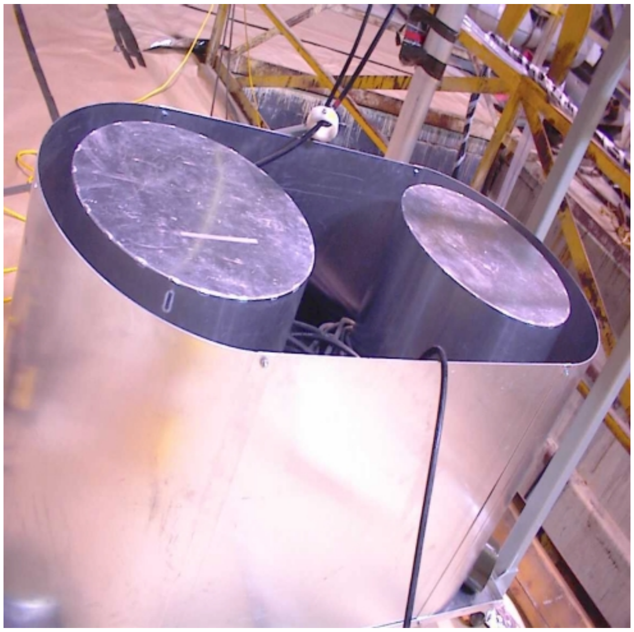


Photo 4. Cable Storage Bin.

Cable Drive. A DC gear motor located directly above the bin drives the tether in either direction while an operator uses a cable-handling pole to direct the tether in the storage bin. The tether is pressed against the motor pulley by a friction idler. The drive supports the weight of the cable hanging down into the cell and also the weight of the free-hanging idler. Controls for the drive are mounted on the deployment frame. The drive requires one 110-V power source.

Hanging Weighted Idler. A free-hanging idler is suspended between two idler pulleys mounted on the framework. This creates a take-up section of the tether so the upper tether drive on the deck does not require precise coordination with the lower drive on the deployment platform. The weight of the idler maintains a constant tension between the framework and the deployment platform. With approximately 25 ft of extension, a tether "buffer" of about 50 ft is available. The vehicle travels at up to 20 ft per minute, providing a 2.5-minute buffer for drive coordination.

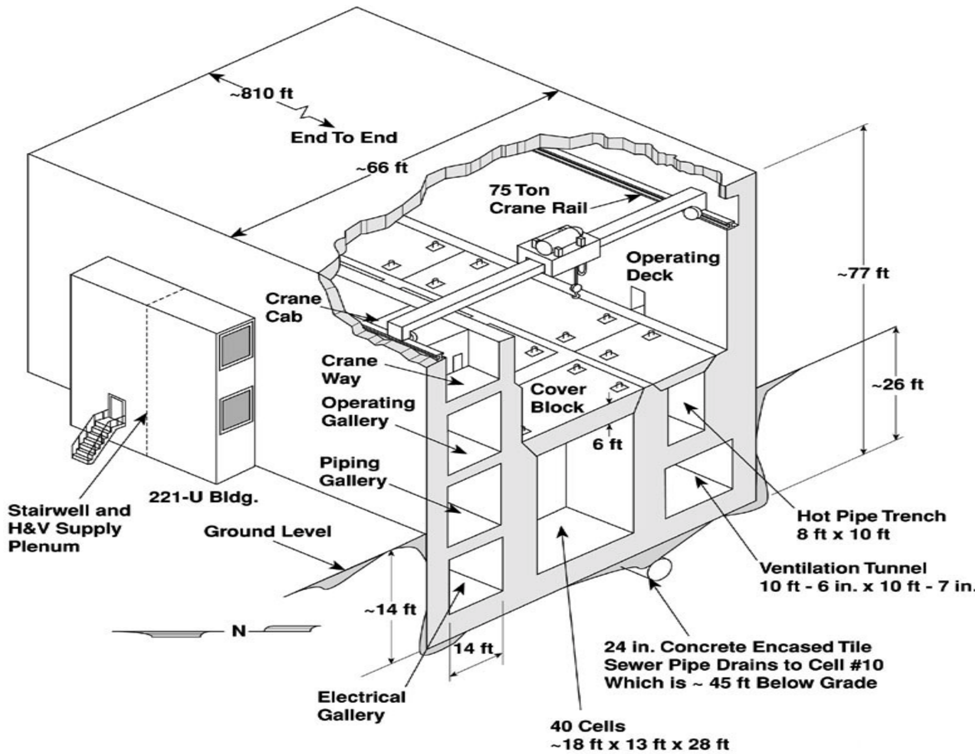
Take-Up Measurement Device. The hanging idler is attached to a measurement line on the framework. The line feeds out as needed from a spring-retracting cord reel. The line is marked so the operator can determine how far the idler is extended. Maintaining a constant idler deployment distance indicates coordination of the two drive systems.

DEPLOYMENT SITE INFORMATION

The 221-U Facility is a multi-story building, approximately 810 ft in length. The building and equipment were originally designed to support the production of plutonium; however, the facility was never used for this purpose. After initial construction, the building was remodeled and used for the recovery of uranium from tank farm wastes. The foundation, walls, and roof are constructed of reinforced concrete. The building is divided into two main portions by a concrete wall that runs the full length of the building. One portion of the building is called the canyon and the other portion contains the galleries. The length of the building is divided into 20 sections, at approximately 40-ft intervals. Each section contains two process cells, approximately 13 ft wide, 18 ft long, and 28 ft deep (below deck level). The cells and canyon deck are currently being used to store contaminated process equipment (Figure 1).

Cell 10 is approximately 48 ft deep and serves as a sump to collect drainage from the process cells. A 24-in.-diameter concrete encased tile drain line is installed beneath the process cells, sloped from each end of the building, discharging to cell 10 at approximately 38 ft below deck level.

Figure 1. 221-U Canyon Building Selection



DEPLOYMENT DESCRIPTION

The Drain Line Characterization Robot was deployed to examine the 24-in. process cell common drain line. The drain line was accessed from the two outfall points into cell 10.

Deployment of the Drain Line Characterization Robot was performed in concert with normal and routine operations activities and in accordance with existing generic work procedures and authorizations at the 221-U Facility. The actual deployment of the Drain Line Characterization Robot was performed at or near the canyon deck level. Therefore, the erection and subsequent removal of scaffolding were not necessary.

The Drain Line Characterization Robot deployment platform and cable management system were deployed from the 221-U Facility canyon deck. Vehicle controls, camera controls, video monitors, and data recording equipment were located in the operating gallery. All camera, vehicle, and data recording controls were remotely operated and monitored from the operating gallery.

The Drain Line Characterization Robot successfully traversed the full length of the 221-U Facility drain line. Several of the process cells have instrumentation assemblies installed through the floor drains that bisect the drain line from top to bottom. These assemblies appeared to be 1-in. steel pipe, with a union at the bottom. Attached to each pipe were two additional 0.5-in. pipes that bent around the central pipe in an “R” shape (Photo 4). The Drain Line Characterization Robot successfully navigated around these and other obstacles, such as personal protection equipment items (e.g., shoe covers, gloves, and pencil dosimeters) and other miscellaneous/ unidentified debris.

One large object was encountered directly in the robot’s path (Photo 5). The object was encrusted by solidified sludge and was fixed to the drain line floor. The robot was used as a battering ram to eventually dislodge this object and complete traverse of the drain line.

Following completion of video recording, the Drain Line Characterization Robot was subject to radiological surveys. Selected equipment was wiped and clean released. All equipment staged in the operating gallery (e.g. data recording, display, and control station) was surveyed and clean released.

Photo 5. Instrumentation Assembly Obstruction in Drain Line.

BASELINE TECHNOLOGY DESCRIPTION

A specific baseline method for data collection equivalent to that obtained by the Drain Line Characterization Robot has not been identified. A plausible scenario for collecting acceptable data would involve sequential opening of multiple process cells. The cell contents would be rearranged and/or removed to provide access to the existing drain line connection (from each process cell to the 24-in. drain line).

Video, radiological, and sample collection equipment would then be lowered into the cell drains to access the 24-in. drain line. This method would result in localized characterization data of the drain line, consisting of approximately 35 discrete points at about 22-ft increments. Due to personnel safety requirements and the relative congestion of deck space in the 221-U Facility, only one process cell can be opened at a time. Each cell opening involves rearranging equipment stored on the canyon deck.

These efforts would also include developing detailed special-purpose work procedures, increasing coverage by radiological and safety personnel, and performing significant engineering evaluation necessary for manipulation of process cell contents. The labor required for such an effort (as well as design, development, and deployment of characterization equipment) would be cost prohibitive.

DEPLOYMENT COSTS AND BENEFITS

Capital costs for the design and development of the Drain Line Characterization Robot, including the deployment platform and cable management systems, are summarized as follows.

- Equipment/parts/purchases: $50,000
- Design of lifting platform and cable management system: $15,000
- Fabrication of platforms and vehicle: $17,000
- Vehicle design and testing: $64,000
- Electronics design and development: $14,000
- Subcontractor deployment support: $10,000
- Subcontractor management and administration: $10,000.

Equipment and material cost reductions were achieved by reusing surplus equipment available from unrelated projects. Surplus equipment and materials included, but were not limited to, the overview camera, radiation sensor, and Zetec cable drive.

Total subcontractor equipment and deployment support totaled $180,000.

Facility costs consisted of 714 man-hours of labor at an estimated average cost of $60 per hour, totaling $42,840.

Miscellaneous in-house consumables are predominated by personal protective equipment. Approximately 42 individual entry/exits were performed at an estimated average cost of $500 each entry, totaling $21,000. Total project cost was $243,840.

Use of the Drain Line Characterization Robot for characterization of the 221-U Facility's process cells common drain eliminated the need for personnel to make repeated entries onto the canyon deck. Regularly assigned facility personnel are capable of performing remote below-deck examinations using this technology. Risks to workers are reduced through the use of the Drain Line Characterization Robot. Potential risks include the following:

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

Entries to the canyon deck and operating gallery areas were made in a routine manner and within normal radiological monitoring and survey requirements. Deployment of the Drain Line Characterization Robot was preceded by radiological survey and smear collection by normally assigned radiological control technicians. This level of participation by radiological control technicians is within normal entry and generic work requirement parameters.

CONCLUSION

The Drain Line Characterization Robot successfully traversed the full length of the 221-U Facility drain line. Data and samples were successfully collected to satisfy the requirements of the SAP, as described in the "Summary" section of this report.

A video record of the general condition of the drain line and a running total of radiological dose and dose rates were collected by the system. A representative sample of drain line sludge was collected from each side of the drain line.

The RF camera and microphone performed as expected, with loss of communication occurring between 80 and 100 ft into the drain lines. Significant interference was encountered on the RF video system while refreshing the packetized digital data transmissions from the radiological instrumentation.

The greatest challenge in deployment of the Drain Line Characterization Robot was acceptable cable management. The innovative design of the cable management system eliminated the need for personnel entry into cell 10 and personnel exposure to possibly hazardous conditions below the deck level.

The Drain Line Characterization Robot, used with the cable management and deployment platform concept, is readily adaptable for otherwise inaccessible inspection and characterization tasks.

Engineered equipment and materials used in this deployment were recovered and staged for possible future use. The control station, video and data recording equipment staged in the operating gallery, and selected items on the deployment platform assembly were clean-released to the subcontractor.

Additional deployment of the Drain Line Characterization Robot is not scheduled at this time. However, the equipment is staged and available for future projects or emergent needs.

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