INNOVATIVE TECHNOLOGY

Summary Report

DOE/EM-0450

Mobile Work Platform

Deactivation and Decommissioning Focus Area

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INNOVATIVE TECHNOLOGY
Summary Report

Mobile Work Platform

OST Reference #2243

Deactivation and Decommissioning
Focus Area

Demonstrated at
Fernald Environmental Management Project
Fernald, Ohio

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 whether 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

Introduction

The Fernald Environmental Management Project (FEMP) is a United States Department of Energy (DOE) facility that once produced uranium metal products for use in the U.S. defense programs. The site is now engaged in a cleanup program to address environmental problems associated with the former production mission. Together, the DOE and Fluor Daniel Fernald (FDF) place their highest priority on the health and safety of the Fernald work force and the public. The DOE continually seeks safer, faster and more cost-effective remediation technologies for use in the Decontamination and Decommissioning (D&D) of nuclear facilities. To this end, the Deactivation and Decommissioning Focus Area (DDFA) of the DOE's Office of Science and Technology (OST) sponsors Large-Scale Demonstration and Deployment Projects (LSDDPs) in which developers and vendors of improved or innovative technologies showcase products that are potentially beneficial to the DOE's projects and to others in the D&D community. Benefits sought include decreased health and safety risks to personnel and the environment, increased productivity, accelerated schedule, and decreased cost.

The Operable Unit 3 Record of Decision (Final ROD) for Final Remedial Action for DOE FEMP requires the removal of piping and electrical conduit as part of the overall decontamination and dismantlement of structures and components at the site. This report describes a comparative demonstration between the innovative Mobile Work Platform (MWP) technology and the baseline, a manual, labor intensive, removal method.

Technology Summary

Problem

At the FEMP and throughout the DOE complex, a typical activity is the removal of piping and conduit when decommissioning a process facility. During production, most of the pipe and conduit was routed overhead to prevent interference with normal work activities and to facilitate the movement of materials within and between the process areas. Current pipe/conduit removal methods are labor intensive, time-consuming, costly and often represent a significant challenge to D&D decision-makers. Because of personnel safety issues, the "cut and drop" approach to piping and conduit removal is not permitted at the FEMP.

Figure 1. Crew staging scaffolding to remove overhead pipe.

The motivation to utilize a remote controlled machine capable of holding, crimping, then cutting sections of pipe and conduit is to reduce the hazard of exposures to personnel that are experienced during the baseline manual removal process. As pictured in Figure 1, the baseline method requires a crew consisting of 5 people to erect scaffolding, to rig, then use hand held power tools to cut and ultimately lower the pipe section to the ground. The next step is to transport the cut pipe section to the waste container manually. Often a sling and pulley system is used to lower the pipe section safely to the ground. When the pipe to be cut is located high above the ground, the danger to personnel using power equipment is increased. Advantages of using the MWP include removing personnel from "harm's way," reducing the quantity of labor intensive work, eliminating the need for rigging activities and eliminating the need for personnel to work at elevated heights, by allowing a machine, specifically designed for the work, to do the job.

How it works (Mobile Work Platform)

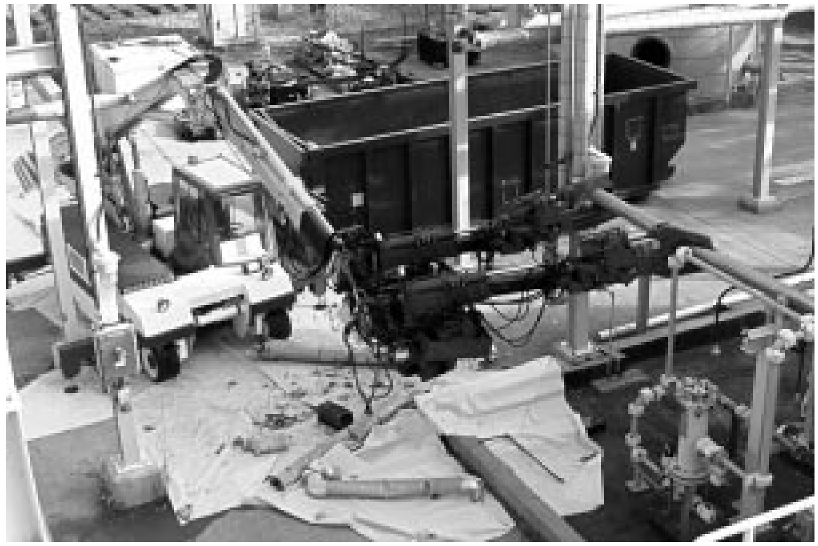

Figure 2. Mobile Work Platform removing pipe at Fernald.

The MWP shown in Figure 2, supplied by Eagle Tech has a four wheel chassis, Model No. 1500, a multi-articulating, a folding main boom attached to the chassis by means of a 360-degree rotating turret assembly. Attached to the telescoping jib end of the main boom are two independently operable arms that are mounted on a common articulating and rotating support platform base called the Rotec. The Rotec enables both arms to pivot around a common point. The Rotec allows both arms to work at a 90-degree angle off either side of the main boom arm. Each arm is able to independently telescope outward or retract to assist in final positioning the shear blade. Each arm is also able to independently articulate right, left, up, and down and also roll to position the shear blade in any position between horizontal and vertical. Both end-effectors have the ability to grab, hold in place, crimp, and shear pipe/conduit and lower the segmented section to the floor, waste container, or a predefined staging area.

The MWP was built to satisfy the following specifications:

- Grab, support, crimp, shear then lower in a controlled manner schedule 40, carbon steel pipe up to 6 inch (in) diameter with an additional 2 in of aluminum jacketed insulation.
- Cut the pipe into sections up to 30 feet (ft) above the ground.
- Hold 1000 pounds (lb) with the main boom positioned parallel to the ground.
- Hold load with engine off, and provide controlled lowering of load.
- Compact to fit into 8 ft wide by 9 ft tall entrance.
- Radio remote controlled operation up to 100 ft away.
- Place pipe sections directly into waste container.
- Travel 90-degrees in either direction from a stationary starting position.

Figure 3. MWP driving off the transport trailer.

The greatest feature of the MWP is the fact that it removes the D&D worker from "harm's way." Use of the Mobile Work Platform will eliminate the need to require workers to operate at heights up to 30 ft off the ground. These severe working conditions are often manual labor intensive and can jeopardize worker safety.

The uniqueness of the MWP is in the robustness of its design. With the capability to hold a 10 ft section of 6 in diameter, schedule 40, carbon steel pipe (weighing more than 200 lb), the MWP is able to manipulate and safely lower sections of pipe after cutting. During the demonstration at the FEMP, the MWP removed a single section of 4 in diameter, carbon steel pipe wrapped in aluminum jacket insulation, measuring 29 ft long. The MWP was able to lower the pipe and then further segment the section to less than 10 ft long directly above the waste disposal container. The MWP encountered no problems in manipulating pipe sections of this size and weight. During the pre-acceptance testing of development, the MWP was tested with a 1,000 lb weight prior to working at the FEMP.

Initially, the operator is seated in the on-board cab and drives the MWP off the tractor-trailer transport vehicle to the work area, see Figure 3. The MWP is self-propelled and has the ability to steer each of the four wheels independently, increasing the maneuvering proficiency. While en route, the end-effector assembly is secured to the chassis to provide added stability during transport.

Once at the work area, the four outriggers are extended laterally and the outrigger jacks are deployed to stabilize the chassis. Then, the operator can leave the vehicle cab and utilize the belt supported radio remote control unit to manipulate the boom and end-effector functions of the MWP. In a typical application of overhead pipe removal, the end-effectors are manipulated via remote control to make final adjustments necessary to properly position the shear jaws around the pipe to be cut, see Figure 4.
The identically designed end-effectors allow the MWP to hold or cut by varying the amount of force applied to the pipe segment. Both end effectors can perform the same functions. The proportional remote control allows the operator to vary the speed and force of the individual functions, giving the operator precise control.

Using an example of a straight section of pipe/conduit, the right shear is moved into position to grasp the pipe, then the left shear is positioned to crimp and cut. Next the left shear is opened and positioned to hold and support the pipe section while cutting with the right shear. Now that the pipe section is separated from the rest of the pipe length, the left shear lowers the section to ground elevation. The next step is to

Figure 4. MWP removing overhead pipe.

position the end-effector shears for the next pipe section to be removed, and the process is repeated.

How it works (manual removal)

The baseline method of removing piping and conduit includes a variety of activities such as manual disassembly, abrasive sawing, open-flame cutting and handheld shearing. During the D&D of the FEMP's Plant 1, the contractor utilized portable electric band saws, and heavy duty electric reciprocating saws combined with scaffolds, scissors lifts, safety harnesses, fall protection devices and other various rigging equipment to perform the pipe and conduit removal task. Some of the rigging equipment required is shown in Figure 5.

Figure 5. Equipment for manual pipe removal methods.

Typically, a crew will build a section of scaffolding, see Figure 6, to support the piping to be removed and attach a clamping device to the building's structural beam The beam clamp, shown in Figure 7, is used to hold the pipe section to be cut. But first, two areas of the pipe must be prepared, so the worker removes the aluminum jacket and insulation if necessary. Qualified riggers then secure the pipe before cutting begins. Once one end is cut through, the saw is carried over to the other side of the pipe and cutting resumes. After the cutting phase has segmented a pipe section from the remaining pipe run, it is carefully lowered to ground level via a sling and pulley system. Then laborers must move the pipe sections to the disposal container. Often, the pipe section has to be manually handled by laborers to maneuver the pipe into the waste disposal container. Sharp edges and fragments of steel commonly protrude from the ends of the pipe section increasing the risk of personnel injury.

Figure 6. D&D worker assembling scaffolding.

Potential markets (MWP)

Potential markets for the MWP technology include the DOE Complex, commercial nuclear facilities or any other location where hazards exist which require the worker to be distanced from the pipe/conduit removal process. The MWP would require some redesign to minimize or eliminate internal radiological contamination of expensive components of the MWP. Also, any external areas which could become contaminated must be redesigned to make it easy to decontaminate those areas.

After a few modifications, such as improvements with the control system and the addition of on-board video cameras the MWP could be become the enabling technology to perform work in more severely radiological contaminated areas.

Figure 7. Beam clamp with nylon strap.

MWP Advantages over the baseline

While the manual removal methods have been in existence for a long time, the MWP has the advantage of removing workers from 'harm's way'. By eliminating the need to elevate workers above ground level and minimizing the quantity of work performed with powered hand tools, the MWP is safer than baseline removal methods.

History shows that the FEMP has an excellent safety record, however accidents may happen and whenever steps are taken to reduce the danger to workers, the project is heading in the right direction.

Demonstration Summary

This report covers the innovative MWP technology demonstrated from November through December 1998 and the baseline methods used in the Plant 1 D&D project during 1996.

The demonstration sites and descriptions

The MWP technology was demonstrated at two locations that are similar to conditions found at Fernald and other places across the DOE complex. For demonstration purposes at the FEMP, an outdoor location and an indoor location were selected which presented a minimum risk of radiological contamination. The MWP technology was first demonstrated outside at the former Maintenance Tank Farm Area (MTFA) for a period of 10 working days, then moved inside to Plant 6's North-West corner, also known as the Waste Water Treatment Facility (WWTF) for 3 working days.

The MTFA was selected because of its overhead pipe racks holding various sized pipes, and 2 in to 4 in vertical and horizontal electrical conduit. For purposes of this demonstration, pipes with a significant potential to contain contamination/hazardous material were identified and removal was not attempted.

The MTFA is an outdoor location, containing an overhead pipe rack with electrical conduit, carbon steel insulated and non-insulated pipe with various diameters from 6 in to 3/4 in. The largest diameter pipe in the MTFA was a 6 in diameter, carbon steel, aluminum jacketed fiberglass insulation fire suppression line. Several carbon steel steam and condensate return lines with aluminum jacketed fiberglass insulation were located within the same pipe rack. In addition, various sizes of smaller diameter conduit and pipes were in the rack as well. The MTFA pipe rack elevation was approximately 20 ft above ground level. The pipes were mounted via saddles, "U" bolts, and angle brackets in the MTFA.

In contrast to the relatively open area of the MTFA, the WWTF presented a narrow entrance (8 ft wide, 9 ft tall), indoor location with low (9 ft high) overhead catwalk flooring within the working area. The MWP was able to reach underneath several nitric acid tanks to remove stainless steel pipe with insulation.

In the WWTF, the MWP was used to safely remove plastic conduit, carbon steel non-insulated pipe, 3 in and 4 in insulated stainless steel pipe and a series of "U" shaped, galvanized steel channel supports measuring 6 in by 2 in. These items were located 10 ft on either side of the narrow hallway within the WWTF. The close quarters of the WWTF tested the ability of the MWP to operate in tight areas with low overhead clearance. Figure 8 shows the MWP working within the WWTF.

Figure 8. MWP removing pipe and conduit within the WWTF.

The purpose of having the MWP demonstrated at two locations at Fernald, was to determine the overall flexibility of the machine using the two extremes, a wide open area versus a tight quarters area, while documenting the resulting production rates. During the demonstration at the FEMP, the MWP was able to remove all of the pipe and conduit identified for removal during the demonstration. A total of 844 lin ft of pipe and conduit were removed over the period of 13 working days.

Table 1. Comparison between two pipe and conduit removal technologies at the FEMP

	Mobile Work Platform Technology	Manual Removal Methods
Production Rate[1]	20 lin ft/hr	50 lin ft/hr
Demonstrated Removal	1 to 6 in diameter plus insulation	1 to 6 in diameter plus insulation
Height above ground	1 to 30 ft	1 to 10 ft
Total number of cuts	168	247

[1] The expected MWP production rate will be greater in future deployments and the production rate for manual removal methods will be less at heights of greater than 10 ft, while the MWP is expected to be higher than the demonstrated production rate.

Table 2. MWP Demonstration Material Summary Table.

	Maintenance Tank Farm Area		Waste Water Treatment Area	
Material[1]	Linear Feet	Aluminum jacketed insulation[2]	Linear Feet	Aluminum jacketed insulation[2]
Carbon Steel Pipe	620	Yes	61	Yes
Stainless Steel Pipe	0	No	79	Yes
Plastic Conduit	9	NA	52	NA
Galvanized Steel Channel	0	NA	23	NA
Total	629		215	

[1]U-bolts, pipe hangers, and other supporting brackets.
[2]Aluminum covered pre-formed fiberglass, asbestos-free insulation 2 in thick.

Key results

The key results of the demonstration are as follows:

- Best Feature: Removes workers from "harm's way". During the demonstration a vertical pipe was cut that had residual water (~1/4 gal.). If this unexpected event had occurred with hand-held power tools, the personnel may have been exposed to contaminated hazardous material. However, all personnel were outside the building during the shearing phase pipe removal and due to the crimping feature of the MWP, no one was sprayed with the liquid.

- Unit cost for the demonstrated application: $4.94/lin ft

- The MWP removed 844 lin ft of pipe and conduit during the 13 day demonstration.

- Successfully removed all pipes and conduits attempted regardless of geometric configuration, including supports (hangers, U-bolts, saddles, posts, channels and other supporting mechanisms).

- The longest single section of pipe removed with bends: 29 lin ft (4 in carbon steel, with 2 in insulation). Largest diameter of pipe removed was: 6 in carbon steel (14 lin ft length, 22 ft above ground level) with an additional 2 in of aluminum covered insulation.

Table 3. Production Rate Summary.

Production Rate	
Average	20 lin ft/hr
First 6 days	13 lin ft/hr
Last 8 days	28 lin ft/hr
Highest single day	36 lin ft/hr

Regulatory considerations

Technical guidance and site training in the areas of radiation protection, health and safety and regulatory compliance were provided to the vendor by FDF.

Commercial availability

Both technologies and their components are commercially available. However, the vendor has performed modifications to the MWP technology and its components to enhance efficiency and productivity. The MWP is available as a vendor provided service or rental.

Future Plans

As a result of the demonstration debriefing, the vendor for the MWP technology, is making modifications to the unit to increase flexibility and productivity. Eagle Tech is examining the possibility of deploying a "teach and learn" system to automate repetitive maneuvers once within the working area. Eagle Tech is also exploring the efficacy of additional end-effectors other than a shear.

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Licensing

The Mobile Work Platform is currently available for purchase or as a vendor provided service from Eagle Tech.

Other

All published Innovative Technology Summary Reports are available on the OST Web site at http://em-50.em.doe.gov under "Publications." The Technology Management System, also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST Reference number for the MWP is 2243.

SECTION 2

TECHNOLOGY DESCRIPTION

Overall Process Definition

Baseline approaches to removing former process piping and conduit materials at the FEMP include power tools like: portable band saws, reciprocating blade saws, and open flame cutting torches. Each of the aforementioned pipe and conduit D&D methods all involve locating people in the immediate vicinity of the cutting process. Each of these methods has drawbacks, such as slow production rates, generation of airborne contamination, creating fire ignition sources, inherent dangers of operating hand held cutting tools, requiring personnel to handle pipe and conduit sections, and large crew requirements.

Figure 9. MWP holding a 1,000-pound weight at the vendor's facility.

In an effort to find a better method of removing former process pipe and conduit, the MWP technology was demonstrated at the FEMP. It was demonstrated in a real-world environment. It was utilized within an area that required the removal of pipe and conduit. The MWP was assesed to determine its ability to satisfy the following objectives:

- Reduce the health and safety hazards to the D&D laborers from:

  –The need to work at heights when cutting pipe, conduit and other components.
  –Equipment or pipe segments being lowered or moved may shift and/or fall suddenly, injuring personnel.
  –Sharp edges left from manual cutting methods and subsequent hands-on handling of cut segments.
  –Manual cutting methods may increase the potential for airborne contamination problems.

- Provide a cost-effective alternative for pipe and conduit removal.

- Provide a comparison to baseline pipe and conduit removal technologies.

The MWP technology has three integral systems: the chassis system, the arm system and the end-effector system. Within the chassis system is housed a propane fueled, 302 cubic inch displacement, V-8 motor that drives a set of hydraulic pumps that provide pressure to move the various articulations of the unit. The hard rubber tires have four wheel 90 degree radius steering and are powered by hydraulic pressure and controlled from standard steering controls within the on-board cab.

The chassis measures 72 in wide by 148 in long and 93 in high. The complete vehicle weighs 30,400 lb as configured for the demonstration at the FEMP. The rear pair of outriggers can extend away from the chassis and all four of the outriggers can be telescoped outward away from the sides.

The arm consisted of a main boom and jib boom are constructed of high tensile strength steel. The jib boom can telescope outward and extend to reach 30 ft above the ground and reach 30 ft out laterally from the chassis. Each end-effector can grab, hold, and cut pipe and conduit into sections ranging in length of about a ft long up to 20 lin ft.

During the demonstration at the FEMP, a 29 lin ft, a 4 in diameter, carbon steel pipe with insulation was removed in one piece. The aforementioned pipe section included several 90-degree bends forming the steam line expansion loop.

As part of the pre-acceptance criteria, the Model 1500 was tested with a weight of 1,000 lb at the manufacturing facility before arriving at the site as shown in Figure 9. The test included lifting the test weight with one end-effector to the maximum height above ground and then rotating the turret 360 degrees. In addition, the shear blade holding the test weight was rolled 90 degrees each direction and the Rotec was rotated 90 degrees in each direction to prove the capability of the MWP.

The end-effectors are designed with a curved shear blade to provide a crimp prior to the shear cut, (Figure 10) to reduce the potential to releasing contaminants within the pipe. The blades (Figure 11) can be easily changed in the field to provide less crimping effect on the pipe, if an inspection of the pipe interior is necessary.

Although not required for use at the FEMP, the MWP was initially equipped with cameras to allow for remote viewing of the operations. The cameras supplied for the demonstration consisted of an on-board receiver video monitor, which can be removed from the MWP and placed at some distance away for remote operation, While on-board the MWP, DC electricity is converted to AC current to power the cameras. The chassis and arm are proven technologies in use at various industrial applications and may be supplied in various chassis sizes, lift capacities and power trains. Currently, the MWP can be operated outside or inside a facility, on concrete floors or may be modified for rough terrain.

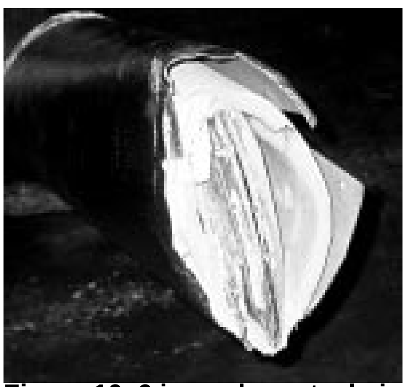

Figure 10. 6 in, carbon steel pipe with insulation is crimped by the MWP.

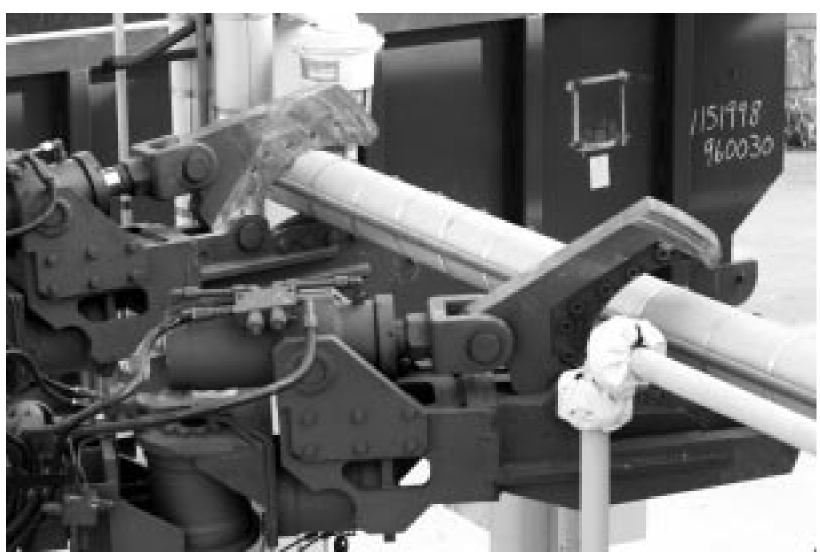

Figure 11. MWP removing pipe at the FEMP's Maintenance Tank Farm.

System Operation

Table 3 summarizes the operational parameters and conditions as well as material and energy requirements, manpower needs, waste streams, and operational concerns and risks for the MWP. The information presented below is specific to conditions encountered at the FEMP.

Table 3. Operational parameters, conditions, requirements and concerns of the MWP technology

Working Conditions	
Work area location	A. Maintenance Tank Farm Area B. Waste Water Treatment Building in Plant 6.
Work area description	A. Open outdoor area with overhead steam pipes (steam, water, air) condensate return pipes fire protection piping. B. Close quarters, waste water treatment nitric acid piping.
Work area hazards	Staying cognizant of overhead suspended loads. Tripping hazards when looking up and walking around with the remote control.
Equipment configuration	The Mobile Work Platform consists of a self-powered chassis, radio remote controlled, main boom, jib boom, multi-articulating dual headed hydraulic shear.
Work crew	One full time MWP operator. 25% utilization of an assistant as a spotter during chassis movement.
Additional support personnel utilized during the demonstration	One full-time data taker. Part-time radiological control technician. Health and Safety personnel as necessary to perform initial sound measurements, noise dosimetry and provide safety guidance.
Training	MWP vendor received 48 hours (h) of FEMP site specific training.
Waste Management	
Primary waste generated	Pipe/conduit segments with aluminum jacketed fiberglass insulation.
Secondary waste generated	Small quantity of "oily" rags with hydraulic fluid.
Waste containment and disposal	30 cubic yard roll-off box.
Equipment Specifications and Operational Parameters	
Technology design purpose	Hold, crimp, cut, and lower up to 6 in diameter, schedule 40, carbon steel pipe.
MWP specifications	Height: 72 in with boom lowered Length: 80 in Width: 84 in Weight: 30,400 lb Reach: 30 ft Fuel Requirement: Standard propane
Radio remote control unit	Depth: 4 in Height: 6 in Width: 10 in Weight: 2 lb Range: >100 ft Six proportional 2 way control levers
Portability	The MWP is able to drive itself onto and off of a flatbed semi-truck.
Materials Consumed	
Fuel	446 lbs. Propane
Preparing work area	Sections of yellow Herculite for hydraulic fluid spill mitigation. Delineation of work area with caution tape.
Personal Protective Equipment (PPE)	Steel toe boots. Safety glasses. Hard hat (reusable). Disposable leather palm gloves.
Fuel container	Propane in standard 33 lb tanks.
Supporting Equipment	
Electrical Generator	Capable of servicing lights (indoors)
Forklifts	Used to deliver propane storage bins.
Lights	4 Halogen work lights with stands. (indoors)
Potential Operational Concerns	
During MWP technology operation	Remaining cognizant of walking under suspended loads. Walking around the work area while looking upwards.
Safety, health and environmental concerns	Noise level measurement (2 hours) = 80.3 dBA (indoors) Carbon Monoxide measurement (1 hour) = 11 ppm (indoors) Propane is a potential source for carbon monoxide.

SECTION 3

PERFORMANCE

Demonstration Plan

Demonstration Site Description

The demonstration of the MWP technology was conducted in accordance with the approved *Mobile Work Platform Work Plan 2500-WP-0036, Rev. 1.* The MWP technology was demonstrated at two very different areas at the FEMP, however both locations had a low potential for radiological contamination. The first was an outdoor location consisting primarily of an extensive overhead pipe rack known as the Maintenance Tank Farm Area (MTFA). The MTFA pipe rack consisted of various pipes and electrical conduit ranging in size from 6 in to 3/4 in diameter carbon steel, galvanized steel, also pipe supports and insulation. The pipe rack was elevated approximately 20 ft above the ground. This location was chosen because of the close similarity in size and layout of "process piping" found within process areas throughout Fernald. The path leading up to the MTFA was as narrow as 9 ft wide.

The second location was Plant 6G's Northwest corner which contained the Waste Water Treatment Facility (WWTF). The entrance leading into the building was 8 ft wide by 9 ft tall while the average overhead clearance within the 'hallway' was less than 9 ft. Pipes and conduit were located overhead and to either side of the hallway. The pipes and conduit included 4 in stainless steel insulated and non insulated pipes, a 6 in "U" shaped galvanized channel support, and carbon steel pipes. Figure 12 shows the MWP working within the close quarters of the WWTF.

Figure 12. MWP working in the WWTF.

Demonstration Objectives

The primary reason for demonstrating the MWP technology was to assess its ability to remove pipe and electrical conduit in a safer, more efficient and cost effective way as compared to the manual/baseline method. The objectives of the demonstration were to:

- Hold, crimp, cut, and lower to the ground up to 6 in diameter, schedule 40 thickness, carbon steel pipe and de-energized electrical conduit with minimum labor and risk to personnel.
- Determine cost effectiveness.
- Evaluate safety improvements and capability of the MWP.

Results

The Demonstration was successful in safely achieving all of the aforementioned demonstration objectives.

In addition to the Cost Benefit Analysis presented in Section 5 of this report, subsequent analysis of the production data gathered during the demonstration yielded a graph of daily production rates and is shown

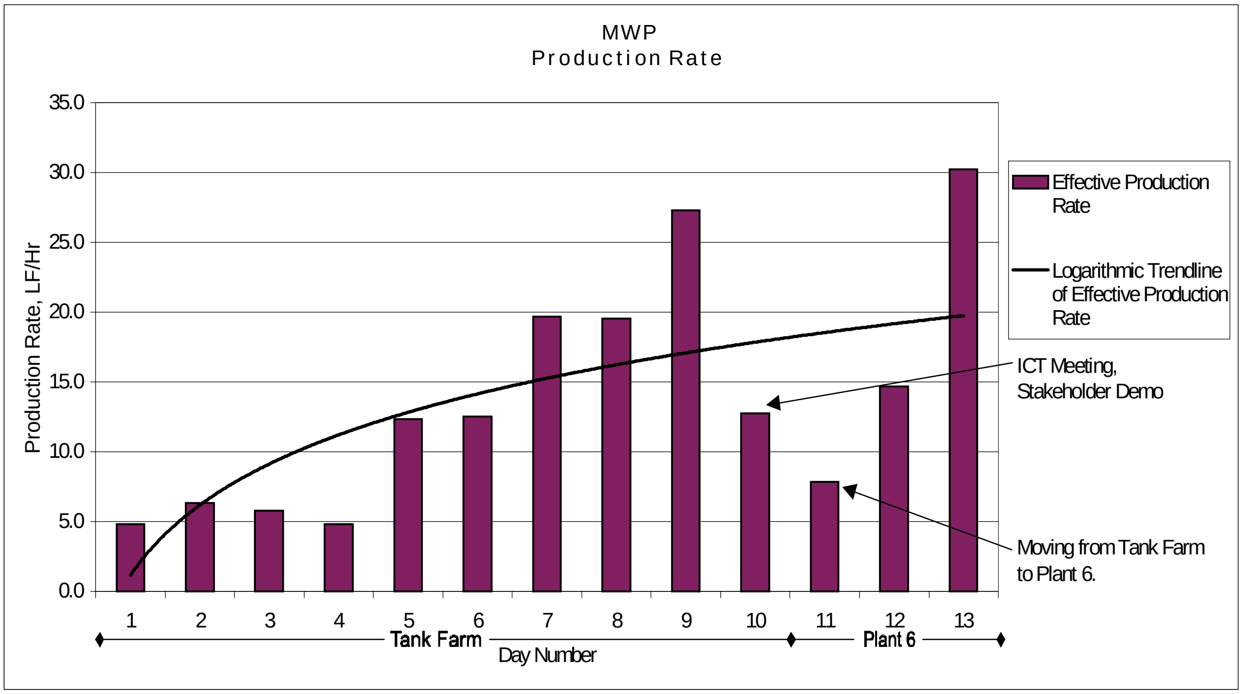

Figure 13. Daily Production Rate.

Figure 13. shows a learning curve related to the growing experience level of the MWP operator. The operator did not have a great deal of experience with the remote control interface prior to the demonstration at the FEMP. As the demonstration progressed, the operator became more proficient with the controls. However, the Integrating Contractor Team concurred that the MWP could have been operated much faster using an experienced operator.

After the demonstration FDF and the vendor conducted a system by system critique of the individual components of the MWP. The results of the critique are shown in Section 7 as potential future enhancements for the next generation of the MWP.

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

The MWP has no known directly competing technology because of its robust size, strength and unique ability to hold, crimp, cut and then lower sections of pipe in a controlled manner. The MWP performs a process that can be compared to manual removal methods. Other companies have previously built robotic arms with a variety of end-effectors that have been deployed in demonstration decommissioning programs. However, none of them have the capability to hold, crimp, cut and lower in a controlled manner. Since the cut and drop approach is unacceptable at the FEMP these products while reviewed were not selected for demonstration.

Technology Applicability

The MWP is useful in many applications where elevated pipe and conduit are required to be safely removed across the DOE sector. By reducing the risk of injury to personnel, the MWP will lower overall cost of D&D projects. With proper modification, the MWP would provide the most benefit in an environment that is high in contamination, high in radiation, and presents a high industrial hazard.

Patents/Commercialization/Sponsor

The MWP technology demonstrated at the FEMP was designed, manufactured, and assembled by Eagle Tech of Solon, Ohio. The MWP can be purchased or is available as a vendor provided service. The MWP technology was sponsored by the DOE's Office of Science and Technology, Large Scale Demonstration and Deployment Project. No regulatory permits were required to demonstrate the MWP at the FEMP.

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SECTION 5

COST

Methodology

A cost analysis was performed to compare the cost of the MWP with the cost of the manual removal method. The objective is to assist decision-makers that are selecting from among competing technologies. This analysis strives to develop realistic estimates that represent actual D&D work within the DOE weapons 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 were eliminated or adjusted to make the estimates more realistic. These adjustments were allowed only when they would not distort the fundamental elements of the observed data (i.e. does not change the productivity rate, quantities, work element, etc.,) and eliminated only those activities which are atypical of normal D&D work. Any changes to the observed data are described in later portions of this section.

The MWP was rented from the vendor for the duration of the demonstration. Only vendor personnel operated the MWP.

Cost and performance data were collected for the MWP during the demonstration. Cost and performance data were collected for the baseline technology during the D&D of Plant No. 1. The following cost elements were identified from the Hazardous, Toxic and Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary (HTRW RA WBS), US Army Corps of Engineers, February 1996, prior to the demonstration. Data was collected to support a cost analysis based on those elements:

- mobilization (including necessary training)
- D&D (removal of process piping)
- demobilization (including equipment decontamination)
- personal protective equipment

Mobilization costs included the cost of transporting technology equipment to the site and costs for training vendor personnel for working on the site.

Demobilization included removal of technology equipment from the site.

PPE costs include all clothing, respirator equipment, etc., required for protection of crewmembers during the demonstration. It was assumed that four changes of reusable PPE clothing items were required for each crewmember. Reusable PPE items were assumed to have a life expectancy of 200 hours. The cost of laundering reusable PPE clothing items is included in the analysis. It was assumed that four changes of disposable PPE clothing items per day were required for each crewmember. Disposable PPE items were assumed to have a life expectancy of 10 hours (the shift length).

Cost data for disposal was not collected during the demonstration for either technology. However, the additional expense would have minimal impact on the cost analysis. Therefore, this omission does not compromise the analysis.

Cost Analysis

Performance was measured and unit costs determined based on lin ft of process piping removed by each technology. For each element, costs were determined from the data collected. See Table 4. Production rates were calculated for each day that data was collected. In calculating production rates, time required for the actual removal of process piping plus time required for normal work stoppages such as PPE changes, mandatory and heat stress breaks, and propane changes were used. Non-standard work stoppages such as for equipment repair, filming of demonstration, severe weather, and safety issues were ignored. To see if a significant learning curve was present, the daily production rates were graphed and a trendline created using a logarithmic regression. The production rate values from the trendlines were used in the cost analysis.

Labor rates used in the analysis are those actually in effect at the FEMP. Contractor indirect costs were omitted from the analysis, since overhead rates can vary greatly among contractors. Engineering, quality assurance, administrative costs and taxes were also omitted from the analysis. The bare unit costs determined by the analysis can be modified by adding site specific indirect costs to produce a site-specific unit cost.

Equipment costs were based on the cost of ownership. For the MWP, an hourly equipment rate was calculated using a spreadsheet based on the methodology outlined in EP 1110-1-8, Construction Equipment Ownership and Operating Expense Schedule, US Army Corps of Engineers, September 1997. The hourly rate is based on the $415,000 capital cost of the MWP, a discount rate of 5.6%, equipment life of 20,000 operating hours as advised by the vendor, estimated yearly usage of 1,040 hours, and estimated operating, maintenance and repair costs.

For both technologies, the cost data was entered into an MCACES Gold project database. Supporting databases for labor, equipment and crews were created for the Fernald Plant No. 1 LSDDP. Laborers, equipment pieces and crews were added to these supporting databases. The project database was priced from the supporting databases.

The following modifications were made to the cost data to reflect a more typical technology deployment. A crew of two operated the MWP for the demonstration. However, for a typical deployment, a crew of only 1.25 would be required, and the crew for the MWP was adjusted accordingly. Other personnel within the work are expected to assist the operator of the MWP, accounting for the 1.25 people. Manual Removal was performed by a crew of three labors. However, manual removal of process piping was performed at a maximum height of 10 ft above ground. A crew of five would be required to manually cut and handle pipe at the heights for which the MWP was designed and demonstrated. Therefore, the crew for Manual Removal was adjusted to include four laborers and one rigger (ironworker). The MWP was demonstrated in a clean environment; therefore, the crew wore no PPE other than normal safety clothing. In an actual deployment, the crew would require the same PPE system as Manual Removal. The cost of PPE was added to the cost of pipe removal by the MWP.

Fixed cost elements (independent of the quantity of inspection work) were calculated as lump sum costs. Comparative unit costs are direct costs with no indirect costs included. This is standard practice in commercial unit price guides such as those published by the R. S. Means Company.

Cost Conclusions

A comparison of the major cost elements from the MCACES cost estimate is shown in Table 4.

Table 4. Summary Cost Comparison

Mobile Work Platform (Innovative)			**Manual Removal** (Baseline)		
Cost Element	**Unit Cost**	**Production Rate**	**Cost Element**	**Unit Cost**	**Production Rate**
Mobilization[1]	$2,988	N/A	Mobilization[1]	$0	N/A
Removal of Piping	$3.99/lin ft	20 lin ft/h	Removal of Piping	$3.29/lin ft	50 lin ft/h
Demobilization[1]	$0[2]	N/A	Demobilization[1]	$0	N/A
PPE	$0.95/lin ft	N/A	PPE	$1.51/lin ft	N/A

[1] These are fixed costs that are independent of the quantity of piping removed.
[2] Demobilization costs are included in mobilization.

Mobilization costs were higher for the MWP because the equipment had to be transported to the site, while Manual Removal required only the use of scaffolding, small tools and power tools which were readily available at the site. The MWP also requires some time for training and equipment familiarization. There are no training costs for Manual Removal.

The MWP required a smaller crew but had a lower production rate than Manual Removal. The net result is that the MWP has a higher unit cost for removal of piping.

Demobilization costs were higher for the MWP due to the cost of removing equipment from the site. There are no demobilization costs for Manual Removal.

The two technologies required similar PPE systems. The MWP required a smaller crew and had a lower production rate than Manual Removal. The net result is that the MWP has a lower cost for PPE.

The comparative unit costs for the two technologies for the demonstrated application are:

$4.80/lin ft - Manual Removal (50 lin ft/h)

$4.94/lin ft - MWP (20 lin ft/h)

Therefore, for the demonstrated application, the MWP offers little cost savings over Manual Removal. The MWP was more costly for mobilization, D&D, and demobilization. Manual Removal was more costly for PPE.

The Integrating Contract Team observed that the MWP would probably show a higher production rate in the hands of an experienced operator. To explore the impact of increased production rate, unit cost was plotted against production rate in Figure 14 for both technologies.

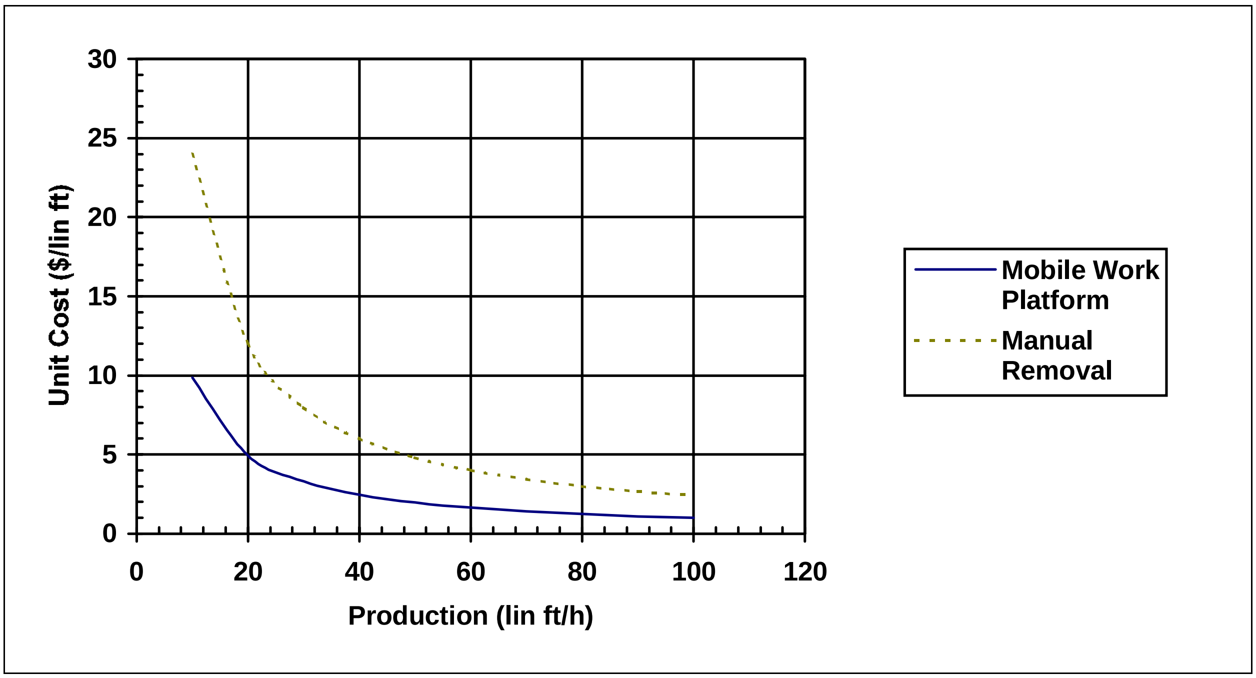

Figure 14. Unit Cost vs. Production.

The graph shows that production rate is a more significant driver for Manual Removal than it is for the MWP, particularly at lower production rates. It also shows that at equivalent production rates, the MWP has a lower unit cost than Manual Removal.

Figure 15 shows total cost vs. quantity of pipe to be removed for a series of production rates for both technologies. The intersection of any two lines representing a manual removal production rate and a MWP production rate represent the quantity of piping removed at which pay back of the $415,000 MWP capital cost is achieved. Based on information from other sources, it is believed that 50 lin ft/h represents the maximum sustainable production rate for manual removal. The maximum sustainable production rate for the MWP is unknown.

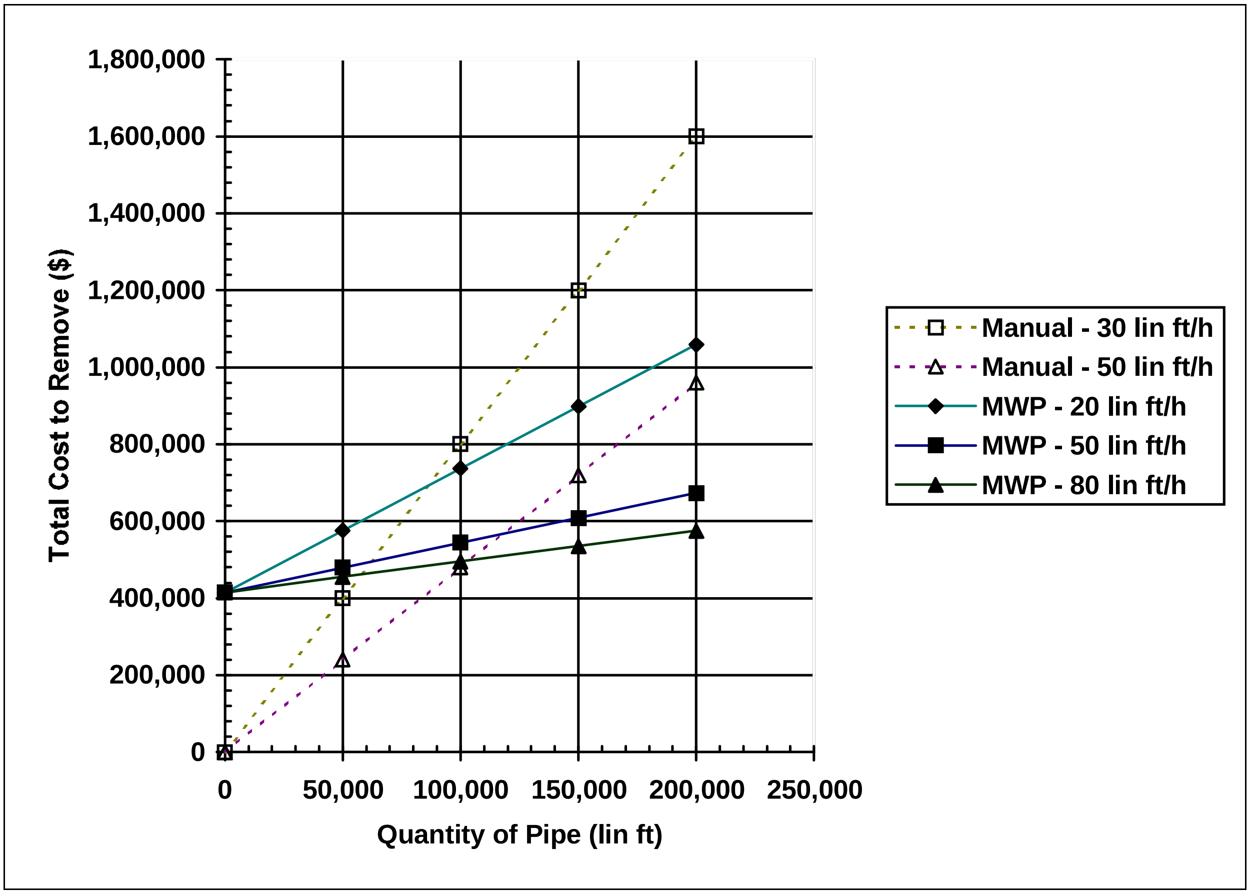

Figure 15. Total cost vs. quantity for various production rates.

A breakeven analysis was performed to determine the amount of pipe that must be removed in order for a deployment to recover the fixed costs for mobilization and demobilization. Figure 16 contains a graph of the breakeven analysis for several production rates for each technology.

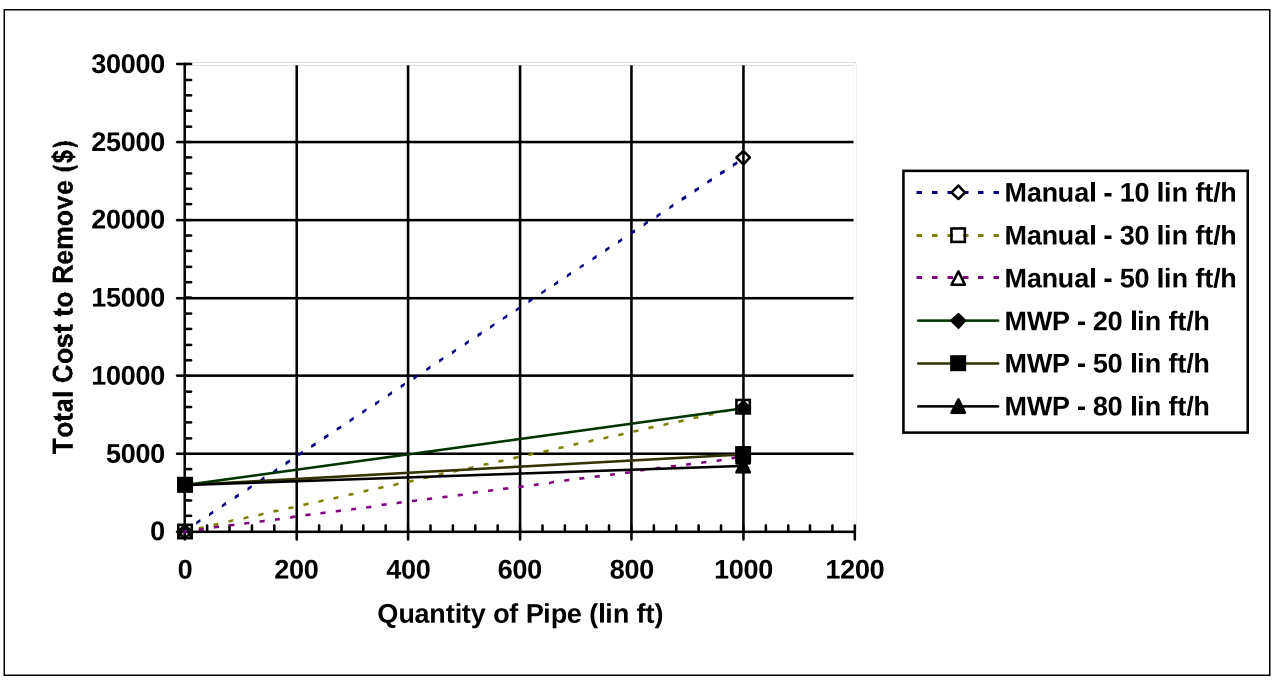

Figure 16. Breakeven analysis.

SECTION 6

REGULATORY AND POLICY ISSUES

Regulatory Considerations

The operation of the MWP technology and the manual removal methods at the FEMP are governed by the following health and safety 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**

—1910.101 to 1910.120 (App E)	Hazardous Materials
—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 issued by the U.S. Department of Transportation (DOT) and DOE:

- **49 CFR Subchapter C** — Hazardous Materials Regulations

—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 Packaging
—174	Carriage by Rail
—177	Carriage by Public Highway
—178	Specifications for Packaging

- **10 CFR Subchapter 1** — Packaging and Transportation of Radioactive Material

Fernald site specific requirements

- **RM – 0045** — Fluor Daniel Fernald Hoisting & Rigging Manual.

- **RM – 0021** Fluor Daniel Fernald Safety Performance Requirements Manual.
- **DOE order 440.1A** Worker Protection Management for DOE Federal and Contractor employees.

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

- **40 CFR Subchapter 1** Solid Waste

Before either the MWP technology or the manual removal methods could be performed at the FEMP, a number of site-specific requirements had to be fulfilled. Those requirements were as follows:

- An approved Safe Work Plan
- An approved Waste Management Plan
- Complete a Nevada Test Site (NTS) Waste Acceptance Criteria Form
- Complete an Environmental ALARA Review/Evaluation – Report And Check List
- Apply and receive an Approved Site Safety Assessment

Safety, Risks, Benefits, and Community Reaction

Since both the MWP and manual pipe removal methods are successful ways to perform the pipe and conduit removal task, there is no current regulatory requirement to apply the Comprehensive Environmental Response, Compensation & Liability Act nine evaluation criteria. Nonetheless, some evaluation criteria are discussed below. Other criteria such as cost and performance were discussed in Sections 3 and 5.

Worker Safety

Enhancing worker safety is the greatest benefit of using the MWP. The MWP is operated in a remote controlled fashion. At the FEMP, during the shearing phase of the pipe removal process, all personnel are required to observe a 30 to 50 ft standoff distance. Therefore, if the scope of work involves cutting overhead pipe or conduit, use of the MWP would:

- Reduce the risk of physical hazards.
- Eliminate the possibility of personnel falling from elevated heights.
- Reduce the chance of personnel being struck by/against, falling objects including pipe, insulation and debris.
- Support ALARA principles.
- Crimp the end of the individual pipe sections lowers the potential to spread radioactive contamination.

Community Safety, Community Reaction and Socioeconomic Impacts

The use of the MWP has a positive impact on community safety and/or socioeconomic issues. During the demonstration at the FEMP, stakeholders were invited to observe the MWP in action. The reaction of the stakeholders was very positive. Community reaction would likely be positive since they are useful tools in helping to remediate the site. By safely removing pipe and conduit, the DOE and taxpayer can expect significant cost savings.

Environmental Impact

As compared to the baseline (manual removal), the MWP would be less likely to impact the environment. The only potential negative environmental impact that could occur with this technology would be a release of contaminated material to the environment during the process of cutting and manipulating process piping. However, this event would be unlikely, because the MWP provides a crimp before the cut takes place. In addition, the pipe is lowered in a controlled manner when using the MWP.

SECTION 7

LESSONS LEARNED

Implementation Considerations

The MWP technology is a commercially available system. Hands-on training can be provided by the vendor and is recommended to familiarize the operator with the uniqueness of the remote controls. To date only one of these units exist; therefore a truly experienced operator does not exist. Based upon the data collected during the demonstration, a graph shown in Figure 13 illustrates that with operating time and experience an operator can significantly improve the production rate.

Technology Limitations and Needs for Future Development

The MWP technology demonstrated at the FEMP could benefit from the following design improvements.

- Provide an improved operator interface (i.e. joystick controls) would increase production rate.
- Employ a “teach and learn” computer system to assist the operator with repetitive manipulations.
- Utilize a laser range finding to assist placement and fine-tune maneuvering of end-effector would automate the final positioning of the shear head.
- Provide an electrical and hydraulic swivel to improve flexibility and reduce the loops of electrical wiring and hydraulic hoses.
- Provide a locking quick connect hydraulic fittings.
- Provide an indicator to view the direction of the individual wheels of the MWP.
- Utilize a telescoping, articulate counter weight.
- Provide flexible boot coverings around hydraulic cylinders, and removable surface paint coatings to enhance decontamination of the unit.

Technology Selection Considerations

Ideally, the MWP is most useful in high radiation areas where personnel are performing pipe and conduit removal tasks. In such areas, the MWP may be an enabling technology. The additional savings in personnel exposure are not applicable at the FEMP as may be encountered at other facilities within the DOE complex.

APPENDIX A

REFERENCES

Fluor Daniel Fernald (FDF), May 1993, *Operable Unit 3 (OU3) Work Plan Addendum, Remedial Investigation Feasibility Study (RI/FS)*, Volume 2 of 2.

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

U.S. Army Corps of Engineers (USACE*).* August 1995.*Construction Equipment Ownership and Operating Expense Schedule*. Region II.

APPENDIX B

REAL EXAMPLES OF SAFETY CONCERNS IN CUTTING PIPE WITH HAND TOOLS

Case #1:

At the FEMP, in May of 1996, two members were cutting overhead piping and lowering the pipe to ground level. One of the team members had finished making his cuts and was descending a ladder when the pipe came loose from the bracket that was holding it. The team member lost control of the pipe, his right hand was pinched between the pipe and a pulley near the floor. The procedure for cutting and removing overhead piping requires the pipe to be tied off prior to the start of cutting and descending operations. During this operation, the pipe was not tied off while it was being cut or while it was being lowered to the ground. Medical personnel also restricted the team member to work activity with no carrying or lifting with the right hand.

Case #2:

At the FEMP, in August of 1996, a team member was cutting a pipe with an air-operated cutting wheel. When the wheel slipped off the pipe, it resulted in a laceration to the first and second digits of his left hand, including an embedded foreign object. The team member required sutures and the removal of the foreign body from the laceration site. Medical personnel placed the team member on restricted work activity of no use of the left hand for five days. At the time of the injury, the team member was not wearing gloves.

Case #3:

At the FEMP, in June of 1996, a Lessons Learned Item was issued pertaining to a team member being struck in the head by a scaffolding pole left in an area where transite paneling was being removed. The pole fell from the third floor striking the team member in the head, the team member was wearing a hard hat as he was jack-hammering concrete. After undergoing extensive evaluation by medical, the employee was released. No injuries or problems were reported by medical or the employee.

APPENDIX C

SUMMARY OF COST ELEMENTS

Fixed Cost

Title ID	Description	Quantity	Unit	Output	Manhrs	Labor	Equipmnt	Materials	Other	Total
33A	**Manual Removal (Baseline)**	**25000**	**lin ft**							
33A.01	Mobilization	1	EA		0	$0	$0	$0	$0	$0
33A.21	Demobilization	1	EA		0	$0	$0	$0	$0	$0
33A	**Total Manual Removal**	**25000**	**lin ft**		**0**	**$0**	**$0**	**$0**	**$0**	**$0**
33B	**Mobile Work Platform (Innovative)**	**25000**	**lin ft**							
33B.01	Mobilization	1	EA		0	$638	$0	$0	$2,350	$2,988
33B.21	Demobilization	1	EA		0	$0	$0	$0	$0	$0
33B	**Total Mobile Work Platform**	**25000**	**lin ft**		**0**	**$638**	**$0**	**$0**	**$2,350**	**$2,988**

This sheet summarizes the fixed costs. It represents the start-up costs necessary to deploy a technology.

Unit Cost

Title ID	Description	Quantity	Unit	Output	Manhrs	Labor	Equipmnt	Materials	Other	Total	Unit Cost
33A	**Manual Removal (Baseline)**	**25000**	**lin ft**								
33A.17	D&D Work (Piping Removal)	25000	lin ft	50	2500	$77,785	$4,410	$0	$0	$82,195	$3.29
33A.18	Disposal	25000	lin ft		0	$0	$0	$0	$0	$0	$0.00
33A.90	PPE	25000	lin ft		0	$0	$0	$0	$37,800	$37,800	$1.51
33A	**Total Manual Removal**	**25000**	**lin ft**		**2500**	**$77,785**	**$4,410**	**$0**	**$37,800**	**$119,995**	**$4.80**
33B	**Mobile Work Platform (Innovative)**	**25000**	**lin ft**								
33B.17	D&D Work (Piping Removal)	25000	lin ft	20	1563	$56,840	$42,813	$0	$0	$99,653	$3.99
33B.18	Disposal	25000	lin ft		0	$0	$0	$0	$0	$0	$0.00
33B.90	PPE	25000	lin ft		0	$0	$0	$0	$23,633	$23,633	$0.95
33B	**Total Mobile Work Platform**	**25000**	**lin ft**		**1563**	**$56,840**	**$42,813**	**$0**	**$23,633**	**$123,286**	**$4.93**

This sheet summarizes the unit costs (costs dependent on quantity).

Total Cost

Title ID	Description	Quantity	Unit	Output	Manhrs	Labor	Equipmnt	Materials	Other	Total	Unit Cost
33A	**Manual Removal (Baseline)**	**25000**	**lin ft**								
33A.01	Mobilization	1	EA		0	$0	$0	$0	$0	$0	$0.00
33A.17	D&D Work (Piping Removal)	25000	lin ft	50	2500	$77,785	$4,410	$0	$0	$82,195	$3.29
33A.18	Disposal	25000	lin ft		0	$0	$0	$0	$0	$0	$0.00
33A.21	Demobilization	1	EA		0	$0	$0	$0	$0	$0	$0.00
33A.90	PPE	25000	lin ft		0	$0	$0	$0	$37,800	$37,800	$1.51
33A	**Total Manual Removal**	**25000**	**lin ft**		**2500**	**$77,785**	**$4,410**	**$0**	**$37,800**	**$119,995**	**$4.80**
33B	**Mobile Work Platform (Innovative)**	**25000**	**lin ft**								
33B.01	Mobilization	1	EA		0	$638	$0	$0	$2,350	$2,988	$2,988.00
33B.17	D&D Work (Piping Removal)	25000	lin ft	20	1563	$56,840	$42,813	$0	$0	$99,653	$3.99
33B.18	Disposal	25000	lin ft		0	$0	$0	$0	$0	$0	$0.00
33B.21	Demobilization	1	EA		0	$0	$0	$0	$0	$0	$0.00
33B.90	PPE	25000	lin ft		0	$0	$0	$0	$23,633	$23,633	$0.95
33B	**Total Mobile Work Platform (Innovative)**	**25000**	**lin ft**		**1563**	**$57,478**	**$42,813**	**$0**	**$25,983**	**$126,274**	**$5.05**

APPENDIX D

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	**Description**
ALARA	As Low As Reasonably Achievable
CFR	Code of Federal Regulations
dBA	Decibels weighted on “A” scale
D&D	Decontamination & Decontamination
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EPA	Environmental Protection Agency
FDF	Fluor Daniel Fernald
FEMP	Fernald Environment Management Project
ft	foot, feet
h	hour
in	inch
lb	pounds
LSDDP	Large Scale Demonstration and Deployment Project
lin ft	Linear Feet
M&I	Management and Integration
MTFA	Maintenance Tank Farm Area
MWP	Mobile Work Platform
NTS	Nevada Test Site
OSDF	On Site Disposal Facility
OSHA	Occupational Safety and Health Administration
OST	U.S. DOE Office of Science and Technology
OU3	Operable Unit 3
PPE	Personal Protective Equipment
ppm	parts per million
ROD	Record of Decision
USACE	United States Army Corps of Engineers
WWTF	Waste Water Treatment Facility (within Building 6G)