INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0410

Remote Control Concrete Demolition System

Deactivation and Decommissioning
Focus Area

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

December 1998

INNOVATIVE TECHNOLOGY
Summary Report

Remote Control Concrete Demolition System

OST Reference #2100

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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SECTION 1

SUMMARY

Technology Description

The U.S. Department of Energy (DOE) Chicago Operations Office and the Federal Energy Technology Center (FETC) jointly sponsored a Large-Scale Demonstration Project (LSDP) at Argonne National Laboratory-East (ANL). The objective of the LSDP is to demonstrate potentially beneficial Decontamination and Decommissioning (D&D) technologies in comparison to current baseline technologies.

The objective of remotely removing and packaging radioactively contaminated concrete during the D&D process is to reduce worker exposure rates, heat stress and injury to personnel. To achieve this objective, the Brokk Remotely Operated Concrete Demolition System was demonstrated in August and September, 1997 at the Janus Research Reactor located in Building 202 of ANL.

The Brokk BM 150, manufactured by Holmhed Systems AB of Sweden and supplied by Duane Equipment Corp., uses a remote operated articulated hydraulic boom with various tool head attachments to perform the work. The machine is designed primarily to drive a hammer and has a reach of fifteen feet. The Brokk can be operated by someone 400 feet away or in a different room with a TV monitor. The machine can be operated up to a 30-degree gradient. The unit requires a 480-volt, 50-amp circuit for its power source. Two attachments were used in this demonstration. The hydraulic hammer and the excavating bucket. The hammer operates at 600 foot pounds and has outputs of 1000 to 1500 beats per minute. The bucket has a capacity of 1/4 cubic yard and has a smooth cutting edge. Other attachments available include a concrete crusher, a La Bounty shear, and a 1/4 yard clamshell bucket. Smaller and larger sizes of the Brokk are available from Duane Equipment Corporation.

Figure 1. Brokk with hammer attachment.

Figure 2. Brokk remote controller.

In comparison with the baseline technology, which is manual jackhammering, the main advantage of the Brokk technology is that it is much faster and safer during the demolition process, thus the amount of exposure to the workers is considerably reduced.

Controlled by one operator with minimal assistance from other laborers, the Brokk demolished and containerized approximately 66 cubic yards of reinforced concrete in 16 working days. Included in the rubble was 48 cubic feet of lead and 96 cubic feet of mixed waste that was segregated and containerized separately.

Key Results

- The Brokk Remote Controlled Concrete Demolition System completed work in 16 days that was projected to take 6 months to complete with manual jackhammering with a four person crew.
- After demolition of the reinforced concrete biological shield walls and the reactor pedestal, the operator was able to use the Brokk to segregate and then containerize the waste.
- The operator of the Brokk was able to perform all of his duties from an adjacent room with the remote controls without entering the contamination area. Minimal assistance from laborers in the work area was required to change the attachments on the Brokk machine.
- The Brokk is shipped fully assembled and there is minimal mobilization and demobilization time required. All attachments, cables and controllers are shipped together with the machine.
- The Brokk machine and all of the attachments were decontaminated and free released from the work area.
- The cost analysis for the Brokk BM technology observed savings of over the pavement breaking baseline because of its much higher production rate, particularly for elevated work conditions up to 15 feet in height.

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Web Site

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

SECTION 2

TECHNOLOGY DESCRIPTION

System Configuration and Operation

The technology, a Brokk BM 150, manufactured by Holmhed Systems AB of Sweden and supplied by Duane Equipment Corp., uses a remotely operated articulated hydraulic boom with various tool head attachments to perform the work. The machine is designed primarily to drive a hammer and has a reach of fifteen feet. Someone can operate the Brokk 400 feet away or in a different room with a TV monitor. The machine can be operated up to a 30-degree gradient. The unit has two continuous rubber tracks but can also be equipped with four solid rubber tires. It has hydraulic outriggers for added stability. The unit requires a 480-volt, 50-amp circuit for its power source. Two attachments were used in this demonstration. The hydraulic hammer and the excavating bucket. The hammer operates at 600 foot pounds and has variable outputs of 1000 to 1500 beats per minute. The bucket has a capacity of 1/4 cubic yard and has a smooth cutting edge. Other attachments available include a concrete crusher, a La Bounty shear, and a 1/4-yard clamshell bucket. Smaller and larger sizes of the Brokk are available from Duane Equipment Corporation.

The Brokk BM150

The Brokk BM150 is a remotely operated articulated hydraulic boom with various tool head attachments to perform the work. The machine is designed to primarily drive a hammer. It has a reach of 15 feet and can rotate a continuous 360 degrees. With the remote control the operator can be as far as 400 feet away or in a different room with the proper video equipment. The machine is shipped completely assembled and only needs the power source attached to become operational.

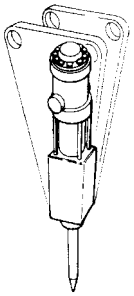
Figure 3 Unloading the Brokk BM150.

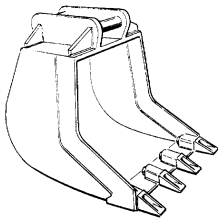
- Weight: 3,086 lb. without attachments
- Height: 49 in
- Width: 44 in
- Length: 92 in

Several different sizes of the Brokk are available for various sizes of demolition projects.

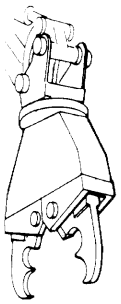
Attachments

Two attachments were included as part of the demonstration, the hydraulic hammer and the excavating bucket. The hydraulic hammer comes with a hardened steel pointed tip, and was used to break the reinforced concrete and then to segregate the waste. The Brokk 150 comes with 600 foot pound hammers and the larger Brokk 250 machine comes with 1000 foot pound hammers. The weight of the hammer for the 150 is approximately 400 pounds and for the 250 is approximately 700 pounds. Other chisel tips are available for the hammer.

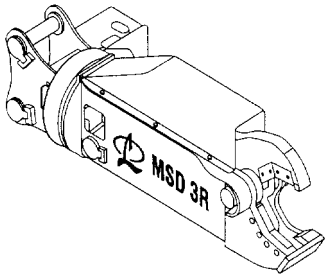




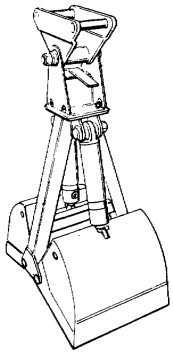
The Brokk 150 and 250 can both be equipped with excavating buckets. The buckets are available in various widths and can be supplied with either smooth cutting edges or toothed. The smooth edge bucket worked very well for interior clean-up and loading of debris. The toothed bucket is generally for excavating soil.



The Brokk 150 and 250 can both be equipped with concrete crushers. The Brokk 150 crushing unit rotates 365° and can crush up to 14 inches of concrete. The Brokk 250 crushing unit also rotates 365° and can crush up to 18 inches of concrete. Both units are ideal for crushing floors, walls and ceilings. The Brokk 250 crusher weighs approximately 600 pounds and the Brokk 150 is approximately 300 pounds.



The Brokk 250 can be equipped with a La Bounty Shear. The shear is capable of cutting rebar, pipe, angle iron and other metal up to 6 inches in width. The La Bounty Shear attachment weighs approximately 600 pounds and is ideal for interior demolition and cutting jobs.



The Brokk 250 can be equipped with a 1/4 cubic yard clamshell bucket for difficult footing and interior excavating projects. The bucket can also be used for interior cleanup after a demolition job. The clamshell bucket is 18 inches wide, 4 feet long and weighs 400 pounds.

SECTION 3

PERFORMANCE

Concrete Removal

The demonstration area was located on the lower level of Building 202 in an area approximately 25 x 25 feet. The concrete reactor pedestal was approximately 3 feet high and 10.5 feet in diameter and located in the center of the work area. The two reinforced concrete shield walls were located on opposite sides of the pedestal and were approximately 2.5 feet thick, 12 feet long and 15 feet high. The Brokk machine was driven off the trailer it was delivered on and lowered into the basement area of Building 202 through a 6 foot by 6 foot floor opening using the facility crane.

The operator of the Brokk was located in an adjacent room during the demonstration. A large, clear plastic window gave him visual contact with the machine. A hard hat, safety glasses and hearing protection were required but no respiratory protection was needed. Workers in the contamination area were required to wear one layer of Tyvek, a full-faced air purifying respirator, work boots, hard hat, hearing protection and gloves.

The workers in the area assisted the Brokk operator when it came time to switch attachments on the machine. They would pull the pins holding the attachment to the arm and then once the attachments were changed, they would put the pins back in place to secure the attachment. The operator from his remote location could perform all other functions.

The machine worked in the area for a total of 16 days. The machine completed the demolition of the shield walls that had been started by manual jackhammering and then finished the pedestal and some other miscellaneous pieces of concrete. The concrete was over 3 feet thick in some areas and contained reinforcing steel beams, lead shielding and rebar. Once the concrete was demolished it was segregated into the different waste streams and the rubble loaded into containers.

Waste Generation

The primary waste generated by the Brokk was concrete with some small amounts of lead. Secondary waste generated included rags from decontamination of the machine following use, smears taken during decontamination, disposable PPE worn by the workers during decontamination and one hydraulic hose that broke during the demonstration.

The measured volume of concrete before demolition was 1460 cu ft. The measured volume of the waste containers generated during demolition was 1650 cu ft of concrete, 48 cu ft of non-radioactive lead and 96 cu ft of activated lead (mixed waste).

Summary of Demonstration Results

The results of demonstrating the Brokk BM150 are listed in Table 1 below:

Table 1 - Performance data

Criteria	Innovative technology: Brokk BM 150	Baseline technology: manual jackhammering
Amount and type of primary waste generated (measured by waste container volume) Waste generated depends on work performed. The Brokk does not generate any waste stream different from the baseline technology with the exception of potentially contaminated hydraulic fluid.	1650 cubic feet of reinforced concrete 48 cubic feet of lead 96 cubic feet of mixed waste	390 cubic feet of reinforced concrete
Crew size utilized	1 operator	2 operators, 2 waste handlers
Days worked	16 days	60 days
Type of secondary waste generated	Used PPE, 1 hydraulic hose, rags, smear papers	Used PPE, rags, smear papers, duct tape
Noise level	100 dBA @ 5 ft.	105 dBA
Developmental status	Commercially available	Commercially available
Safety concerns	Main hazards are heavy equipment operation, noise, falling debris	Worker fatigue and heat stress, falling concrete pieces, lifting hazards, noise, falls and contamination exposure
PPE Requirements	Hard hat, hearing protection, safety glasses, safety shoes	Hard hat, hearing protection, safety shoes, anti-contamination clothing, double gloves, full faced air purifying respirator, fall protection
Set-up requirements	Electric power supply, move machine to work area	Erection of temporary scaffolding, running air hoses

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVE TECHNOLOGIES

Technology Applicability

In order to meet regulatory criteria for unrestricted use, any site that has a need for concrete demolition and removal would benefit from the use of the Brokk machine. Demonstrated in August and September, 1997 as an alternative to manual jackhammering, this technology showed several advantages:

- Because the machine is small, it can be used inside to perform demolition work. The machine is able to perform in very tight areas with limited access and can be controlled to prevent damage to other parts of the building structure. The high speed of the hammer reduces the time required to perform the demolition work.

- The remote controlled operation of the Brokk is an excellent safety feature. The operator of the machine is removed from the dangers of falling concrete and environmental hazards. In a radiation area, the operator is removed from the machine and the dose rate is greatly reduced or eliminated.

- The numerous attachments made for the Brokk make it very versatile. The operator can use the same machine to perform the demolition work, sort the debris into different waste streams and then containerize the material.

- Using a remote operated machine in place of a manually operated tool greatly reduces worker fatigue, heat stress and the exposure of working directly in a contaminated area.

The remote controlled operation of the equipment, the ability of the machine to work in small areas, the speed of the demolition process and the different attachments for the machine make the Brokk technology a useful tool in reducing schedule duration and project cost.

Competing Technologies

There are a number of technologies currently available to D&D professionals for the purpose of breaking or cutting concrete for removal.

Other technologies available are:
- manual jackhammering (the ANL baseline technology)
- backhoe mounted jackhammer
- skid steer loader (Bobcat) mounted jackhammer
- robotics (Rosie) with jackhammer attachment
- explosives
- expandable grout
- diamond wire cutting
- high pressure and ultra-high pressure water cutting

SECTION 5

COST

Introduction

This cost analysis compares the relative costs of the innovative technology of remote demolition, and baseline technology of manual demolition. It presents information which will assist Decontamination and Decommissioning (D&D) planners in decisions about using the innovative technology in future D&D work. This analysis strives to develop realistic estimates that represent D&D work within the DOE complex. However, this is a limited representation of actual cost, because the analysis uses only data observed during the demonstration. Some of the observed costs will include refinements to make the estimates more realistic (such as elimination of cost factors which are not part of normal work but included in the demonstration to evaluate equipment performance). These are allowed only when they will not influence the fundamental elements of the observed data (e.g., do not change the productivity rate, quantities, work elements, etc.). The Brokk BM 150 Remote Controlled Concrete Demolition System Report, (1997) provides additional cost information and is available upon request from the Argonne National Laboratory (ANL).

Methodology

The Brokk BM 150 innovative technology was demonstrated at ANL under controlled conditions that facilitated observation of the work procedures and typical duration of those procedures. The cost analysis for the innovative technology is based on observations made during concrete demolition using the Brokk BM 150, an advanced remote-controlled demolition system.

The baseline technology was performed using a rented 90-lb pavement breaker (similar to a jackhammer). From observing demolition of concrete with the pavement breaker and subsequent calculations, the test engineer developed labor estimates, productivity rates, and projected demolition duration for the activity.

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, is 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 facilitate comparison with costs for the individual site. Consequently, the ANL indirect expense rates for common support and materials are omitted from this analysis. Overhead and General and Administrative (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" of the rates used at ANL. Engineering, quality assurance, administrative costs and taxes on services and materials are also omitted from this analysis for the same reasons indicated previously.

The standard labor rates established by ANL for estimating D&D work are used in this analysis for the portions of the work performed by local crafts. Costs for site owned equipment, such as trucks for transport or Health Physics Technician (HPT) radiological survey equipment, are based on an hourly rate for Government ownership that is computed using OMB Circular No. A-94. Quoted rates for the vendor's costs are used in this analysis for performing training of the site's personnel and includes the vendor's G&A, overhead, and fee mark-up costs. Additionally, the analysis uses an eight-hour workday with a five-day week. The production rates and observed duration used in the cost analysis do not include "non-productive" items such as work breaks, donning and doffing clothing, loss of dexterity (due to cumbersome Personal Protective Equipment (PPE)), and heat stress. These "non-productive" items are accounted for in the analysis by including a Productivity Loss Factor (PLF). The PLF is a historically based estimate of the fraction of the workday that the worker spends in non-productive activities.

Cost Data

In determining whether it would be more cost effective to purchase, lease, or use a vendor-provided service, each option must be identified and evaluated. The options and the corresponding costs are listed below.

Table 2 - Innovative technology acquisition costs

ACQUISITION OPTION	ITEM	COST
Equipment Purchase	Brokk BM 150	$89,000
Vendor Provided Service	1-40 hours w/ operator 40-60 hours w/ operator over 60 hours w/ operator	$185/hr $165/hr $145/hr
Equipment & Attachments Lease	1-40 hours without operator 40-60 hours without operator over 60 hours without operator Attachments - Clamshell/Shear/Crusher Attachments - Long term lease	$775/day $750/day $700/day $300/day $200/day/month

Observed unit costs and production rates for principal components of the demonstrations for both the innovative and baseline technologies are presented in Table 3 below.

Table 3 - Summary of unit costs & production rates observed during the demonstration

INNOVATIVE TECHNOLOGY			BASELINE TECHNOLOGY		
Cost Element	**Unit Cost**	**Production Rate**	**Cost Element**	**Unit Cost**	**Production Rate**
Remote Demolition	$17.10/ft^3	11.4 ft^3/hr	Manual Demolition	$254.87/ft^3	0.63 ft^3/hr

The unit costs and production rates shown do not include mobilization (Dismantlement work breakdown structure cost element subtotal excluding the Productivity Loss Factor amount from Table C-1 of Appendix C divided by quantity of 1,460 ft^3).

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 4. This table is intended to help the technology user identify work differences that can result in cost differences.

Table 4. Summary of cost variable conditions

Cost Variable	Brokk BM 150	Manual Demolition Hammer
Scope of Work		
Quantity and Type	Remote control demolition of a reactor footing, and walls. Quantity of 1460 ft^3.	Manual demolition of reactor footing and walls. Quantity of 1460 ft^3 (assumed quantity extrapolated from 133 ft^3 actually observed based on production rates).
Location	Inside 3125 ft^3 space within a reactor facility.	Inside 3125 ft^3 space within a reactor facility.
Nature of Work	Decommissioning Reactor and surrounding area by dismantling the reactor, and demolishing the pedestal, and wall which encased the reactor.	Decommissioning Reactor and surrounding area by dismantling the reactor, and demolishing the pedestal, and wall which encased the reactor. Majority of work from scaffold and room is too small for more than one crew.
Work Environment		
Worker Protection	Hard hat, safety goggles, ear protection	Goggles, Double Gloves, Ear Protection, Full Protective Clothing, Double outer boot covers, and respirator. Full scaffolding gear.
Level of Contamination	Classified as a contaminated area and a radiation area. Operator worked from outside of the contaminated area.	Classified as a contaminated area and a radiation area.
Work Performance		
Acquisition Means	Equipment and equipment operator provided by vendor. No instruction required.	Site personnel with rented equipment.
Production Rates	Productivity is based on 1460 ft^3 of wall removal. The productivity is calculated as an average of 11.4 ft^3/hr.	Based on the 133 ft^3 of wall removal in one month, the productivity is calculated as 0.63 ft^3/hr.
Equipment & Crew	One Brokk BM, Hammer and Bucket plus one equipment operator.	90 lb pavement breaker attached to an 185 cfm air compressor
Work Process Steps	1. Ship equipment to work area 2. Place equipment in treatment location 3. Setup 4. Perform demolition 5. Decontaminate and release 6. Load equipment into container for shipping.	1. Transport to work area 2. Place equipment in the treatment location 3. Setup 4. Perform demolition 5. Decontaminate and release 6. Transport equipment
End Product	Wall removed.	Wall removed.

Potential Savings and Cost Conclusions

The manual demolition baseline, for the conditions stated in Table 4 and assumptions established in Appendix C, is more than a factor of ten times the cost of the Brokk BM 150 innovative technology for this demonstration.

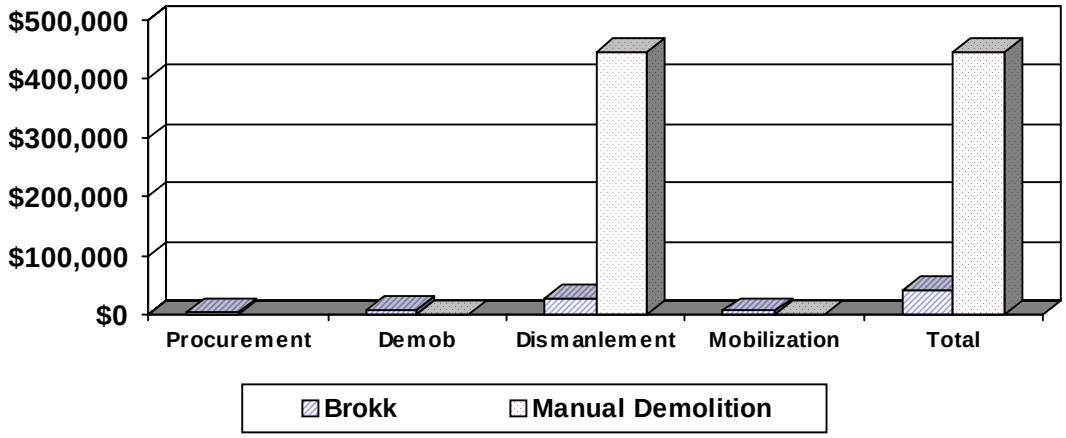


Figure 4. Technology comparison.

The costs comparison for the Brokk BM with use of pavement breaker is dominated by the production rates observed. The Brokk BM out strips the baseline's production rate by a factor of 19. The production comparison would be much less favorable if the removal was beyond Brokk BM's reach. The nature of this demonstration is particularly adverse to the baseline alternative (working from scaffolds and in limited space) and the baseline production would improve where more pavement breakers could be used at the same time and where work is not elevated. Other minor factors that may influence the costs are the rates charged for leasing the Brokk BM equipment (rates used in this analysis were based on a one day lease), the cost for shipment, and the strength of the concrete. In this demonstration the concrete was 10,000 psi. Normal concrete strength is 3000 psi to 4000 psi.

In addition to demolishing concrete, the Brokk BM can also excavate the debris into containment containers by changing the arm attachment from a hammer to a bucket. After the job is completed, the equipment is decontaminated and removed from the site.

The cost analysis for the Brokk BM technology observed savings over the pavement breaking baseline because of its much higher production rate, particularly for elevated work conditions up to 15 feet in height.

Concrete packaging and disposal costs were not included in the cost estimate. There would not be any significant differences in disposal costs between the baseline and innovative technology.

SECTION 6

REGULATORY/POLICY ISSUES

Regulatory Considerations

The regulatory/permitting issues related to the use of the Brokk Remote Controlled Concrete Demolition System at the ANL Janus 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)

- 10 CFR 835 Occupational Radiation Protection

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

These are the same regulations that govern the baseline technology of manual jackhammering.

The waste form requirements/criteria specified by disposal facilities are used by ANL:

- *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

These waste form requirements/criteria may require the stabilization or immobilization of final waste streams. This requirement would be valid for any concrete removal technology.

Safety, Risks, Benefits, and Community Reaction

The Brokk technology incorporates a remotely operated control system that removes the operator from the machine. During the demonstration, the operator did not have to enter the contamination zone to perform the work and this reduced the risk of exposure. This also reduced the risk of personal injury from falling concrete.

The use of the Brokk technology rather than manual jackhammering would have no measurable impact on community safety or socioeconomic issues.

SECTION 7

LESSONS LEARNED

The Brokk Remote Controlled Concrete Demolition System demonstrated at Argonne National Laboratory is a commercially available product that does not have any implementation issues. The setup time is very short and the equipment is easy to operate. The equipment is sized to fit inside most buildings, which makes it ideal for interior demolition.

The Brokk, with the hydraulic hammer, is able to break concrete much faster and safer than with a manually operated jackhammer. The machine is very powerful but can be controlled so that there is no damage to other areas of a building during partial demolition.

With the excavating bucket, the Brokk is able to pick-up and load most of the rubble created during demolition. The operator can also segregate material if required by regulations.

The remote controlled operation of the Brokk reduces the risk to the operator of exposure to radiation or hazardous materials, personnel injury and heat stress.

The many attachments available for the Brokk machine makes it very versatile for all types of demolition work, both interior and exterior.

Any site that has a need for contaminated concrete removal, both interior and exterior, would benefit from the use of the Brokk technology.

Appendix A

REFERENCES

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Appendix B

ACRONYMS AND ABBREVIATIONS

ACE	Activity cost estimate (sheets)
ALARA	as low as reasonably achievable
ANL	Argonne National Laboratory
β/γ	beta/gamma
BL	baseline
cf	cubic feet
cf/min (cfm)	cubic feet per minute
cm^2	square centimeters
CFR	*Code of Federal Regulations*
CP-5	Chicago Pile-5
CSB	centrifugal shot blast
D&D	decontamination and decommissioning
dBA	decibels
DDFA	Deactivation and Decommissioning Focus Area
Decon	Decontamination
Demo	Demonstration
Demob	Demobilization
DOE	U.S. Department of Energy
dpm	disintegrations per minute
Equip	equipment
ESH	Environment, Safety, and Health
FCCM	facilities capital cost of money
FETC	Federal Energy Technology Center
G&A	general and administrative markup cost
H&S	health and safety
HEPA	high-efficiency particulate air
HP(T)	Health Physics (technician)
hr	hour(s)
HTRW	hazardous, toxic, radioactive waste
IH	industrial hygiene
in	inches
lbs	pounds
lf	linear feet (foot)
LLW	low-level waste
LS	lump sum
LSDP	Large-Scale Demonstration Project
MCACES	microcomputer assisted cost engineering system
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
PCs	protective clothing
PLF	productivity loss factor
PPE	personnel protective equipment
PSIG	pounds per square inch gallons
RA	remedial action
RPM	revolutions per minute
SAFSTOR	safe storage
TC	total cost
USACE	U.S. Army Corps of Engineers
VAC	volts alternating current

WAC	waste acceptance criteria
WBS	work breakdown structure
WM	waste management
WMO	waste management operations

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 - Brokk BM 150

MOBILIZATION (WBS 331.01)

Load Equipment

Definition: Transport of the Brokk BM 150 equipment requires mobilization at the vendor location in Boston, Massachusetts. The equipment has a special metal container which holds the Brokk BM 150, the remote control unit, and all of the required cables for operation. The cost element includes the time required for the mobilization.

Transport Equipment

Definition: Transport Brokk BM 150 equipment from Boston Massachusetts to Shipping/Receiving at Argonne National Laboratory in Illinois. This cost element also includes time required for of the equipment to be shipped.

Assumptions: The mobilization at the vendor site is included in the shipping charge of $1.50/mile. The vendor provides the loading, transport, and unloading included in the travel cost. The hourly equipment rate of $87.50/hr was determined using the vendor quote of $700/day bare equipment cost based on an eight hour day. The equipment operator, provided by the vendor, traveled by air for two hours from Boston to the CP-5 site in Argonne, IL at a rate of $57.50/hr derived from the vendor quote of $145/hr with operator and subtracting the equipment cost. An additional cost of $500 used to cover the cost of the airline ticket.

Lower Equipment into Demonstration Area
Definition: Transport Brokk BM 150 equipment from receiving area to CP-5.

Assumptions: Crew consist of site personnel including one equipment operator and two D&D workers for two hours. The Brokk BM 150 is lowered to demonstration location by crane. Assuming crane can be prorated by the hour from $160.65/day (MEANS, 1995).

Set-Up of Equipment
Definition: Time required to prepare equipment for operation. This cost element includes safety inspection.

Assumptions: The total duration was observed at two hours. Crew is assumed (based on judgment of the test engineer for what would be normal practice for work) to consist of one electrician (1 hr), one operator (30 minutes), and one safety inspector (30 minutes).

Unpack, Survey & Prepare
Definition: Equipment is unpacked, surveyed for radiological contamination, and prepared for use (includes wrapping cables and body with plastic to minimize potential contamination).

Assumptions: Assumed duration of 30 minutes and crew make up based on judgment of the test engineer. Crew consists of one Health Physics Technician (HPT) to take and count smears.

DISMANTLING (WBS 331.17.04)

Set-Up Each Morning
Definition: Time required for maintenance, and set up of the equipment. This cost element includes the vendor operator labor rate.

Assumptions: The duration is assumed to be fifteen minutes. Crew is assumed (based on judgment of the test engineer for what would be normal practice for work one equipment operator at a rate of $57.50/hr.

Perform Demolition
Definition: This activity calculates the cost for the concrete break-up using the crusher attachment on the Brokk BM 150.

Assumptions: Equipment rate of $87.50/hr, plus an addition cost for the attachments of $200/day ($200/8hr/day= $25/hr). The vendor operators rate is $57.50/hr. Quantity is computed from wall dimensions of 1,460 ft^3. Based on observations from the demonstration, the production rate is 11.4 ft^3/hr and a unit duration is 0.085 hr/ ft^3. At this rate, removal of the wall will require (1,460 ft^3/0.085 hr/ ft^3)/5.59 hours/day = 22 days). There are approximately 5.59 productive hours out of an 8 hour work day based on demonstration observations.

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

Assumptions: Since the demonstration is performed by remote control, the only personal protective equipment required is hard hat, safety glasses, and ear protection. Used an assumed total cost of $22.

HPT Support
Definition: This activity includes periodic check and survey work by the HPT.

Assumptions: The observed amount of effort by the HPT was approximately 2 hours per day.

Productivity Loss Factor
Definition: This cost element provides for safety meeting, project planning meetings, and other activities that are not wall removal activities.

Assumptions: The observed production was 7 hours out of a 10 hour day. This is proportioned to 5.59 hours our of an 8 hour day. The non productive time is assumed as 2.41 hours for each 8 hour day.

DEMOBILIZATION (WBS 331.21)

Decontamination of Equipment

Definition: Brokk BM 150 equipment is surveyed for contamination and decontamination is performed as needed for free release.

Assumption: The assumed (from test engineer observation) duration of ten hours was used for an HPT. Used rags, and water as equipment resulting in a negligible equipment cost.

Return equipment operator
Definition: Return trip -Same as Mobilization – Equipment operator transport

Shipping
Definition: Return trip - Same as Mobilization - Unload and Transport

The activities, quantities, production rates and costs utilized in the innovative technology are shown in Table C-1.

Table C-1. Cost summary - Brokk BM 150

Work Breakdown tructure (WBS)	Unit Cost (UC) Labor HRS	Labor Rate	Equipment HR	Equipment Rate	Other	Total UC	Total Quantity (TQ)	Unit of Measure	Total Cost (TC) note	Innovative Technology Comments
MOBILIZATION (WBS 331.01)								**Subtotal**	**$ 5,092.18**	
Load and Transport Equipment			16.00	$ 87.50	1530.00	$ 2,930.00	1	each	$ 2,930.00	Vendor provides shipping of the equipment at a charge of $1.50 per mile for 1020 miles. The equipment rate is derived from the vendor quote bare cost of equipment of $700/day, based on an eight hour day.
Equipment Operator Transport	8.00	$ 57.50			$ 500.00	$ 960.00	1	each	$ 960.00	Covers flight from Boston to Illinois at a equipment operator rate of $57.50/hr, derived from the vendor quote of $145 per hour, and subtracting out the equipment cost. Plus $500 for the fight.
Site Orientation for Vendor	8.00	$ 57.00				$ 456.00	1	each	$ 456.00	Site specific training for vendor personnel.
Lower Equipment into building	2.00	$ 164.55	1.00	$ 20.08		$ 349.18	1	each	$ 349.18	Two D&D workers @ $33.60/hr, one equipment operator @ $39.85/hr, and one crane @ $160.65/day for a duration of one hour with vendor operator standby $57.50/hr.
Set up of Equipment	0.50	$ 167.32	0.50	$ 87.50		$ 127.41	1	each	$ 127.41	Labor rates for one electrician @ $49.67/hr, an equipment operator @ $39.85/hr, and a safety inspector at $77.80/hr
Additional Set up	0.50	$ 49.67	0.50	$ 87.50		$ 68.59	1	each	$ 68.59	The electrician was needed for an additional 30 minutes.
Unpack, Survey & Prepare	0.50	$ 113.50	0.50	$ 87.50		$ 100.50	2	each	$ 201.00	One Health Physics Technician (HPT) @ $56/hr and vendor standby $57.50/hr
DISMANTLEMENT (WBS 331.17.04)								**Subtotal**	**$ 27,429.15**	
Set-Up Each Morning	0.25	$ 57.50	0.25	$ 87.50		$ 36.25	22	days	$ 797.50	Includes maintenance of the equipment.
Perform Demolition	0.085	$ 57.50	0.0850	$ 112.50		$ 14.45	1,460	ft3	$ 21,097.00	The attachment for the Brokk BM 150 is $200/day, used with an equipment rate of $87.50/hr, and a labor rate of $57.50/hr.
Personal Protective Equipment					$ 22	$ 22.00	1	each	$ 22.00	Hard hat, goggles, & ear protection
HPT Support	2.00	$ 56.00				$ 112.00	22	days	$ 2,464.00	Periodic check and survey (2 hrs/day)
Productivity Loss Factor	2.41	$ 57.50				$ 138.58	22	days	$ 3,048.65	8 hour day / 1.43 (observed factor) = 5.59 productive hours and 2.41 hours for meetings, suit up, etc.
DEMOBILIZATION (WBS 331.21)								**Subtotal**	**$ 6,495.80**	
Decontaminate Equipment	8.00	$ 158.30	8.00	$ 87.50		$ 1,966.40	1	each	$ 1,966.40	Three D&D workers decontaminate the equipment @ $33.6/hr with vendor standby
Equipment Release	10.00	$ 56.00				$ 560.00	1	each	$ 560.00	One HPT @ $56/hr performs surface smears and final release
Reassemble Equipment	2.00	$ 124.70	2.00	$ 87.50		$ 424.40	1	each	$ 424.40	Two D&D workers @ $33.60/hr reassembled equipment after it was released and includes vendor standby
Return of Equipment operator	2.00	$ 57.50			$ 500	$ 615.00	1	each	$ 615.00	Covers labor, and a two hour flight from Illinois to Boston
Shipping			16.00	$ 87.50	$ 1,530	$ 2,930.00	1	each	$ 2,930.00	Return from Illinois site to vendor in Boston
PROCUREMENT COST								**Subtotal**	$ 3,191.03	
Procurement Cost					$ 3,191	$ 3,191.03	1	each	$ 3,191.03	Cost of administering vendor contract
Note: TC = UC * TQ								**TOTAL:**	**$ 42,208.15**	

Baseline Technology - Manual Demolition

MOBILIZATION (WBS 331.01)

Preliminary Survey
Definition: This cost element is for testing the manual demolition equipment for prior contamination to prevent additional radiation on the site.

Assumption: The effort is assumed to be 30 minutes using a crew of two HPT's and one D&D worker.

Transport Equipment
Definition: The on-site transport to the CP-5 is provided in this cost element.

Assumption: The rental firm provides the delivery of the equipment including truck, and truck driver. The vendor charges a rate of $75 in each direction.

Setup Equipment
Definition: Time to set-up equipment for demolition.

Assumptions: The effort is assumed to take one hour and requires one D&D worker to attach the 185 cfm air compressor to the pavement breaker. The rental quote for rental of an air compressor is $650/month, and pavement breaker @ $250/month. The total hourly equipment rate based on an eight hour day is $5.68/hr.

DISMANTLEMENT (WBS 331.17.04)

Set-Up (each morning)
Definition: Time required for setting up in one location, and maintenance of the equipment each morning.

Assumptions: The duration is 15 minutes each morning and the crew is 1 D&D workers.

Perform Demolition
Definition: Manual demolition of the footing, and wall inside the reactor building using a 90 lb pavement breaker.

Assumptions: Based on observation of 146 ft^3 of work, two D&D workers and a pavement breaker at a rate of $250/month, plus an air compressor at a rate of $650/month. Quantity is computed from wall dimensions of 1,460 ft^3. Based on observations, the production rate is 0.63 ft^3/hr and a unit duration is 1.58 hr/ ft^3. At this rate, removal of the wall will require (1,460 ft^3/1.58 hr/ ft^3)/5.59 hours/day = 415 days). There are approximately 5.59 productive hours out of an 8 hour work day based on demonstration observations.

PPE

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).

Productivity Loss Factor
Definition: This cost element provides for safety meeting, project planning meetings, and other activities that are not wall removal activities.

Assumptions: The observed production was 7 hours out of a 10 hour day. This is proportioned to 5.59 hours our of an 8 hour day. The non productive time is assumed as 2.41 hours for each 8 hour day

HPT Support
Definition: This activity includes periodic check and survey work by the HPT.

Assumptions: The observed amount of effort by the HPT was approximately 2 hours per day.

DEMOBILIZATION (WBS 331.21)

Decontaminate and Survey Out
Definition: Equipment and personnel are surveyed for contamination and decontamination is performed as need for free release.

Assumption: The duration of 2 hour is assumed for two HPT's and one D&D worker.

Transport for Return
Definition: Same as Mobilization – Transport Equipment

Assumption: Rental service of $75 each way.

The activities, quantities, production rates and costs utilized in the baseline are shown in Table C-2.

Table C-2. Baseline technology - manual demolition 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)	Baseline Technology Comments
Mobilization (WBS 331.01)								**Subtotal**	**$ 187**	
Preliminary Survey	0.5	$ 145.60				$ 72.80	1	each	$ 72.80	Two Health Physics Technicians (HPT) @ $56/hr and one D&D worker at $33.60/hr.
Transport Equipment					$ 75.00	$ 75.00	1	each	$ 75.00	Vendor provided service of $75 in each direction
Setup Equipment	1.0	$ 33.60	1.0	$ 5.63		$ 39.23	1	each	$ 39.23	One D&D worker @ $33.60to attach the pavement breaker @ $1.56/hr to the 185 cfm air compressor at $4.07/hr.
Dismantlement (WBS 331.17.04)								**Subtotal**	**$ 444,995**	
Setup (each morning)	0.25	$ 33.60	0.25	$ 5.63		$ 9.81	415	days	$ 4,070	D&D worker @ $33.60/hr for equipment maintenance
Perform Demolition	1.580	$ 67.20	1.580	$ 5.63		$115.07	1,460	ft3	$ 168,004	Two D&D workers at a rate of $33.60/hr. A 90lb pavement breaker, plus the air compressor @ $5.63/hr
Personal Protection Equip					$ 185	$185.00	830	man day	$ 153,550	$46.33 /day per person for Personal Protection Equipment for 4 equipment operators
Productivity Loss Factor	2.41	$ 67.20	2.41	$ 5.68		$175.64	415	days	$ 72,891	8 hour day / 1.43 (observed factor) = 5.59 productive hours and 2.41 hours for meetings, suit up, etc.
HPT Support	2.00	$ 56.00				$112.00	415	days	$ 46,480	One HPT @ $56/hr for 2 hr/day
Demobilization (331.21)								**Subtotal**	**$ 378**	
Decon and Survey Out.	2.0	$ 145.60	2.0	$ 5.68		$302.56	1	each	$ 303	Two HPT @ $56/hr and one D&D worker at $33.60/hr.
Transport for Return					$ 75.00	$ 75.00	1	each	$ 75	Rental service of $75 in each direction
								TOTAL:	**$445,560**	