INNOVATIVE TECHNOLOGY
Summary Report

Liquid Nitrogen-Cooled Diamond-Wire Concrete Cutting

OST Reference #2107

Deactivation and Decommissioning Focus Area

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MASTER

Demonstrated at
Hanford Site
Richland, Washington

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INNOVATIVE TECHNOLOGY

Summary Report

Purpose of this document

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

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SECTION 1

SUMMARY

Liquid Nitrogen-Cooled Diamond-Wire Concrete Cutting can be used to cut through thick concrete walls, floors, and structures without using water to cool the cutting wire. The diamond wire is cooled with liquid nitrogen in a 0.9-m (3-ft) long by 7.6-cm (3-in.) diameter pipe housing. The nitrogen evaporates, so no contaminated liquid waste is generated. Other than the use of liquid nitrogen, the system is a conventional diamond-wire saw assembly with remote hydraulic controls. Setup of the hydraulic-powered drive wheel and the diamond wire for cutting requires a relatively short period of time using people with minimal training. Concrete dust generated during the cutting is considerable and requires control. The production rate of this improved technology is 0.78 m^2/hr (8.4 ft^2/hr). The production rates of traditional (baseline) water-cooled diamond-wire cutting and circular saw cutting technologies are 1.11 m^2/hr (12 ft^2/hr), and 0.45 m^2/hr (4.8 ft^2/hr), respectively. The liquid nitrogen-cooled system costs 189% more than conventional diamond-wire cutting if contaminated liquid wastes collection, treatment, and disposal are not accounted for with the baseline. The new technology was 310% more costly than a conventional diamond circular saw, under the conditions of this demonstration (no wastewater control). For cutting a 0.9-m x 3.7-m (3-ft x 12-ft) wall, the improved technology costs $17,000, while baseline diamond-wire cutting would cost $9,000 and baseline circular-saw cutting would cost $5,500. The improved system may cost less than the baseline technologies or may be comparable in cost if wastewater control is included.

■ Technology Summary

The liquid nitrogen-cooled diamond-wire concrete cutter is an improved technology designed and fabricated by Bluegrass Concrete Cutting, Inc., of Greenville, Alabama. This improved technology was demonstrated for the U.S. Department of Energy's (DOE) C Reactor Interim Safe Storage (ISS) Project as part of the Large-Scale Demonstration and Deployment Project (LSDDP) at the DOE's Hanford Site in Washington.

Diamond-wire cutting has been used traditionally with water injected into the kerf for cooling and dust control. Liquid nitrogen is a desirable alternative cooling agent for concrete sawing because the nitrogen evaporates, leaving no potentially contaminated liquid waste. In this demonstration, a 0.9-m (3-ft) long by 7.6-cm (3-in.) diameter pipe housing was installed around the diamond wire, into which liquid nitrogen was sprayed. Liquid nitrogen is available in portable Dewar tanks from commercial welding gas dealers.

The diamond wire is made of a 6.4-mm (0.25-in.) aircraft-quality steel cable with diamond-impregnated beads. Each diamond-impregnated bead is separated from the next by a spring, and three-bead/spring combinations are each separated by a 3,629-kg (8,000-lb) pressure brass crimp.

A 50-hp hydraulic pump drives a hydraulic motor that powers the diamond-wire saw-drive wheel. The 0.9-m (3-ft) diameter drive wheel generates wire tension and moves the diamond wire as fast as 25 m/sec (82 ft/sec). Speed and tension on the diamond-wire saw are controlled remotely by adjusting a cylinder valve and a needle valve on the hydraulic pump.

Problem Addressed

The liquid nitrogen-cooled diamond-wire concrete cutting was assessed in an effort to find ways of eliminating cooling water from the conventional cutting process. With baseline concrete cutting technologies, the portion of water that does not evaporate forms a slurry with concrete dust that must be managed as a waste product. If the concrete is radiologically contaminated, the waste slurry must be captured, treated, and disposed appropriately. Dry cutting may be preferred, and the concrete dust can be collected with a vacuum filtration system.

Features and Configuration

The improved technology uses the following components:

- An electric/hydraulic power unit requiring 60-amp, 3-phase, 480-volt current. The unit is 0.8 m (32 in.) wide, 1.5 m (60 in.) long, and 1.2 m (48 in.) high. The hydraulic pump is rated at 129 L/min (34 gal/min) and 207 bars (3,000 psi). The unit weighs 680 kg (1,500 lb) and has lifting hooks and forklift guides.
- A hydraulically powered drive wheel, 0.9 m (3 ft) in diameter. The drive wheel can be located up to 30.1 m (100 ft) away from the electric/hydraulic power unit. The drive wheel unit and guide pulleys weigh less than 90 kg (200 lb). The hydraulic system uses once-through cooling water that does not become contaminated.
- A diamond-wire saw with a pipe housing added; the length of diamond wire depends on the size of cut.

The equipment is easy to set up; however, the saw and wire must be housed in a temporary enclosure that is exhausted via a vacuum filtration system. Pre-drilled holes are required to string the diamond-wire saw around or through the concrete structure being cut.

Potential Markets/Applicability

The liquid-nitrogen cooled diamond-wire concrete cutting technology is useful at DOE, U.S. Environmental Protection Agency (EPA), or U.S. Nuclear Regulatory Commission (NRC) sites where contaminated concrete must be cut as part of a demolition process, especially where use of water is undesirable. The technology could be used at other public or commercial facilities where concrete cutting is required.

Advantages of the Improved Technology

- The technology can be used to cut almost any engineered concrete structure (walls and floors of nearly any size).
- Using liquid nitrogen for cooling the diamond-wire eliminates the use of cooling water that could become contaminated; however, dust must be controlled with an adequately sized HEPA vacuum filtration unit. The use of smaller amounts of water to control dust than with baseline tools may be favorable in some cases.
- Adequate dust collection must be compared to the use of cooling water for each project. An engineering evaluation would determine if dust collection is more economical than slurry collection.

The following table summarizes the advantages and shortfalls of the improved technology compared to the water-cooled baseline technologies (diamond-wire saw cutter and a diamond circular saw).

Category	Comments
Cost	More expensive than the baseline technologies. (For a wall 0.9-m [3-ft] thick and 3.7-m [12-ft] high, the costs are $17,000, $9,000, and $5,500 for the improved, water-cooled diamond wire, and water-cooled circular saw technologies, respectively.) A major cost component is a tent enclosure to control dust emissions, which is not needed with the baseline technologies; costs depend on dust control and contaminated wastewater handling.
Performance	Cutting rate is 70% as fast as the water-cooled diamond wire, but 75% faster than the use of a circular saw.
Implementation	Does not require capture of wastewater slurry.
Secondary Waste	Dry waste can be handled easier than wastewater slurry.

Category	Comments
ALARA/Safety	Can control cutting 30 m (100 ft) away from a potential radiation source.
Ease of Use/Training	Easy operation by an operator experienced in diamond-wire cutting; not as easy to learn as the baseline circular saw.

Operator Concerns

The dust generated requires the use of a dust-control technology. A high-capacity high-efficiency particulate air (HEPA) filter was used for this demonstration; standard commercial filters could be used for non-contaminated sites. A small amount of water could also be used to control dust, but this concept was not evaluated. If the wire breaks during operations, whiplash can occur behind the saw.

Skills and Training

As with any diamond-wire saw, special operator experience is needed to properly control the wire tension.

■ Demonstration Summary

Liquid nitrogen-cooled diamond-wire concrete cutting was demonstrated by the Hanford Site C Reactor Technology Demonstration Group during March 1998.

Demonstration Site Description

Liquid nitrogen-cooled diamond-wire concrete cutting was demonstrated for the first time by the DOE at its Hanford Site. A concrete wall at the C Reactor was cut to separate a section of the wall that is to remain standing from a section to be demolished. See Figure 1. The section remaining is part of the outside of the reactor safe storage enclosure (SSE).

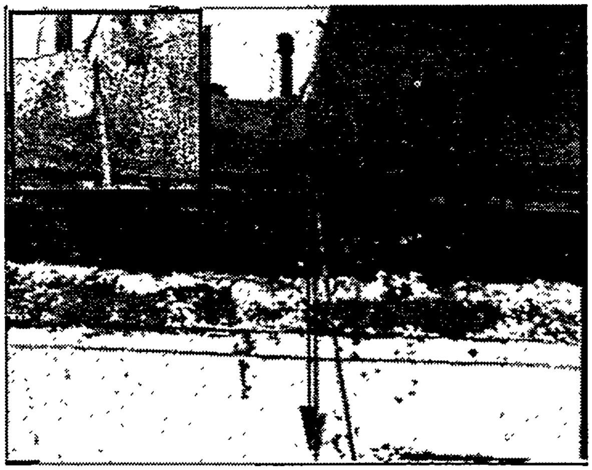

Figure 1. Diamond wire and cut line.

Regulatory Issues

There are no special regulatory or permit requirements associated with implementation of this technology. Normal worker safety practices should be applied when using this tool in accordance with applicable regulations, particularly 10 *Code of Federal Regulation* (CFR), Parts 20, 835, and proposed Part 834, to protect workers and the environment from radiological contaminants; and 29 CFR Occupational Safety and Health Administration (OSHA) worker requirements.

Technology Availability

The system is readily available through Bluegrass Concrete cutting, Inc., Greenville, Alabama.

Technology Limitations/Needs for Future Development

- As presently designed and operated during the demonstration, the area that can be cut with the improved technology is limited to 2.5 m^2 (27 ft^2). Overheating and wire damage occurs beyond this point.

- Immersing the diamond-cutting cable in liquid nitrogen and/or injecting some of the liquid nitrogen into the kerf could be investigated for system improvements.

- A combination of liquid nitrogen cooling and minimal water injection for dust control could be developed to improve dust collection and cutting performance.
- Unless special ventilation is used, indoor use of the liquid nitrogen-cooled saw is limited because of the nitrogen gas produced, which displaces oxygen in enclosed areas. (The demonstration was at an outdoor area.)

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Other
All Published Innovative Technology Summary Reports are available at http://em-50.em.doe.gov. The Technology Management System, also available through the EM50 Web site, provides information about Office of Science and Technology (OST) programs, technologies, and problems. The OST Reference Number for Liquid Nitrogen-Cooled Diamond-Wire Concrete Cutting is 2107.

SECTION 2

TECHNOLOGY DESCRIPTION

■ Overall Process/Technology Definition

The DOE nuclear facility decontamination and decommissioning (D&D) program requires that the best technologies on the market today be used to carry out its work. This improved technology demonstration tested the performance of liquid nitrogen as a coolant for diamond-wire concrete sawing, thereby reducing or eliminating the use of water that may become contaminated and the problems associated with its control and disposal.

Diamond-wire cutting provides an excellent method for reducing radiation dosage and thus be in accordance with the "as low as reasonably achievable" (ALARA) principle. Setting up the liquid nitrogen-cooled diamond-wire saw requires proximity to potential radiation sources, but the operator can be as far as 30 m (100 ft) away from the source during actual cutting when there is maximum potential for spread of contamination.

The diamond wire is looped around the concrete to be cut. The diamond-wire cutting assembly consists mainly of an electric/hydraulic power unit and drive wheel that pulls the diamond wire through the kerf. The power unit and the drive wheel are connected with two pairs of hydraulic hoses. A cooling pipe housing includes two tubes mounted over the diamond wire that spray liquid nitrogen onto the wire as it travels horizontally through the pipe housing. The nitrogen is supplied from a 196-L (51.6-gal) Dewar tank that can be obtained from a welding gas supplier. This system is designed for a liquid nitrogen flow rate of 50 L/hr (13.2 gal/hr).

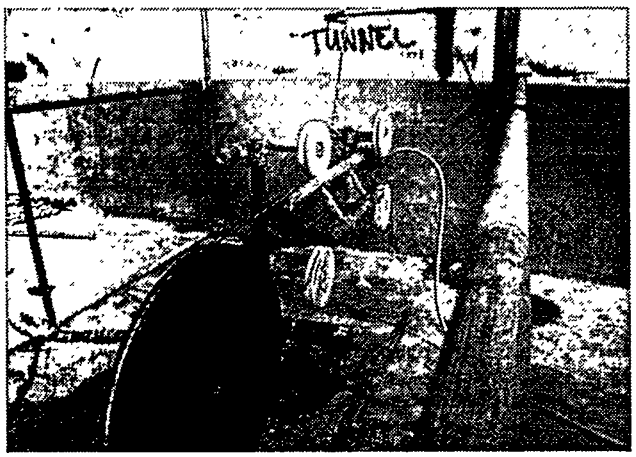


Figure 2. Diamond wire saw.

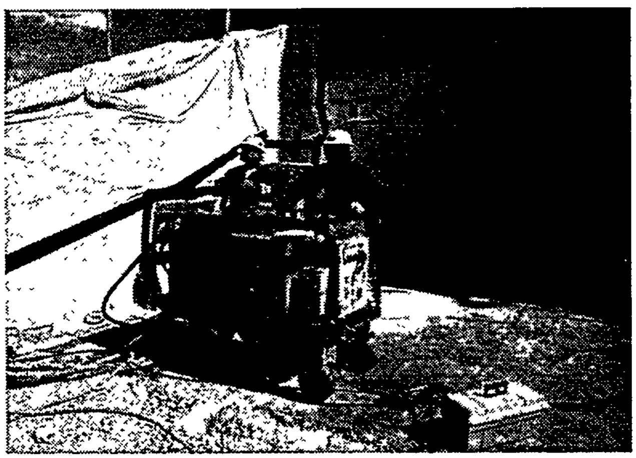


Figure 3. Electric/hydraulic power unit.

The power unit dimensions are 0.8 m (32 in.) wide, 1.5 m (60 in.) long, and 1.2 m (48 in.) high, weighing 680 kg (1,500 lb). The electric/hydraulic power unit is connected by hydraulic hoses to a hydraulic motor turning a 0.9-m (36-in.) diameter flywheel (drive-wheel).

The power unit assembly has the following equipment:

- 37 kw (50-hp), 480-volt, 3-phase electric motor with a 60-amp motor controller
- 129-L/min (34-gal/min), 207-bar (3,000-psi) hydraulic pump, driven by the electric motor
- Heat exchanger for cooling the hydraulic fluid (Note: The fluid used is derived from vegetable oil)
- Drain hose for discharging cooling water used in the heat exchanger
- Hydraulic fluid storage tank
- Hydraulic operating controls
- A pair of 15.2-m (50-ft), 199-cm (0.75-in.) hydraulic hoses for a system that tensions the diamond wire
- Two valves on top of the power unit for speed, rotation, and tension control.

The hydraulically powered drive-wheel assembly, which can be located up to 30 m (100 ft) away from the power unit, has the following equipment:

- 0.9-m (3-ft) long, 7.6-cm (3-in.)-diameter stainless steel liquid nitrogen cooling pipe
- Diamond wire, length as required for cut
- 0.9-m (36-in.)-diameter drive wheel
- 129-L/min (34-gal/min), 207-Bar (3,000-psi) hydraulic motor for drive-wheel power
- Small hydraulic motor for diamond-wire tensioning
- Diamond-wire guide rollers.

(Note: The wheel assembly track is outfitted with a continuous sprocket that is used for tensioning the diamond wire.)

The drive unit is assembled and built by Bluegrass Concrete Cutting, Inc. from off-the-shelf components.

The wire assembly consists of diamond beads, springs, and spacers mounted by Bluegrass Concrete Cutting, Inc., on a 6.4-mm (0.25-in.) diameter aircraft wire. The diamond beads on the cutting wire are manufactured by TruCo (Columbia, South Carolina) with DeBeers (South Africa) diamonds supplied by Diamant Boart (Belgium).

Figure 4 shows how the drive wheel, wire, and guide rollers are assembled.

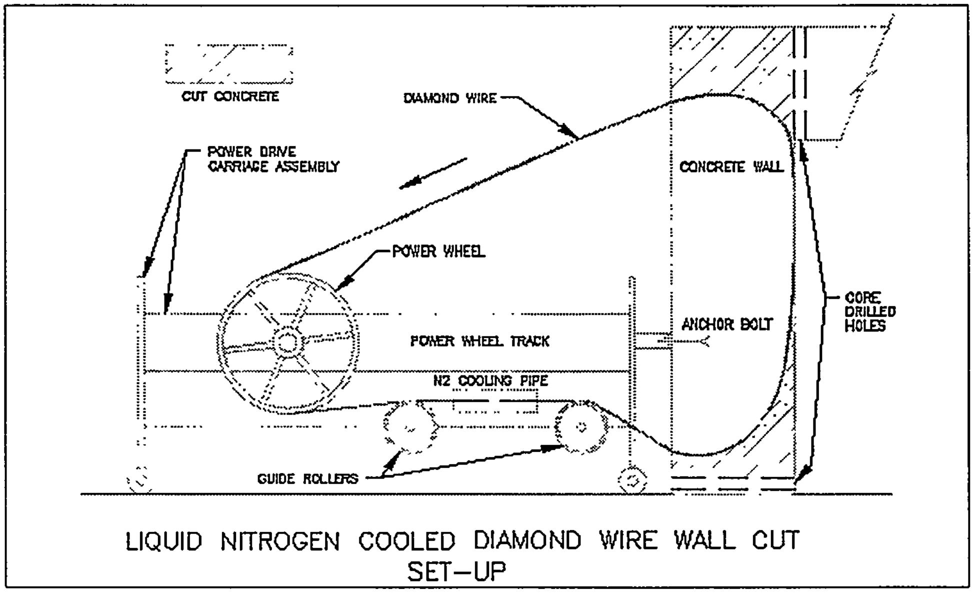


Figure 4. Schematic of system assembly.

■ System Operation

Setup

D&D workers drill holes approximately 5.1 cm (2 in.) in diameter through the concrete so that the diamond wire can be looped around the object to be cut. In most situations for cutting walls, one hole is drilled through the wall at the bottom and another at the top. If there is no ceiling at the top, then only the bottom hole needs to be drilled. The diamond wire is manually routed through the holes and mounted on the drive wheel for cutting. The drive wheel frame is solidly mounted with anchor bolts to the wall or floor.

Nitrogen stored in Dewar tanks is connected by tubing rated for cryogenic service to the pipe housing that is mounted between the drive wheel and the wall being cut. At the remote hydraulic control unit, a source of cooling water, approximately 19 L/min (5 gal/min), is connected to the hydraulic fluid heat exchanger. (Cooling water discharged from this heat exchanger is not contaminated.)

The drive wheel unit with tensioning track, pulleys, and diamond wire must be in an enclosure to contain concrete dust generated from the kerf. For the demonstration, a three-sided tent-type structure was set up against the wall. Air and vaporized nitrogen were exhausted from one side of the tent with a vacuum HEPA filtration unit. Makeup air was admitted on the other side through two openings. The air flow path was such that air flowed across the saw system components and minimized the amount of concrete dust that settled on the components.

If the wire breaks while operating, it can whiplash back into the area outside of the enclosure behind the end opposite the concrete wall. A plywood board was secured behind this end to contain a potential whiplash, and the area was barricaded to preclude pedestrian traffic within approximately 6 m (20 ft) behind the board.

After the diamond wire is threaded into place, the location where the wire protrudes at the other side of the wall is enclosed with temporary plastic and/or wooden boards. This contains dust that might otherwise become airborne on the far side of the wall.

Operation

When the wire has been installed, the operator starts the electric motor on the remote hydraulic control power unit and then tensions the diamond wire before cutting. With a system hydraulic pressure of 100 to 150 bars (1,450 to 2,175 psi), the wire speed is approximately 25 m/sec (82 ft/sec). The diamond wire is cooled by 50 L (13.2 gal) of liquid nitrogen per hour as it passes through the stainless steel cooling pipe housing. Inside the pipe housing, the liquid nitrogen from a pressurized Dewar tank is applied from tubing at two points above the diamond wire as the wire travels through the pipe housing. Figure 5 shows the pipe housing. Insulating spiral steel brushes are mounted within the cooling pipe housing to limit loss of nitrogen through the two openings.

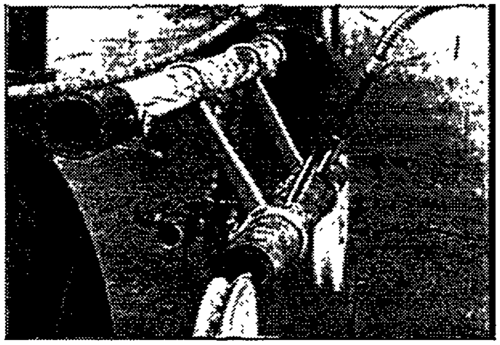


Figure 5. Cooling pipe housing for applying liquid nitrogen to the diamond wire.

The diamond wire is tensioned by a small hydraulic motor that engages a continuous sprocket mounted on the flywheel track. The cutting operation continues until the drive wheel reaches the end of the diamond-wire tensioning track, at which point the drive wheel requires restroking. Restroking is accomplished by manually resetting the drive wheel to the beginning of the tensioning track, cutting out the appropriate length of the diamond wire, and resplicing the wire. Restroking is required every time the tensioning track is at the end. The track assembly is mounted with bolted anchors at the concrete wall for stability.

As the cutting operation proceeds, a large amount of fine concrete dust is generated. For this demonstration a complete temporary tent-type atmospheric enclosure was constructed to contain and collect the dust. The exhaust port of the enclosure was connected to a HEPA vacuum filtration system. The breathing air in the enclosure must be checked before anyone enters to restroke the assembly because the nitrogen displaces air as it vaporizes, causing the oxygen levels to fall. Technicians operating the equipment do not normally wear respiratory protection. However, oxygen monitoring and respiratory protection for dust were required when entering the enclosure.

SECTION 3

PERFORMANCE

Demonstration Plan

Site Description

At its former weapons production sites, DOE's Office of Science & Technology/Deactivation and Decommissioning Focus Area, in collaboration with the Environmental Restoration Program, is conducting an evaluation of improved technologies that might prove valuable for facility D&D projects. As part of the Hanford Site LSDDP, at least 20 technologies are being demonstrated and assessed against baseline technologies currently in use. If successfully demonstrated at the Hanford Site, these improved technologies could be implemented at other DOE sites and similar government or commercial facilities.

The demonstration described in this report was conducted by Bechtel Hanford, Inc., the DOE's Environmental Restoration Contractor responsible for the D&D program at the Hanford Site. One objective of the LSDDP is to show how to use commercially available, and recently developed technologies to place Hanford's C Reactor into an ISS mode for up to 75 years, or until the final disposal of the reactor's core is completed. The C Reactor ISS objectives include placing the reactor in a condition that will not preclude or increase future decommissioning costs, but will minimize the potential for releases to the environment and reduce the frequency of inspections, thereby reducing potential risk to workers.

Nuclear facilities undergoing D&D are typically chemical and/or radiologically contaminated. To support this D&D work, the DOE sometimes requires tools for cutting concrete in places where water cannot be used for cooling the saw cutters. The tool must be easy and economical to operate, capable of operating in a wide range of ambient temperatures, and easy to decontaminate with conventional equipment. The tool must also be safe for workers. The liquid nitrogen-cooled diamond-wire saw satisfies these needs and is an alternative to traditional technologies used for cutting concrete.

At the C Reactor, concrete structures attached to the safe storage enclosure (SSE) must be cut away. The SSE contains the reactor block and consists of the reactor shield walls and a new roof. Abutting walls are segmented from the shield walls and then demolished. The improved and baseline technologies were demonstrated on the following 0.91-m (3-ft)-thick concrete walls that abutted the SSE walls:

	Improved Technology Nitrogen-Cooled Diamond Wire	**Baseline Technology Water-Cooled Diamond Wire**	**Baseline Technology Water-Cooled Circular Saw**
Height of wall	3.66 m (12 ft)	3.66 m (12 ft)	12.2 m (40 ft)
Face area of cut	3.2 m^2 (36 ft^2)	3.2 m^2 (36 ft^2)	11.1 m^2 (120 ft^2)
Fraction of area actually cut	3/4	All	2/3
Area actually cut	2.5 m^2 (27 ft^2)	3.2 m^2 (36 ft^3)	7.4 m^2 (80 ft^2)

All of the walls involved were heavily reinforced with steel bars within approximately 6 cm (2.5 in.) of the surface. The walls cut with diamond-wire technologies were not within radiologically contaminated areas of the C Reactor complex. In this situation, water runoff associated with the diamond-wire technologies did not have to be completely collected and treated for disposal. The wall cut with the diamond circular saw was contaminated on one side.

Performance Objectives

The objectives of the demonstration include evaluating the following desired capabilities and design features for the equipment:

A. Can cut structural concrete up to 1.2 m (4 ft) thick
B. Is easily decontaminated with conventional equipment
C. Operates in ambient temperature environments from 3 to 40°C (37 to 104°F)
D. Minimizes secondary waste generation, especially liquid waste that may become contaminated
E. Ability to use a HEPA vacuum filtration unit for any airborne particulates generated.

Demonstration Chronology

The demonstration was conducted mainly during March 1998 on walls 0.9 m (3 ft) thick at the Hanford Site C Reactor building complex. The walls were identified for demolition and had to be segmented from the main structure, which is to remain standing for ISS. Maintaining integrity of the SSE walls is vital. Saw cuts between walls being demolished and the walls of the SSE were required because steel reinforcing bars connect these concrete structures.

Improved Technology

The tent enclosure for concrete dust containment was set up before the nitrogen-cooled system arrived on site. Liquid nitrogen for this demonstration was obtained from a local welding equipment supplier shortly before the day of the demonstration.

Baseline Technologies

The improved technology was evaluated against two baseline technologies. One baseline technology is the same diamond-wire system that the improved technology uses, but cooled with water instead of liquid nitrogen. The other is a typical diamond-tipped circular saw on a wall-mounted track. The circular saw technology is the typical diamond-tipped round saw blade placed on the shaft of a hydraulic motor, which is mounted on a track for operation.

Both the circular saw and diamond wire are driven by hydraulic motors, and water for cooling and dust control is applied in the kerf. Diamond-wire cuts are made with the drive system and tensioning system set up once only on one side of the concrete structure, and the wire is pulled through as it travels. Unless very large-diameter blades are used, circular saw cuts can be accomplished with partial-depth cuts made from each of the two sides of the concrete structure, as was done at this site.

The water-cooled diamond-wire cut was made the day after the nitrogen-cooled system was demonstrated. The water-cooled diamond circular saw cuts were made approximately a month after the diamond-wire cuts.

■ Technology Demonstration Results

Key Demonstration Results

- Liquid nitrogen can be used as a cooling medium for diamond-wire cutting of thick reinforced concrete structures.
- No potentially contaminated liquid waste was generated.

- Cuts 30% slower than a conventional water-cooled diamond-wire saw, but 75% faster than a conventional water-cooled diamond circular saw. Reduced production rate compared to water-cooled diamond-wire cutting is attributed to concrete dust buildup in the kerf that could be contaminated.
- Using liquid nitrogen for cooling the diamond-wire eliminates the use of cooling water that could become contaminated; however, dust must be controlled with an adequately sized HEPA vacuum filtration unit. The use of smaller amounts of water than with baseline tools to control dust may be an option in some cases.
- Adequate dust collection must be evaluated against the use of cooling water for each project. An engineering evaluation can determine if dust collection is more economical than slurry collection.
- The diamond wire can be quickly installed, and the operator can be remote from the contaminated structures being cut.
- The diamond beads on the liquid nitrogen-cooled wire showed increased wear compared to the water-cooled diamond wire.
- The bead-tensioning springs in the wire assembly showed discoloration caused by elevated temperatures during later stages of cutting the first wall. Liquid nitrogen cooling was stopped when approximately 75% of the first wall cut was completed, because the cutting rate would have been slowed down further to prevent damage to the wire caused by overheating.

Successes

- Can reduce or eliminate potentially contaminated wastewater
- Quick to install
- Can be operated remotely
- Produces smooth cut.

Shortfalls

- Dust control may require an atmospheric enclosure
- Cutting rate is slower than with a water-cooled wire, and the area of cut is limited
- Diamond wire shows increased wear compared to baseline diamond wire.

Meeting Performance Objectives

The technology demonstrated that liquid nitrogen can be used as an alternative to water cooling for performing reinforced concrete cutting with a diamond-wire cutting system. The results of the performance objective evaluation are as follows, with respect to the performance objectives listed in the Demonstration Objective section:

Item A (cut structural concrete up to 1.2 m [4 ft] thick) was demonstrated on walls that were 0.9 m (3 ft) thick using a conventional diamond-wire saw system to which a liquid nitrogen cooling apparatus had been added. The system is designed for cutting structures thicker than 1.2 m (4 ft); the vendor has successfully tested the equipment on 1.2-m (4-ft)-thick concrete.

Item B (equipment easily decontaminated) was not checked in the field because the saw system was used only on non-contaminated concrete walls. The hydraulic power and control unit can be remotely located in a clean environment and is normally not subject to contamination. The saw components are designed so that they can be cleaned by conventional means and surveyed, except for the diamond wire, which is disposable.

Item C (operable at 3 to 40°C [37 to 104°F]) was not checked in the field, but all components are designed so that they can operate in the specified temperature range.

Item D (minimizes secondary waste, especially potentially contaminated liquid waste) was demonstrated in that only dry dust from a 9.5-mm (0.37-in.) wide kerf was generated.

Item E (use with a HEPA vacuum filtration unit) was demonstrated using a tent enclosure, with vacuum HEPA filter units, furnished and erected by onsite D&D workers. The first filtration unit used did not have sufficient filter capacity and was replaced.

Comparison of the Improved Technology to Baseline

Performance of concrete cutting is based on the face area of the cut. It was intended that the demonstration of the improved system would include at least one 0.9-m-thick by 3.6-m (3-ft-thick by 12-ft) wall, or a face cut of 3.26 m^2 (36 ft^2). However, by the time three-fourths of the cutting had progressed, the wire was overheating and the demonstration using nitrogen cooling stopped. (The vendor indicated afterward that the likely cause of overheating was a buildup of concrete dust in the kerf.) Accordingly, Table 1 shows the wall height that was cut with the improved technology as three-fourths of 3.6 m, which is 2.7 m (9 ft). For the baseline water-cooled diamond circular saw, the limited radius of the saw blade meant that only a 30-cm (1-ft)-deep cut could be made on each side of the wall. Thus, only two-thirds of the 0.9-m (3-ft)-wall thickness was cut, as shown in Table 1. There are no steel reinforcing bars connecting the middle third with the adjacent SSE, so in this instance the middle third can be simply sheared away without risking damage to the wall of the SSE.

Table 1. Summary of evaluation parameters of the improved and baseline technologies

Parameter Evaluated	Technologies		
	Improved Technology	Water-Cooled Diamond Wire	Water-Cooled Diamond Circular Saw
Wall Thickness x Height (Rebar Size)	0.9 m x 2.7 m (3 ft x 9 ft)(1) (#8 & #10)	0.9 m x 3.6 m (3 ft x 12 ft) (#8 & #10)	(2/3) x 0.9 m x 12.2 m (3 ft x 40 ft) (#8 & #10)
Setup Time	4 manhour (2 hr for 2 people)	4 manhour (2 hr for 2 people)	36 manhour (6 hr on each side of the wall, 12 hr total for 3 people)
Production Rate(2)	130 cm^2/min (0.14 ft^2/min)	185.8 cm^2/min (0.20 ft^2/min)	74.3 cm^2/min (0.08 ft^2/min) for total of 2/3 of wall thickness
Contaminated Wastewater	None(3)	126.7 L/m^2 (3 gal/ft^2)	126.7 L/m^2 (3 gal/ft^2)
ALARA	Good Saw can be operated remotely up to 30 m (100 ft)	Good Saw can be operated remotely up to 30 m (100 ft)	Fair Operator is near surface to be cut
Safety	• Oxygen depletion in enclosure • Danger if wire breaks	Danger if wire breaks	Saw is heavy to set on track
Enclosure	Required(4)	None	None
Ease of Use	Easy operation by an experienced operator	Easy operation by an experienced operator	More difficult to set up

(1) The wall was 3.6 m (12 ft) high, but only 0.9 m (9 ft) was successfully cut with the improved technology.
(2) Saw cuts are quantified in terms of area of the face cut. For example, a 0.9-m (3-ft) thick, 3.6-m (12-ft) long cut is 3.2 m^2 (36 ft^2).
(3) The improved and baseline diamond-wire systems use cooling water (for cooling hydraulic fluid) that flows through a heat exchanger and does not contact concrete or become contaminated.
(4) The improved saw system might be capable of using small amounts of water for dust control, in which event an enclosure would not be required.

Because the circular saw blade demonstrated could not cut deeper than 30 cm (1 ft) on either side of the 0.9-m (3-ft)-thick concrete walls, the uncut middle section was segmented by ramming, which leaves a rough surface finish that is not as easy to survey for contamination. The baseline water-cooled diamond-wire saw leaves the same smooth wall finish as does the liquid nitrogen-cooled system. A baseline circular saw with a larger-radius blade could leave the entire cut surface smooth.

With liquid nitrogen-cooled cutting, concrete dust was generated, and controlling the dust was important. The baseline technologies use water injected into the kerf; this water provides cooling, washout of the concrete dust, and dust emissions control (so no enclosure exhausting to a vacuum HEPA filtration system is needed). Before a concrete cutting task, the generation of cooling water secondary waste versus dust containment resulting from liquid nitrogen cooling should be evaluated.

The nitrogen-cooled system was fully functional for approximately 2.5 m^2 (27 ft^2) of face cutting, after which dust buildup in the kerf caused decreased cutting rates and increased heat. For face cuts exceeding 2.5 m^2 (27 ft^2), the modifications described in Section 7 (injecting liquid nitrogen and possibly water into the kerf) could be considered.

Because of the variety of functions and facilities, the DOE complex presents a wide range of D&D working conditions. The working conditions for an individual job directly affect the manner in which D&D work is performed. The improved and baseline technology comparisons presented in this report are based on a specific set of conditions and/or work practices found at the Hanford Site, as summarized in Table 2.

Table 2. Summary of variable conditions (2 Pages)

Variable	Improved Technology	Baseline Technologies
Scope of Work		
Location	Hanford Site C Reactor	Same
Nature of Work	Segmenting wall	Same
Work Environment		
Worker Protection	Level D PPE	Same
Level of Contamination	None	Same
Work Performance		
Acquisition Means	Vendor-provided service	Same for water-cooled and circular saw; assumed to be site owned
Production Rates:	0.78 m^2/hr (8.4 ft^2/hr)	Water-cooled diamond wire - 1.1 m^2/hr (12 ft^2/hr); Circular saw - 0.45 m^2/hr (4.8 ft^2/hr)
Equipment and Crew	Vendor's crew assumed to consist of two workers with part-time support from an industrial hygienist and part-time support from a D&D worker	The water-cooled diamond-wire alternative includes two vendor workers and part-time support from a D&D worker, and the circular saw uses three D&D workers

Table 2. Summary of variable conditions (2 Pages)

Variable	Improved Technology	Baseline Technologies
Work Process Steps	1) Transport personnel and equipment 2) Vendor workers undergo site orientations and security arrangements 3) Safety meeting 4) Operate saw 5) Transport personnel and equipment back to vendor's headquarters	Same as the improved technology for the water-cooled diamond-wire alternative. The circular saw process steps are: 1) Safety meeting 2) Set up equipment 3) Operate saw 4) Demobilize equipment

Skills and Training

As with any diamond-wire saw, special operator experience is needed to control the wire tension properly.

Operational Concerns

The diamond wire may break while cutting. The area in the back of the diamond-wire driving wheel should have a protective shield, such as a plywood sheet, and this area should be avoided by personnel. The potential for the wire to break increases as the wire tension is increased.

Secondary waste generation consists of fine dust generated by the diamond-wire saw. Cutting contaminated media requires dust control (i.e., an enclosure to prevent the escape of radionuclides). However, it also would be advisable to construct an enclosure for non-contaminated media because a large amount of dust is produced.

Where liquid nitrogen is used in enclosed areas, personnel should not be in the enclosed areas unless monitoring indicates that adequate oxygen is present for breathing.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVE TECHNOLOGIES

■ Technology Applicability

- The liquid nitrogen-cooled cutting technology can be used on any concrete structure where a conventional water-cooled diamond-wire saw would be used.
- Modifications described in Section 7 would apparently be needed for face cuts exceeding 2.5 m^2 (27 ft^2).

■ Competing Technologies

- The liquid nitrogen-cooled diamond-wire cutting system demonstrated is unique, but any firm that has a conventional diamond-wire saw can use a similar cooling concept.
- Other improved technologies that avoid water cooling and that could be demonstrated include direct cutting with liquid cryogenic nitrogen at very high pressures and laser cutting.

■ Patents/Commercialization/Sponsors

- There are no known U.S. patents for the liquid nitrogen-cooled diamond-wire cutting system.
- The liquid nitrogen-cooled diamond-wire system demonstrated at the Hanford Site is available through Bluegrass Concrete Cutting, Inc., Greenville, Alabama.

SECTION 5

COST

Introduction

This section provides a cost-effectiveness analysis that compares the costs for the improved and baseline technologies used to cut through thick, reinforced concrete walls at the Hanford C Reactor. For the conditions of this demonstration, the improved technology was 189% more expensive than the baseline water-cooled diamond-wire saw and 310% more than the baseline circular saw. A major cost factor for the improved technology demonstration was the construction of an enclosure for dust control. The baseline technologies used water for dust control as well as for cooling. The improved technology may also be capable of using a combination of liquid nitrogen and water for dust control, but did not do so during this demonstration. Using water will affect the costs, depending on the specific site conditions and requirements.

The cost analysis assumes site ownership of the equipment and site labor. The cost-effectiveness estimate is based on cutting through a 0.9-m (3-ft)-thick reinforced concrete wall containing rebar ranging from 2.2 to 2.5 cm (0.87 to 1 in.) in size. The cuts were made as follows:

- 2.5 m^2 (27 ft^2) with the improved liquid nitrogen-cooled diamond-wire concrete cutter
- 3.2 m^2 (36 ft^2) with the baseline water-cooled diamond-wire concrete cutter
- 11.1 m^2 (120 ft^2) with the baseline diamond circular saw (Pro Cut model 6500RW) and shear. While the circular saw cut only two-thirds of the way through the wall, the additional cost for shearing the remainder of the wall with heavy equipment is very small and disregarded in these calculations.

To create an equivalent comparison, the costs for the improved and baseline diamond-wire demonstrations were extrapolated to an 11.1-m^2 (120-ft^2) cut, matching that of the wall cut that was made with the baseline circular saw and shear. The cost using the circular saw was extrapolated from the 7.4 m^2 (80 ft^2) actually cut to 11.1 m^2 (120 ft^2).

The cost-effectiveness analysis includes erecting and disassembling an enclosure for the improved technology, unloading and loading equipment to and from the work area, setting up in the work area, moving the diamond-wire saws to the next cut area, replacing and/or splicing the diamond wire, and disposing (non-contaminated waste) of the slurry water for both baseline saws.

Cost Data

The improved technology uses commercially available equipment, except for a cooling pipe unit fabricated from 7.6-cm (3-in.)-diameter stainless steel pipe. The liquid nitrogen-cooled diamond-wire saw has a purchase price of $8,000, plus $2,000 for required accessories. A hydraulic power unit is also required, which has a purchase price of $18,000. For applications requiring an enclosure with a vacuum HEPA filtration system, a Pentek VAC-PAC Model 9 can be purchased for $22,999 if an adequate system is not already available on site and used for multiple tasks. Except for the HEPA filtration system, these purchase costs also apply to the baseline water-cooled diamond-wire saw. Table 3 shows the different methods of acquisition and their associated costs for the improved technology.

Table 3. Improved technology acquisition costs

Acquisition Option	Item	Cost
Equipment Purchase	1. Bluegrass liquid nitrogen-cooled diamond-wire cutter 2. Required accessories 3. Hydraulic power unit 4. Pentek VAC-PAC Model 9 HEPA filter system*	1. $ 8,000 2. 2,000 3. 18,000 4. 22,999
Vendor Provided Service	1. Mobilization and demobilization/travel 2. Two D&D technicians and equipment (per day, excludes federal per diem) 3. Diamond-wire charge per square foot of cut	1. $1,000-3,000 2. 1,400 3. 25
Equipment Rental	1. Mobilization and demobilization/travel 2. Daily (excludes HEPA filtration) 3. Weekly (excludes HEPA filtration) 4. Monthly (excludes HEPA filtration)	1. $1,200 2. 250 3. 1,000 4. 3,000

* HEPA filter units already onsite and used for multiple tasks would probably be used with the acquisition option.

The vendor-provided service option is used in this cost analysis, with support from onsite workers to unload/move/load heavy components, drill holes in concrete, thread diamond wire through holes, furnish/erect tent enclosure, furnish/operate ventilation/filtration systems, and monitor for oxygen. Observed unit costs and production rates for principal components of the demonstrations for both the improved and baseline technologies are presented in Table 4.

Table 4. Summary of production rates and unit costs

Activity	Improved - Nitrogen-Cooled Diamond Wire		Baseline - Water-Cooled Diamond Wire		Baseline - Water-Cooled Circular Saw	
	Production Rate m²/hr (ft²/hr)	Unit Cost $/m² ($/ft²)	Production Rate m²/hr (ft²/hr)	Unit Cost $/m² ($/ft²)	Production Rate m²/hr (ft²/hr)	Unit Cost $/m² ($/ft²)
Cut Wall	0.78 (8.4)	$677 ($62.90)	1.11 (12.0)	$426 ($39.54)	0.45 (4.8)	$312 ($28.94)

The unit costs and production rates shown do not include mobilization or other losses associated with non-productive portions of the work (i.e., work breaks and wire splicing/repair). The intent of this table is to show unit costs at their elemental level that are free of site-specific factors (i.e., work culture or work environment influences on productivity loss factors). Consequently, the unit costs shown in the above table are the same unit costs for the corresponding line item in Tables B-1, B-2.1, and B-2.2 of Appendix B. Tables B-1, B-2.1, and B-2.2 can be used to compute site-specific costs by inserting quantities and adjusting the units for conditions of an individual D&D job.

Some features of the demonstration are unique to this demonstration and affect cost. Consequently, the conditions at other sites will result in different costs. The following conditions for this demonstration are judged to be the principal cost-affecting factors related to site-specific conditions:

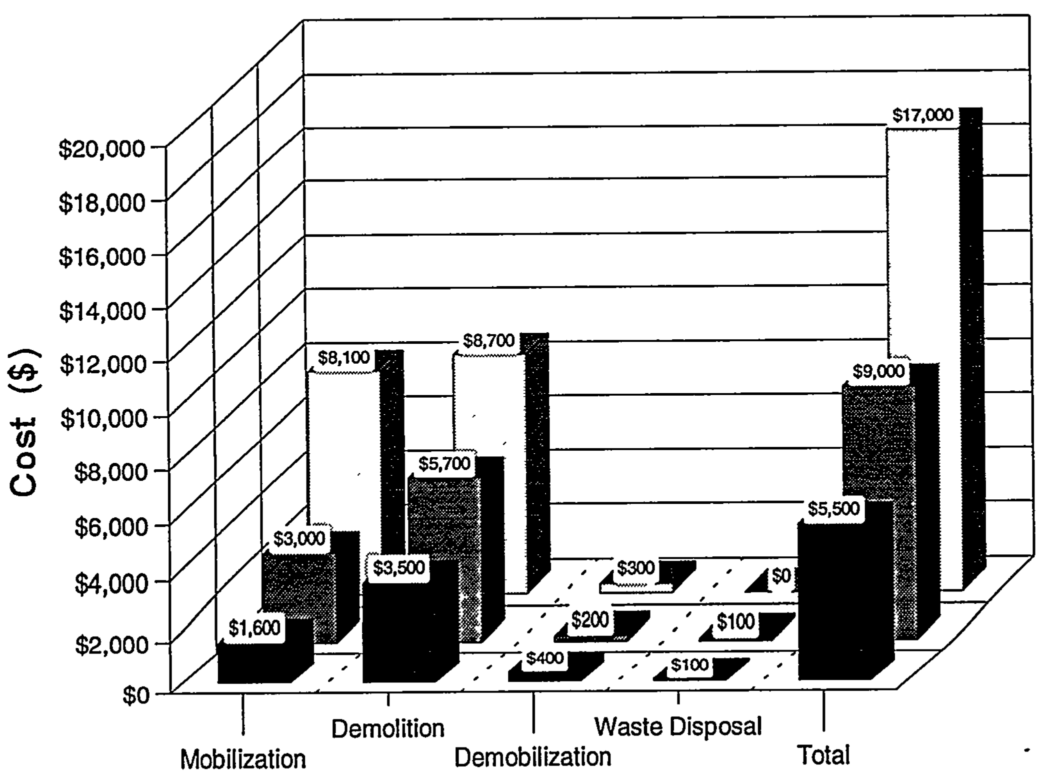
- The improved technology demonstration used an enclosure and vacuum HEPA filtration system for dust control; in some cases, a small amount of water may be acceptable and cost significantly less.

- All of the cuts are assumed to be performed in uncontaminated areas.
- Waste disposal costs were not a factor in the cost analysis. Worker and equipment time were the only costs for waste disposal at a gravel pit used at the Hanford Site for disposal of uncontaminated slurry wastes for the baseline technologies. Disposal of contaminated wastewater could greatly increase the costs of the baseline technologies at sites where wastewater treatment is expensive. At the Hanford Site, transport, treatment, and disposal of contaminated wastewater costs $0.18/L ($0.68/gal,) plus the cost for settling and filtering solids from the slurry generated with the baseline technologies.

Where contamination is encountered and all runoff of wastewater and slurry must be controlled, there would be additional costs for capture of all such wastes and stabilization disposal of wet solids removed therefrom, as well as increased costs caused by donning/doffing of personal protective equipment and longer equipment setup/takedown times.

Cost Comparison

Refer to Appendix B for detailed cost tables for the improved and baseline technologies. The costs are summarized in Figure 6.



Dollars may not add exactly due to rounding.

Figure 6. Cost summary.

Cost Conclusions

The major cost drivers for the improved technology during the demonstration were constructing and disassembly of the enclosure for dust control, diamond-wire usage, and liquid nitrogen usage. The baseline technologies used water for dust control and, therefore, did not require an enclosure. However, the baseline technologies created large amounts of wastewater and slurry. The improved technology may also be capable of using a combination of liquid nitrogen and water for dust control that would result in smaller amounts of water and slurry than with the baseline technologies.

The production rates for wall cutting were 130, 185.8, and 74.3 cm^2/min (0.14, 0.20, and 0.08 ft^2/min) for the improved, baseline diamond-wire, and baseline circular saw technologies, respectively. These translate to 0.78, 1.11, and 0.45 m^2/hr (8.4, 12.0, and 4.8 ft^2/hr), respectively. According to the test engineer, both the improved and baseline diamond-wire saws are much more complex to run than the baseline circular saw, requiring more operator training. This is an important potential cost driver when considering the government ownership option.

Because the demonstration cuts were in areas already designated as non-contaminated, there was no radiological control technician (RCT) support and no contaminated waste. Applications in contaminated work areas should account for the necessary RCT support and collection, treatment, and disposal of contaminated waste. In this analysis, a major cost driver for the improved technology was the construction of a containment tent, or enclosure, for dust control. This enclosure was not required for the baseline technologies. This situation may not hold true for other applications at other sites. Comparisons of improved and baseline technologies where both (or neither) require an enclosure may result in a much smaller cost difference. The use of an enclosure may prove to be more effective for some contaminated applications where the need to minimize liquid waste (i.e., waste generated from using water for dust control) is of extreme importance.

The tables in Appendix B allow the readers to estimate the costs of their job by inserting their site's quantities into the tables.

SECTION 6

REGULATORY AND POLICY ISSUES

■ Regulatory Considerations

- At the Hanford Site, where there is a potential for emission of radionuclides, the State of Washington Administrative Code (WAC) 246-247 requires an air quality permit. A project that has multiple demolition activities in progress, has an air quality permit, and the liquid nitrogen-cooled diamond-wire cutting operation must meet the conditions of the permit, which in this case requires an enclosure exhausted via a vacuum HEPA filtration unit.

- Should the technology be deployed at nuclear facilities in other states, project managers should check with local and state air quality requirements.

- The system can be used in daily operation under the requirements of 10 CFR Parts 20 and 835, and proposed Part 834 to protect workers and the environment from radiological contaminants; and 29 CFR Parts 1910 and 1926, OSHA worker requirements.

- Although the demonstration took place at a Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) site, no CERCLA requirements apply to the technology demonstrated.

■ Safety, Risk, Benefits, and Community Reaction

Worker Safety

- Liquid nitrogen can cause frostbite, severe injuries, or death if mishandled or spilled.

- An oxygen-deficient environment is created in an enclosed area when liquid nitrogen converts to nitrogen gas. Constant air monitoring for breathable air is required.

- The erection of a physical shield and restriction of access in back of the driving wheel is required for safety of personnel if the rotating diamond wire should break.

- Normal radiation protection worker safety procedures used at the facility apply.

Community Safety

It is not anticipated the implementation of the cutting technology would present any adverse impacts to community safety.

■ Environmental Impact

It is not anticipated that implementation of the cutting technology would present any adverse impacts to the environment if dust emissions are controlled.

■ Socioeconomic Impacts and Community Perception

No socioeconomic impacts are expected in association with use of this technology.

SECTION 7

LESSONS LEARNED

■ Implementation

No special implementation concerns apply to the liquid nitrogen-cooled diamond-wire technology. A source of portable Dewar tanks with liquid, low-temperature nitrogen that can make timely deliveries must be identified.

■ Technology Limitations/Needs for Future Development

- As presently designed and operated during the demonstration, the area that can be cut with the improved technology is limited to 2.5 m^2 (27 ft^2). Overheating and wire damage occurs beyond this point.
- To improve performance, Bluegrass Concrete Cutting, Inc., recommends liquid nitrogen be inserted into the kerf. Small-scale testing by Bluegrass Concrete Cutting, Inc., indicates increased cooling performance of the diamond wire and dust reduction with this modification. Bluegrass Concrete Cutting, Inc. also suggests that a mixture of liquid nitrogen and water injected into the kerf will provide even greater cutting performance while using less water than with traditional diamond-wire cutting.
- An improvedr diamond-wire cooling method might be obtained by having the wire totally submerged in liquid nitrogen as the wire passes through the cooling pipe. However, a cooling pipe housing redesign and experimentation would be required.
- The insertion of liquid nitrogen, and possibly small amounts of water, in the kerf would be less costly than a cooling tube redesign. The performance of a liquid nitrogen and water mixture injected into the kerf should be considered for evaluation.

■ Technology Selection Considerations

- The technology is suitable for DOE D&D sites or other sites where concrete structures must be segmented.
- The amounts and types of secondary waste that are acceptable should be the basis for using either liquid nitrogen or water for cooling. Small amounts of liquid slurry from the baseline cutting operation may be collected with less effort than dust waste. Collection of dust waste requires an enclosure of the driving wheel, wire and pulleys, and coverage of the kerf at the back of the wall. All dust collection techniques require adequate ventilation and dust filtering.
- This new technology should be considered for any concrete cutting situations where contaminated liquid waste is difficult to handle or is not acceptable.

APPENDIX A

REFERENCES

10 CFR Part 20, "Standards for Protection Against Radiation," *Code of Federal Regulations*, as amended.

10 CFR Part 834, "Environmental Radiation Protection," *Code of Federal Regulations*, as proposed.

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

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

29 CFR Part 1926, "Safety and Health Regulations for Construction," *Code of Federal Regulations*, as amended.

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

APPENDIX B

COST COMPARISON

Introduction

The cost-effectiveness analysis computes the cost for a concrete wall decontamination job by using hourly rates for equipment and labor.

The selected basic activities being analyzed come from the Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary (HTRW RA WBS), USACE, 1996. The HTRW RA WBS, developed by an interagency group, used in this analysis to provide consistency with the established national standards.

Some costs are omitted from this analysis so that it is easier to understand and to facilitate comparison with costs for the individual site. The overhead and general and administrative (G&A) markup costs for the site contractor managing the demonstration are omitted from this analysis. Overhead and G&A rates for each DOE site vary in magnitude and in the way they are applied. Decision makers seeking site-specific costs can apply their site's rates to this analysis without having to first back-out the rates used at the Hanford Site.

The following assumptions were used as the basis of the cost analysis:

- Oversight engineering, quality assurance, and administrative costs for the demonstration are not included. These are normally covered by another cost element, generally as an undistributed cost.
- The vendor-provided service rates include procurement costs of 7.5% so that the costs of administering the contract are accounted for (7.5% x $1,400/day/10 hr/day) plus per diem for two workers (2 workers x $80/day/10/hr/day) = $140/hr labor + $10.50/hr procurement + $16/hr per diem.
- The procurement cost of 7.5% was applied to all purchased equipment costs so that the costs of administering the purchase are accounted for (this cost is included in the hourly rate).
- The equipment hourly rates for the Government ownership option are based on general guidance contained in Office of Management and Budget (OMB) circular No. A-94 for Cost Effectiveness Analysis.
- The equipment hourly rates for the site-owned equipment that may be used in support of the improved equipment (e.g., the site-owned truck that transports the rented improved equipment from the warehouse receiving to the C Reactor) uses standard equipment rates established at Hanford.
- The standard labor rates established by the Hanford Site for estimating D&D work are used in this analysis for the portions of the work performed by local crafts.
- The analysis uses a 10-hr work day.
- Additionally, an anticipated life of 5 years for the power unit and saw is used. An average usage of 500 hr/year is used in the calculation of hourly rate for the each of the technologies.

MOBILIZATION (WBS 331.01)

Erect Enclosure: An assumption was made that a crew of four D&D workers would take two 9-hour days to construct an approximately 18.6-m^2 (200-ft^2) enclosure. The baseline technologies used water for dust control and did not require an enclosure.

Transport to and from Site: This activity includes transport of personnel and equipment to the C Reactor from Seattle, Washington and back again (the vendor has several equipment base locations from which to mobilize) is based on a quote from the vendor.

Vendor Matriculation: The vendor personnel obtain badges (2 hours), site orientation (4 hours), and site-specific review of the Safety/Health Plan (0.25 hours) for an assumed total of 8 hours.

Unload/Move Equipment to Work Area: This activity is the observed time for unloading the equipment from the truck with a forklift and moving it to the work area.

Setup Equipment: This activity involves the preparation required at the work area prior to operation of the equipment and is based on the observed duration.

DECOMMISSIONING (WBS 331.17)

Cut Concrete Wall: During the demonstration, each of the technologies had different cut sizes, approximately 27 ft^2 for the innovative liquid nitrogen-cooled diamond wire, 36 ft^2 for the baseline diamond wire, and 120 ft^2 for the baseline circular saw. The respective production rates were 0.14, 0.20, and 0.08 ft^2/min. These production rates are for actual cutting time and do not include mobilization and other losses associated with non-production portions of the work (i.e., work breaks and wire splicing/repair). The innovative and baseline diamond-wire demonstration costs were extrapolated to equal the 120-ft^2 circular saw production. Both innovative and baseline diamond-wire technologies consume wire at a cost of \$25/ft^2 of cut. The innovative technology consumed liquid nitrogen at a rate of 50 L/hr at a cost of \$2.35/L (the saw uses 180-L bottles).

Move Saw to Next Cut: This is the observed time to move the diamond-wire water-cooled saw 30 ft to the next cut. The baseline circular saw did not require movement because all of the necessary track is costed under the setup.

Replace/Splice Wire: This is the observed time to replace or splice the diamond-wire saws, both nitrogen and water cooled. Blade replacement for the water-cooled circular saw is included in the operating cost, which is built into the hourly equipment rate.

DEMOBILIZATION (WBS 331.21)

Disassemble Equipment: This includes the durations observed for equipment disassembly for each of the innovative and baseline technologies.

Load Equipment: This activity is the observed time for moving the equipment from the work area and loading it onto a truck with a forklift. It was assumed that loading the water-cooled circular saw and tracks would take 0.5 hr.

WASTE DISPOSAL (WBS 331.18)

Disposal of Water and Slurry: This is the time for the disposal of the water and slurry resulting from the baseline diamond-wire water cooled and circular saw cuts. The estimated time assumes 0.5 hr for loading and unloading and 0.5 hr of total transit time to and from the gravel pit. There was no disposal charge at the gravel pit for water and slurry disposal. Also, the innovative technology only had refuse from the containment tent and did not incur any incremental disposal costs.

The details of the cost analysis for the innovative and two baseline technologies are summarized in Tables B-1, B-2, and B-3.

Table B-1. Cost summary - improved nitrogen-cooled diamond-wire cutting technology

Work Breakdown Structure (WBS)	Unit	Unit Cost $	Qty	Total Cost $	Computation of Unit Cost: Production Rate	Duration (hr)	Labor & Equipment Rates: Labor Items	$/HR	Equipment Items	$/HR	Other Costs and Comments
MOBILIZATION (WBS 331.01)		Subtotal		$ 8,076.44							
Erect Enclosure	SF	$ 8.43	600	$ 5,056.80							
Transport to and from Site	LS	$1,200.00	1	$ 1,200.00							
Vendor Matriculation	LS	$1,332.00	1	$ 1,332.00		8.00	BCC	$ 166.50			
Unload/Move Equipment to Work Area	LS	$ 62.20	1	$ 62.20		0.25	2DD	$ 230.44	FL+VP	$18.35	
Setup Equipment	LS	$ 425.44	1	$ 425.44		1.75	2DD+BCC	$ 230.44	VP	$12.67	
DEMOLITION (WBS 331.17.04)		Subtotal		$ 8,652.63							
Radiological Control Technician Support	LS										Not applicable for this demonstration
Cut Wall	SF	$ 62.90	120	$ 7,547.93	8.4		1/4IH+1/4DD +BCC	$ 188.19	VP	$12.67	Blade usage = $25/sf, liquid nitrogen = $2.35/L
Move Saw to Next Cut	LS	$ 33.48	3	$ 100.43		0.17	same	$ 188.19	VP	$12.67	
Replace/Splice Diamond Wire	LS	$ 100.43	10	$ 1,004.28		0.50	same	$ 188.19	VP	$12.67	
DEMOBILIZATION (WBS 331.21)		Subtotal		$ 311.40							
Remove Enclosure	LS	$ 15.99	1	$ 15.99		0.25	2DD	$ 63.94			
Disassemble Equipment	LS	$ 161.25	1	$ 161.25		0.90	BDD	$ 166.50	VP	$12.67	
Load Equipment	LS	$ 134.16	1	$ 134.16		0.35	2DD+BCC	$ 364.97	FL+VP	$18.35	
WASTE DISPOSAL (WBS 331.18)		Subtotal		$ 0.00							
		$ 0.00		$ 0.00							No disposal charges were incurred
TOTAL				$ 17,040.47							

Crew Item	Rate $/HR	Abbreviation	Crew Item	Rate $/HR	Abbreviation	Crew Item	Rate $/HR	Abbreviation	Crew Item	Rate $/HR	Abbreviation
D&D Worker	31.97	DD									
Bluegrass Concrete Cutting	166.5	BCC				VAC-PAC	12.67	VP			
(Includes equipment)						Forklift	5.68	FL			
Industrial Hygienist	54.77	IH									

1. Unit Cost = (Labor + Equipment Rate) x Duration + Other Cost, or = ((Labor + Equipment Rate) / Productivity Rate) + Other Cost
2. Abbreviations for Units: LS = lump sum; SF = square feet; and, HR = hour.

Table B-2. Cost Summary - Water-Cooled Diamond-Wire Saw Baseline Technology

Work Breakdown Structure (WBS)	Unit	Unit Cost $	Qty	Total Cost $	Computation of Unit Cost						Other Costs and Comments
					Production Rate	Duration (HR)	Labor & Equipment Rates				
							Labor Items	$/HR	Equipment Items	$/HR	
MOBILIZATION (WBS 331.01)		**Subtotal**		**$ 2,994.30**							
Transport Vendor to and from Site	LS	$1,200.00	1	$ 1,200.00							
Vendor Matriculation	LS	$1,332.00	1	$ 1,332.00		8.00	BCC	$ 66.50			
Unload/Move Equipment to Work Area	LS	$ 59.03	1	$ 59.03		0.25	2DD+BCC	$230.44	FL	$ 5.68	
Setup Equipment	LS	$ 403.27	1	$ 403.27		1.75	2DD+BCC	$230.44		$ 0.00	
DEMOLITION (WBS 331.17.04)		**Subtotal**		**$ 5,704.63**							
Radiological Control Technician Support											Not applicable for this demonstration
Cut Wall	SF	$ 39.54	120	$ 4,744.93	12		1/4DD+BCC	$ 74.49		$ 0.00	Blade usage = $25/SF
Move Saw to Next Cut	LS	$ 29.08	3	$ 87.25		0.17	same	$ 74.49		$ 0.00	
Replace/Splice Diamond Wire	LS	$ 87.25	10	$ 872.46		0.50	same	$ 74.49		$ 0.00	
DEMOBILIZATION (WBS 331.21)		**Subtotal**		**$ 239.69**							
Disassemble Equipment	LS	$ 157.04	1	$ 157.04		0.90	BCC	$ 74.49		$ 0.00	
Load Equipment	LS	$ 82.64	1	$ 82.64		0.35	2DD+BCC	$230.44	FL	$ 5.68	
WASTE DISPOSAL (WBS 331.18)		**Subtotal**		**$ 74.36**							
Disposal of Water & Slurry	LS	$ 240.86	1	$ 74.36		1.00	2DD	$230.44	FL+FB	$ 10.42	No disposal charge at gravel pit
TOTAL				**$ 9,012.98**							

Crew Item	Rate $/HR	Abbreviation	Crew Item	Rate $/HR	Abbreviation	Crew Item	Rate $/HR	Abbreviation	Crew Item	Rate $/HR	Abbreviation
D&D Worker	$ 31.97	DD									
Bluegrass Concrete Cutting	166.5	BCC									
(Includes equipment)						Forklift	$ 5.68	FL			
Industrial Hygienist	54.77	IH				Flatbed Truck	$ 4.74	FB			

1. Unit Cost = (Labor + Equipment Rate) x Duration + Other Cost, or = ((Labor + Equipment Rate) / Productivity Rate) + Other Cost
2. Abbreviations for units: LS = lump sum; SF = square feet; and, HR = hour.

Table B-3. Cost summary - Water-cooled circular saw baseline technology

Work Breakdown Structure (WBS)	Unit	Unit Cost $	Qty	Total Cost $	Computation of Unit Cost						Other Costs and Comments
					Production Rate	Duration (HR)	Labor & Equipment Rates				
							Labor Items	$/HR	Equipment Items	$/HR	
MOBILIZATION (WBS 331.01)		Subtotal		$ 1,590.89							
Unload/Move Equipment to Work Area	LS	$ 28.16	1	$ 28.16		0.25	2DD	$ 63.94	CCS+FL	$ 48.68	
Setup Equipment	LS	$1,562.74	1	$ 1,562.74		11.25	3DD	$ 95.91	CCS	$ 43.00	
DEMOLITION (WBS 331.17.04)		Subtotal		$ 3,472.75							
Radiological Control Technician Support											Not applicable for this demonstration
Cut Wall	SF	$ 28.94	120	$ 3,472.75	4.8		3DD	$ 95.91	same	$ 43.00	
DEMOBILIZATION (WBS 331.21)		Subtotal		$ 350.12							
Disassemble Equipment	LS	$ 277.82	1	$ 277.82		2.00	3DD	$ 95.91	same	$ 43.00	
Load Equipment	LS	$ 72.30	1	$ 72.30		0.50	3DD	$ 95.91	CCS+FL	$ 48.68	
WASTE DISPOSAL (WBS 331.18)		Subtotal		$ 74.36							
Disposal of Water & Slurry	LS	$ 74.36	1	$ 74.36		1.00	2DD	$ 63.94	FL+FB	$ 10.42	No disposal charge at gravel pit
TOTAL				$ 5,488.12							

Crew Item	Rate $/HR	Abbreviation	Crew Item	Rate $/HR	Abbreviation	Crew Item	Rate $/HR	Abbreviation	Crew Item	Rate $/HR	Abbreviation
D&D Worker	$ 31.97	DD				Water Cooled Circular Saw	$43.00	CCS			
						Forklift	$ 5.68	FL			
						Flatbed Truck	$ 4.74	FB			

1. Unit Cost = (Labor + Equipment Rate) x Duration + Other Cost, or = ((Labor +Equipment Rate) / Productivity Rate) + Other Cost
2. Abbreviations for units: LS = lump sum; SF = square feet; and, HR = hour.

APPENDIX C

ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Description
ALARA	as low as reasonably achievable
BHI	Bechtel Hanford, Inc.
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
FETC	Federal Energy Technology Center
G&A	general and administrative (costs)
HEPA	high-efficiency particulate air (filtration)
HTRW	hazardous, toxic, radioactive waste
ISS	interim safe storage
LSDDP	Large Scale Demonstration and Deployment Project
PPE	personal protective equipment
RCT	radiological control technician
SSE	safe storage enclosure
USACE	U.S. Army Corps of Engineers
WAC	*Washington Administrative Code*
WBS	work breakdown structure