INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0401

Oxy-Gasoline Torch

Deactivation and Decommissioning
Focus Area

Prepared for
U.S. Department of Energy
Office of Environmental Management
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OST Reference #1847

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Focus Area

Demonstrated at
Fernald Environmental Management Project –
Building 1A and 66
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 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."

TABLE OF CONTENTS

APPENDICES

SECTION 1

SUMMARY

Introduction

The United States Department of Energy (DOE) continually seeks safer 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 sponsors Large-Scale Demonstration Projects (LSDP) at 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, and decreased cost and schedule.

Under the D&D Implementation Plan of the DOE's Fernald Environmental Management Project (FEMP), non-recyclable process components and debris that are removed from buildings undergoing D&D are disposed of in an on-site disposal facility (OSDF). Critical to the design and operation of the FEMP's OSDF are provisions to protect against subsidence of the OSDF's cap. Subsidence of the cap could occur if void spaces within the OSDF were to collapse under the overburden of debris and the OSDF cap. Subsidence may create significant depressions in the OSDF's cap in which rainwater could collect and eventually seep into the OSDF. To minimize voids in the FEMP's OSDF, large metallic components are cut into smaller segments that can be arranged more compactly when placed in the OSDF. Component segmentation using an oxy-acetylene cutting torch was the baseline approach used by the FEMP's D&D contractor on Plant 1, Babcock and Wilcox (B&W) Services, Inc., for the dismantlement and size-reduction of large metal components. Although this technology has performed satisfactorily, improvements are sought in the areas of productivity, airborne contamination, safety and cost.

This demonstration investigated the feasibility of using an oxy-gasoline torch as an alternative to the baseline oxy-acetylene torch for segmenting D&D components. The oxy-gasoline torch is similar in operation to the oxy-acetylene torch but uses gasoline instead of acetylene as the fuel. Benefits expected from using the oxy-gasoline torch include:

- increased cutting speed, particularly for metal thicknesses greater than 1 inch;
- reduced airborne contamination;
- readily available and less expensive fuel;
- increased worker safety;
- reduced cost of operation.

This report provides a comparative analysis of the cost and performance of the baseline oxy-acetylene torch currently used by B&W Services, Inc., and the innovative oxy-gasoline torch.

Technology Summary

Baseline Technology

In-situ component segmentation is a fully developed process that is widely used throughout the DOE Complex for size-reducing D&D debris in preparation for disposal, including placement in an OSDF. The technology used at the FEMP for segmenting components is an oxy-acetylene cutting torch. Combustible paint on the surfaces of components is first stripped from the areas that are to be cut with the torch to reduce the risk of fire and airborne contamination. This is normally done using paint solvents that are applied to the surfaces, allowed time to react with the paint, and then scraped off. Components are then cut into segments in accordance with FEMP's OSDF waste acceptance criteria (WAC, see Appendix D) that stipulate the maximum dimensions of debris that can be placed in the OSDF.

Innovative Technology

The Petrogen®[1] oxy-gasoline torch developed by Petrogen International, Ltd., is a fully mature and commercially available metal-cutting torch system. Before the Petrogen design, earlier models of the torch were plagued by backflash – a hazardous condition in which the flame of the torch ignites the gasoline in the fuel line and travels up the line to the gasoline tank causing an explosion. Petrogen has developed and patented innovative redesigns of the torch and gasoline tank that incorporate several proprietary features that make it safer, more reliable, and eliminate the possibility of backflash.

The Petrogen oxy-gasoline torch system is designed for cutting steel. Since its demonstration at the FEMP, it has seen increasing application at DOE sites, in private industries, as well as internationally. Appendix E lists some of the new deployment sites for the oxy-gasoline torch following its demonstration at the FEMP Plant 1 LSDP.

The torch can be used for cutting steel underwater at depths down to 600 feet.

How It Works

The oxy-gasoline torch is fueled by a mixture of gasoline and oxygen. The fuel components are delivered to the torch via hoses from a pressurized gasoline tank and a cylinder of oxygen, both of which are portable. The gasoline tank may be pressurized either by a built-in hand pump or by an external source of compressed air. The gasoline and oxygen are combined in a mixer in the head of the torch. The fuel mixture travels to the tip of the torch where it is lit (see Figure 6). After a few seconds of pre-heating, the tip of the torch becomes warm enough to vaporize the gasoline in the tip. The rapid expansion results in a high velocity stream of highly combustible oxygen/gasoline vapor that fuels the cutting flame of the torch. Vaporization of the fuel in the tip is an endothermic process that reduces overheating of the tip and extends its life.

The pressurized gasoline tank was also developed by Petrogen and has been tested and approved by the Underwriter's Laboratory. Safety features that have been built into the tank include a fill cap that integrates a pressure relief valve, and a check valve inside the tank that stops the flow of gasoline if the hose ruptures and a sudden surge in the flow is detected. Figure 1 shows the torch, tank, and cutting tips. Figures 2 and 3 show the torch in operation.

Figure 1. Oxy-gasoline Tank, Torch, and Cutting Tips

[1] Petrogen is a registered trademark of Petrogen International, Ltd.

Figure 2. Cross-section of a carbon steel beam up to three inches thick, after being cut with the Oxy-gasoline Torch.

Figure 3. Oxy-gasoline Torch being used to segment a process tank constructed of 2-inch thick carbon steel.

Demonstration Summary

The demonstration of the baseline oxy-acetylene torch and the innovative oxy-gasoline torch was conducted in Buildings 1A and 66 at the FEMP between September 23 and October 10, 1996. The purpose of the demonstration was to assess the oxy-gasoline torch as a viable alternative to the baseline oxy-acetylene torch for the dismantlement and size-reduction of metallic D&D debris at the FEMP. The components segmented included a shield wall, an axle shaft, a drum crusher, and a pulverizer base. All components were made of carbon steel.

Key Results

The key results of the demonstration are summarized below. Detailed descriptions and explanations of these results are in Section 3 of this report.

- The oxy-gasoline torch outperformed the oxy-acetylene torch in all areas in which the torches were evaluated.

Productivity

- The oxy-gasoline torch cut all thicknesses of steel between 0.5 and 4.5 inches (see Figure 4) faster than the oxy-acetylene torch. For thicknesses of 0.5 inches or less, both torches performed comparably. However, as the metal thickness increased, the relative cutting rate of the oxy-gasoline torch over the oxy-acetylene torch increased considerably. At a thickness of 4.5 inches, the oxy-gasoline torch cut 3 times as fast as the oxy-acetylene torch.

  The anomalous trend in the cutting rates shown in Figure 4 is a result of the varying geometry and accessibility of the debris being segmented (see Section 3, Treatment Performance).

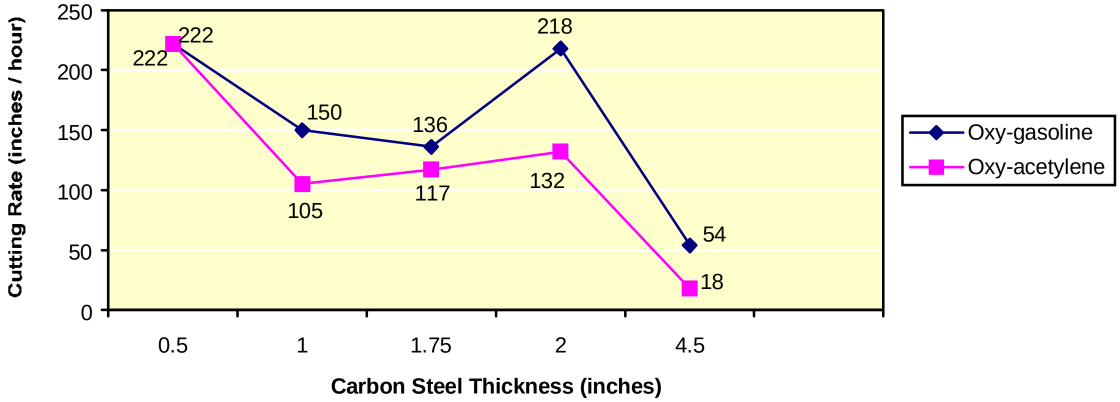

Figure 4. Cutting rates achieved by the oxy-acetylene and oxy-gasoline Torches on various thicknesses of carbon steel.

Operation

- Both the oxy-gasoline and the oxy-acetylene torches are easy to set up and operate. Workers who are experienced in using an oxy-acetylene torch can be trained to use the oxy-gasoline torch within one hour.
- Only minor problems arose during the demonstration and these were a result of the worker's inexperience in using the torch and were quickly and easily resolved.

Cutting Effectiveness

- During the demonstration, the oxy-gasoline torch cut effortlessly through carbon steel up to 4.5 inches thick and produced clean cuts with minimal kerf. The oxy-acetylene torch performed well on metal thicknesses up to 2 inches but its performance relative to the oxy-gasoline torch fell significantly on thicker steel. It produced jagged cuts with considerable kerf.
- The oxy-gasoline torch easily cut through rusted surfaces while the oxy-acetylene torch was unable to.
- The oxy-gasoline torch can be used to cut steel that is in direct contact with concrete without the risk of the concrete shattering and causing a projectile hazard.
- Neither torch was able to cut cast iron.

Cost of Performing D&D Work

- The cost of segmenting D&D debris at the FEMP with the oxy-gasoline torch was less than with the oxy-acetylene torch for all thicknesses of steel (see Figure 5). The measured costs included all expenses incurred during the segmentation process such as labor, personal protective equipment (PPE), capital cost of the equipment and fuel.

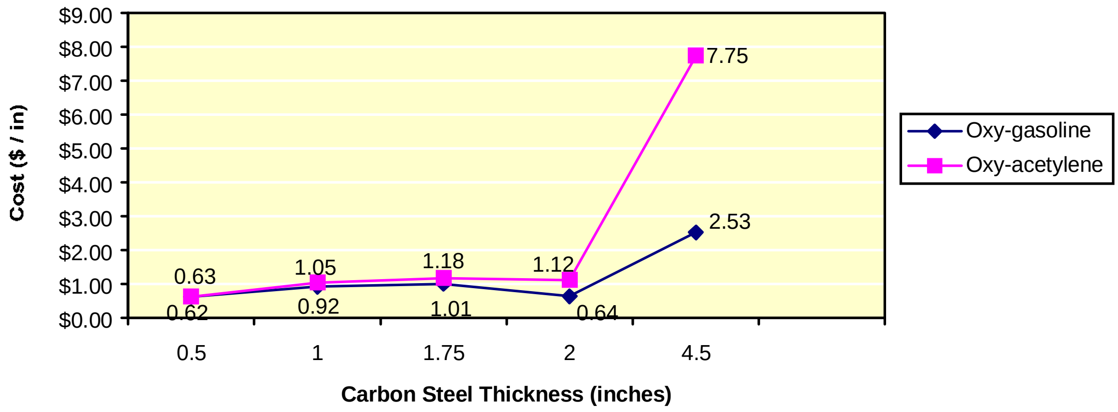

Figure 5. Hourly cost of using the oxy-acetylene and oxy-gasoline torches to cut various thicknesses of carbon steel.

Airborne Contamination

- The oxy-gasoline torch produces carbon dioxide (colorless) and water (emitted as white translucent steam) during cutting. In addition to carbon dioxide and water, the oxy-acetylene torch produces highly toxic carbon monoxide, as well as carbon, which is emitted as a black sooty, smoke?

Health and Safety

- Liquid gasoline is safer to handle than pressurized acetylene gas. In its liquid form, gasoline will neither burn nor explode. Acetylene can burn even in the absence of oxygen, and will explode if subjected to high temperature, excessive pressure or shock.
- The oxy-gasoline torch is inherently safe because its design keeps the gasoline in a stable, liquid state as it moves from the tank, through the hose, through the torch and into the tip of the torch. Because liquid gasoline cannot burn, backflash up the fuel line is impossible. The tank also has a check valve that senses surges in the flow of gasoline and immediately stops the flow if the fuel line ruptures. If the acetylene line ruptures, the gas could escape undetected and could result in an explosion.
- The oxy-gasoline torch produces a granular slag that has a lower thermal capacity than molten steel. This significantly reduces sparking and popping that are characteristic of the oxy-acetylene torch, and reduces the risk of fire and injury to the operator.

Portability

- The oxy-gasoline torch cutting system (including gasoline tank, fuel and oxygen) is more portable than the oxy-acetylene system. A full cylinder of acetylene gas weighs about 250 pounds. A full tank of gasoline holds 2.5 gallons, weighs about 30 pounds, and will cut about the same amount of steel as the 250-pound cylinder of acetylene.

Permits, Licenses and Regulatory Considerations

Both torches were operated by the FEMP's D&D contractor, B&W Services, Inc. Petrogen International, Ltd. supplied the oxy-gasoline torch and trained the D&D workers to operate it. Fluor Daniel Fernald (FDF) provided support in the areas of radiation protection, and health and safety. An open flame permit was required to operate the torches.

Technology Limitations and Needs for Future Development

Based on its demonstrated good performance, the oxy-gasoline torch does not appear to require any further development. The oxy-gasoline torch operates differently from the oxy-acetylene torch and workers will require specific training in its use (e.g. procedures for lighting the torch).

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Web Site

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SECTION 2

TECHNOLOGY DESCRIPTION

Overall Process Definition

The purpose of the demonstration was to assess the benefits that may be derived from using the innovative Petrogen oxy-gasoline torch as an alternative to the baseline oxy-acetylene torch for the dismantlement and size-reduction of metallic D&D debris at the FEMP.

During dismantlement, debris is cut using a torch into smaller segments that can be arranged more compactly when placed in a disposal facility. For storage in the FEMP's OSDF, the size of the segments is governed by the FEMP's waste acceptance criteria (see Appendix D). Debris is normally segmented in place before removal from buildings undergoing D&D.

In comparing the oxy-gasoline and oxy-acetylene torches, the following parameters were assessed:

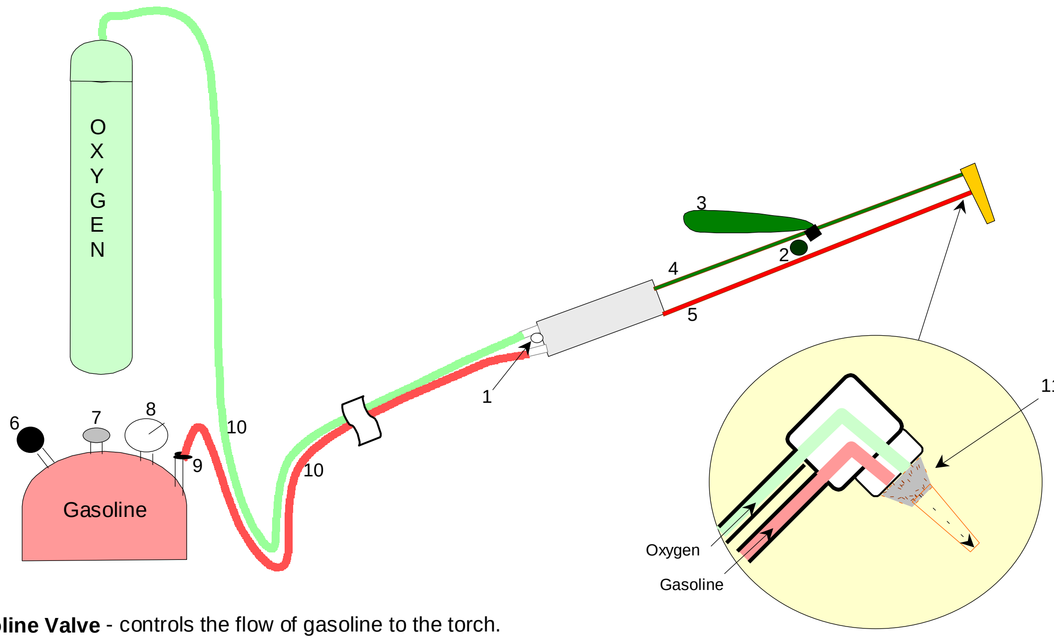
- worker health and safety;
- productivity rates;
- cost of performing D&D component segmentation;
- airborne contamination;
- equipment operation and ease of use.

Figure 6 illustrates the main components of the Petrogen oxy-gasoline torch cutting system which are the torch, a gasoline tank (also designed by Petrogen), a cylinder of oxygen, and connecting hoses.

The gasoline tank is pressurized using either the hand pump that is built into the tank, or by connecting it to an external source of compressed air. The liquid gasoline and oxygen are delivered to the torch via separate hoses. Control valves on the torch adjust the flow of oxygen and liquid gasoline to a cone shaped mixer in the head of the torch. Up to the point where the gasoline enters the mixer, it is in a liquid state. Because liquid gasoline cannot burn, backflash up the fuel line is prevented. A wick inside the mixer serves to disperse the gasoline evenly throughout the mixer and contributes to an even flame. The mixture is forced through to the tip of the torch where it is lit. A few seconds after the fuel mixture is lit, the tip of the torch begins to heat up and becomes sufficiently hot to vaporize the oxygen/liquid gasoline mixture. The rapid expansion produces a high-velocity stream of the vaporized gasoline and oxygen that is ejected from the tip of the torch and provides a strong force to the cutting flame. Vaporization of the gasoline is an endothermic process that helps to prevent the tip of the torch from overheating and extends its life.

The oxy-gasoline torch relies on 100% oxidation to cut through metal, rather than on melting. The torch oxidizes steel to a granular slag that is blown out of the cut by the force of the flame. The force and momentum of the gasoline vapor (about four times denser than acetylene) drive the fuel deep into the cut where it continues to burn and oxidize the metal. This enables the oxy-gasoline torch to cut through thicker metal easier and faster than other oxy-fuel torches (including the oxy-acetylene torch) and produces a clean cut with minimal kerf. The granular slag is also less likely to clog the tip of the torch during cutting, unlike the molten steel produced by other torches.

In contrast, the oxy-acetylene torch depends on a combination of oxidation (about 70%) and melting (about 30%) to cut metal and is slower because some of the molten metal re-solidifies and has to be re-cut. This produces cuts with considerable kerf and rough edges.



1. **Gasoline Valve** - controls the flow of gasoline to the torch.
2. **Oxygen Valve** – controls the flow of oxygen to the torch.
3. **Cutting Lever**- regulates the on/off flow of oxygen to the head of the torch.
4. **Oxygen Line** – delivers oxygen to the fuel mixer in the head of the torch.
5. **Gasoline Line** – delivers liquid gasoline to the fuel mixer in the head of the torch. Because liquid gasoline cannot burn, backflash up the gasoline line is prevented.
6. **Hand Pump** - pressurizes the gasoline tank to a minimum of 10 psi that is required to deliver the gasoline to the head of the torch.
7. **Tank Filler Cap** – seals the tank after filling. The cap has a built-in pressure relief safety valve.
8. **Pressure Gauge** – for monitoring the pressure in the tank. The gauge fits into an adapter with a check valve that prevents fuel from escaping if the gauge is accidentally broken off.
9. **Gasoline Hose connector and Shut-Off Valve** – controls the on/off flow of gasoline to the torch.
10. **Hoses** – deliver oxygen and liquid gasoline to the torch.
11. **Fuel Mixer –** Liquid gasoline and high-pressure oxygen combine in the cone-shaped mixer and are forced though a matrix of wicks and grooves. The mixture is lit and as the tip of the torch warms up, it vaporizes the gasoline passing through it. The gasoline expands rapidly and the volatile vapor gushes from the tip of the torch producing a strong flame.

Figure 6. Schematic of the Petrogen oxy-gasoline torch.

System Operation

Table 1 summarizes the operational parameters and conditions of the oxy-gasoline torch demonstration.

Table 1: Operational parameters and conditions of the oxy-gasoline torch demonstration

Working Conditions	
Work area location	Building 66 and 1A of Plant 1 at the FEMP site.
Work area access	Accessible to a forklift for removal of segmented components.
Work area description	Cordoned off sections of Buildings 66 and 1A that were undergoing D&D.
Work area hazards	Tripping hazard from hoses. Airborne contamination. Fire and burn hazards. Securing and transporting heavy segments of steel.
Equipment configuration	The gasoline tank, oxygen cylinder and torch were transported directly to the work area.

Labor, Support Personnel, Specialized Skills, Training	
Work crew	Three-person work crew: • 1 burner • 1 vacuum hose holder • 1 fire watch
Additional support personnel	• 1 data taker • 1 radiation technician • 1 health and safety observer (provided as necessary) • Riggers for lifting and lowering segmented components (provided as necessary)
Specialized skills/training	Workers were trained by the Petrogen representative to operate the oxy-gasoline torch.
Waste Management	
Primary waste generated	Segmented components.
Secondary waste generated	Disposable PPE High-efficiency particulate air (HEPA) filter and vacuum hose Residue (oxidized steel)
Waste containment and disposal	Emissions were collected using a vacuum & HEPA filtration system. Residue was shoveled and packaged for disposal.
Equipment Specifications and Operational Parameters	
Technology design purpose	Cutting metal.
Coupling distance (distance between cutting tip and steel)	Range: 0.25 – 2 inches Optimal - 0.25 in.
Dimensions	Gasoline tank (2.5 gallon) - 10 in diameter x 12 in high Gasoline hose - 20 ft (standard) Oxygen hose - 25 ft (standard) Torch - 20 in (90° head) Oxygen tank - Supplied by user
Portability	The oxy-gasoline torch and components are easily transported by handcart to project sites. The gasoline tank weighs approximately 30 lbs. when full.
Materials Used	
Work area preparation	Barricades and caution tape were erected around the perimeter.
Personal protective equipment	Cotton coveralls and outer gloves, hood, and booties Rubber shoe covers Marmak™ fire retardant outer coveralls Nitrile gloves with liners Leather gloves Leather apron Air purifying respirators
Air filtration	Vacuum hose and HEPA filter used to collect emissions.
Utilities/Energy Requirements	
Fuel	Gasoline and oxygen.

Assessment of Technology Operation

Operational Strengths of the Oxy-gasoline Torch Technology

- The Petrogen oxy-gasoline torch is a safe and effective means of dismantling and size reducing metallic D&D components.
- The design of the Petrogen oxy-gasoline torch eliminates backflash up the fuel line.
- Throughout the demonstration, the oxy-gasoline torch performed without any significant mechanical problems. Problems that arose were minor and quickly resolved.
- The oxy-gasoline torch system (including fuel) can be easily transported by handcart and easily mobilized directly to the work site.
- The oxy-gasoline torch can be used to cut steel that is in direct contact with concrete without the risk of the concrete shattering and causing a projectile hazard.
- The optimal coupling distance between the tip of the torch and the steel being cut is 0.25 inches for both the oxy-gasoline and the oxy-acetylene torch. The oxy-gasoline torch will perform effectively at coupling distances up to 2 inches allowing for greater flexibility when cutting steel under unusual conditions. At coupling distances greater than 0.25 inches, the performance of the oxy-acetylene torch deteriorates rapidly.

Operational Weaknesses of the Oxy-gasoline Technology

- The oxy-gasoline torch did not demonstrate any operational weaknesses during the demonstration. The only minor problem that arose was related to the worker's inexperience in using the system, and not to deficiencies in the system. Workers had to manually adjust the pressure in the gasoline tank to compensate for the difference in elevation between the tank and the torch in order to maintain adequate gasoline pressure. This problem can be eliminated by fitting the torch with a pressure regulator that is available from Petrogen.

SECTION 3

PERFORMANCE

Demonstration Plan

Demonstration Objectives

The investigation assessed the oxy-gasoline torch based on its performance, relative to the oxy-acetylene torch, in achieving the following demonstration objectives:

- increased productivity;
- decreased cost;
- decreased airborne contamination;
- improved worker safety.

Demonstration Site Description

The oxy-gasoline torch was demonstrated in Building 1A and 66 of Plant 1 at the FEMP site. Once the equipment designated for segmenting was identified, caution tape was erected. Ladders and a manlift provided access to the components being segmented.

Demonstration Boundaries

Both the oxy-gasoline torch and oxy-acetylene torch were demonstrated under identical conditions for in-situ segmentation. Cutting was limited to metallic components made of carbon steel.

Treatment Performance

Both torches were evaluated on similar types of equipment and materials, including a shield wall, an axle shaft, a drum crusher, and a pulverizer base. All components were made of carbon steel. Typically, components constructed of steel less than 2 inches thick included tanks and sheet metal that had simple geometries and which were easily accessed. At thicknesses greater than 2 inches, the debris comprised mostly structural steel and equipment that had irregular geometries and were not as easily accessed. This resulted in anomalous trends in the cutting rates for both torches (see Table 3) as metal thickness increased, but did not skew their performance relative to each other.

During the demonstration, the torch cutters stated empirically that when using the oxy-gasoline torch to cut metal up to 0.5 inches thick, its performance was identical to an oxy-acetylene torch. For the cost analysis and comparison purposes, therefore, the production data collected when using the oxy-gasoline torch to cut metal up to 0.5 inches thick were also used for the oxy-acetylene torch (see Table 3).

Performance relative to demonstration objectives

Table 2 summarizes the performance results of the two torches versus the objectives listed above.

Table 2. Performance comparison between the oxy-gasoline torch and the oxy-acetylene torch

Performance Factor	Oxy-acetylene Torch	Oxy-gasoline Torch
Productivity (Rate of cutting steel)	See Table 3	
Emissions (Airborne Contamination**)**	Carbon monoxide, carbon soot, carbon dioxide and water	Carbon dioxide and water
Worker Safety	Acetylene will explode if subjected to heat or shock. Backflash can occur. Significant sparking and popping during cutting present fire and burn hazards. Danger from moving heavy acetylene tank (hoist and rigging are often required to lift tank to higher elevations)	Liquid gasoline will not burn or explode due to heat or shock. Backflash is eliminated. Minimal sparking and popping during cutting. Small gasoline tank can be easily carried to higher elevations
Unit Cost of performing D&D work ($/in)	See Table 4	
PPE requirements	Both required the same level of PPE. Total PPE used with the oxy-gasoline torch was lower because of its higher productivity.	

Increased Productivity

The oxy-gasoline torch achieved higher productivity rates than the oxy-acetylene torch in cutting all thicknesses of steel between 0.5 and 4.5 inches. For thicknesses of 0.5 inches or less, both torches performed comparably. Table 3 summarizes the cutting rates achieved by the two torches during the demonstration. Note that as metal thickness increased, the relative cutting rate of the oxy-gasoline torch over the oxy-acetylene torch increased considerably. This illustrates the superior performance of the oxy-gasoline torch over the oxy-acetylene torch, particularly for metal thicknesses of 2 inches or greater.

Table 3. Comparison of cutting rates of the oxy-acetylene and oxy-gasoline Torches on various thicknesses of steel

	Cutting Rate (in. / h)				
Equipment Used	**≤ 0.5 in. Steel**	**1 in. Steel**	**1.75 in. Steel**	**2 in. Steel**	**4.5 in. Steel**
(A) Oxy-acetylene	222	105	117	132	18
(B) Oxy-gasoline	222	150	136	218	54
Difference in Productivity (B-A)	0	45	19	86	36
Variance in Productivity [(B-A)/A]	0%	43%	16%	65%	200%

Improved Cutting Effectiveness

The oxy-acetylene torch cuts steel using a combined process of oxidation (about 70%) and melting (about 30%). Oxidation produces a granular slag of iron oxide that is blown from the cut. Melting produces a rough kerf along the edges of the cut, and in metal thicknesses greater than 1 inch, some of the molten steel solidifies before the cut is complete and has to be re-cut. This slows the cutting speed of the oxy-acetylene torch.

The oxy-gasoline torch oxidizes the metal 100% to a granular slag that is blown from the cut. In addition, gasoline vapor is four times as dense as acetylene vapor and continues burning down the cutting jet for a longer distance than acetylene. This allows the flame to penetrate deeper into the cut and the oxy-gasoline torch is therefore able to cut greater thicknesses of steel easier and faster than the oxy-acetylene torch, and it leaves smoother edges along the cut.

The oxy-acetylene torch is ineffective in cutting through rusted surfaces because the steel is already oxidized (to rust) and the cutting process then relies on the torch melting through the surface. The oxy-gasoline torch is able to oxidize the rust (iron oxide) even further (to ferroso-ferric oxide), thereby cutting through the rusted surface. Neither torch was able to cut cast iron.

The oxy-acetylene torch produces molten steel during cutting. When it is used to cut steel that is in contact with masonry, the molten steel rapidly transfers heat to the masonry causing it to expand quickly and shatter, posing a projectile hazard to workers. The granular slag produced by the oxy-gasoline torch has a lower thermal capacity and heat transfer rate than molten steel and does not cause this problem.

Decreased Cost of Performing D&D Work

The cost of segmenting D&D debris with the oxy-gasoline torch was less than with the oxy-acetylene torch for all metal thicknesses. At thicknesses of 0.5 inches or less, the lower cost of segmenting with the oxy-gasoline torch is due to the lower cost of the gasoline fuel; at thicknesses greater than 0.5 inches, even further savings are realized due to the higher productivity of the oxy-gasoline torch. Table 4 provides a comparison of the costs of segmenting D&D debris at the FEMP. The costs reflect all expenses incurred during the segmentation process and include labor, capital cost of equipment, PPE and fuel.

Table 4. Comparison of the cost of segmenting various thicknesses of steel using the Oxy-acetylene and Oxy-gasoline Torches

	Unit Cost ($ / in)				
Equipment Used	≤ 0.5 in. Steel	1 in. Steel	1.75 in. Steel	2 in. Steel	4.5 in. Steel
Oxy-acetylene Torch	$0.63	$1.05	$1.18	$1.12	$7.75
Oxy-gasoline Torch	$0.62	$0.92	$1.01	$0.64	$2.53
Difference in Cost (B-A)	-$ 0.01	-$ 0.13	-$ 0.17	-$ 0.48	-$ 5.22
Variance in Cost [(B-A)/A]	-2%	-12%	-14%	-43%	-67%

Decreased Airborne Contamination

The gasoline used by the oxy-gasoline torch is oxidized 100% during combustion to carbon dioxide (colorless) and water (emitted as white translucent steam), and no carbon monoxide is produced. The oxy-acetylene torch does not fully oxidize the acetylene fuel and the byproducts of combustion include carbon dioxide, steam, carbon monoxide (highly toxic), and carbon (emitted as a black sooty smoke). Air samples of emissions were not taken during the demonstration and no quantitative data are available.

Increased Worker Safety

Liquid gasoline is safer to handle because it will not burn or explode if exposed to heat or shock. Acetylene, however, will explode when exposed to heat or shock, even without an oxygen source.

The oxy-gasoline torch integrates safety features including a gasoline delivery system that prevents backflash up the fuel line (a danger with the oxy-acetylene torch), a check valve in the gasoline tank that senses surges in the flow of gasoline (e.g. due to a hose rupture) and immediately stops the flow of gasoline, and a relief valve that prevents over-pressurization of the gasoline tank.

The oxy-gasoline torch oxidizes the steel 100% during cutting and the resulting slag is granular and has a lower thermal capacity than molten steel. This results in significantly less sparking or popping than the oxy-acetylene torch, reduced danger to the torch operator, and reduced risk of fire in the work area.

The gasoline tank used with the oxy-gasoline torch weighs 30 pounds compared to 250 pounds for the acetylene tank. It is easier and safer to transport, particularly when working on upper floors or scaffolding.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Technology Applicability

The oxy-gasoline torch is a fully developed and commercially available tool for cutting and segmenting steel. Its superior performance over the baseline oxy-acetylene torch, particularly in the areas of productivity, cost and worker safety, makes it a prime candidate technology for deployment throughout the DOE Complex. Increased cutting speeds, especially in metal thicknesses greater than 2 inches, have the potential to accelerate dismantlement schedules and significantly reduce D&D costs.

Competing Technologies

The baseline technology with which the oxy-gasoline torch competes is the oxy-acetylene torch, which is used extensively throughout the DOE Complex to segment and size-reduce large metallic D&D components. Other technologies that may be used for segmenting are:

Plasma arc cutting

The plasma arc cutting technology is based on establishing a direct current (DC) arc between a tungsten electrode and the metal being cut. The arc is established in a gas that flows though a constricting orifice in the torch nozzle to the metal surface. The constricting effect of the orifice on both the gas and the arc results in very high current densities and high temperatures in the stream (17,540°F – 42,740°F). The stream, or plasma, consists of positively charged ions and free electrons. The plasma is ejected from the torch at a very high velocity and, in combination with the arc, melts the contacted metal and blows the molten metal away. A typical cut starts at the metal edge, and a through cut is made in a single pass by simply moving the torch along at a fixed rate of speed.

This technology can cut though metals such as carbon steel, stainless steel, and aluminum. It is able to cut most metals up to 7 inches thick.

The plasma cutter is very expensive and not as portable, durable or rugged as other cutting technologies such as the oxy-gasoline torch is. Another disadvantage is the particulate airborne contamination that is generated with this technology, which tends to clog the HEPA filters quickly.

Abrasive water jet cutting

The abrasive water-jet cutting technology uses a fine stream of highly pressurized water (up to as 55,000 psi) to propel a granular abrasive at the surface being cut. The water is pressurized by a hydraulically driven intensifier pump. The water flows though a chamber where it is mixed with the abrasive; the most common being crushed garnet. This mixture of water and abrasive is then forced though a wear-resistant nozzle with a small orifice, which focuses the abrasive jet stream on the component being cut. The pressurized jet stream exits the orifice at extremely high velocities, producing erosion that yields a clean cut with minimal kerf.

This technology can cut though most metals up to 9 inches thick. It can be used on piping and tank over a wide range of diameters. Advantages of this technology are that the system is flexible and can cut many different materials. It is a non-thermal process and no sparks are generated during use. This makes it ideal for potentially explosive atmospheres. A major disadvantage of this system in a nuclear environment would be the large volume of possibly contaminated water that would be generated. In addition, the extremely high pressures used by the system present a safety risk.

Oxy-propane torch

The oxy-propane torch operates in the same manner as the oxy-acetylene torch. Propane is much cheaper than acetylene (but more expensive than gasoline) and is readily available. It is also somewhat safer than acetylene but not as safe as gasoline. The oxy-propane torch, however, uses about 25-30% more oxygen than the oxy-acetylene and the oxy-gasoline torches, and its cutting performance is inferior to both.

Patents/Commercialization/Sponsor

This demonstration involved the use of a fully developed technology as required under the terms of the LSDP. The oxy-gasoline torch has been patented by its developer, Petrogen International, Ltd., from which it can be purchased. The U.S. patent number is 1,036,590.

SECTION 5

COST

Introduction

This analysis compares the costs of using the Petrogen oxy-gasoline torch and an oxy-acetylene torch for segmenting large metallic components in preparation for disposal in the FEMP's OSDF. The purpose of the cost analysis is to present validated demonstration data that were collected during the LSDP in a manner that will enable D&D decision-makers to select the preferred technology for their specific applications. It strives to develop realistic estimates that are representative of work performed within the DOE-Complex, however, the reader should be aware that it is only a limited representation because it uses only data that were observed during the limited duration of the demonstration, and is based on prevailing conditions at the FEMP. Some of the observed costs have been eliminated or adjusted to make the estimates more realistic. These adjustments have been made only when they do not distort the fundamental elements of the observed data (i.e., they do not change productivity rates, quantities, work elements, etc.), or when activities are atypical of normal D&D work. Additional cost information and demonstration data are contained in the *Detailed Technology Report for the Oxy-gasoline Torch*, FEMP, 1997 which is available upon request from the Fernald Environmental Management Project.

Methodology

Cost and performance data were collected for each technology during their respective demonstrations. The following cost elements were identified in advance of the demonstrations, and data were collected to support a cost analysis based on these drivers:

- **Mobilization:** includes the cost of transporting equipment to the demonstration site, training the crew members to use the equipment, providing crew members (including vendor-provided personnel) with FEMP site-specific training, constructing temporary work areas, and installing temporary utilities.

- **D&D Work:** includes the cost of labor, utilities consumed, supplies, and the amortized capital cost of using the equipment during the demonstration.

- **Demobilization:** includes removal of support equipment such as riggings and manlifts, disconnection of temporary utilities, dismantlement of temporary work areas, disposal of secondary waste, and equipment decontamination and removal from the site.

- **Personal Protective Equipment** (PPE) costs include all protective clothing, respirators, etc., required for protection of crew members during the demonstration.

Unit costs and production rates were determined based on linear feet of cutting required to segment the steel components in accordance with FEMP's WAC (see Appendix D). Separate cost and productivity data were collected for cutting various thicknesses of steel ranging from 0.5 to 4.5 inches.

Where work activities were performed by the D&D contractor, labor rates used in the analysis were those in effect at the FEMP at the time of the demonstration. Contractor indirect costs were omitted from the analysis since overhead rates can vary greatly among contractors and locations. Site-specific costs such as engineering, quality assurance, administrative costs and taxes were also omitted from the analysis. Where appropriate, D&D decision-makers may modify the FEMP base unit costs determined by this analysis to include their respective site-specific indirect costs.

PPE costs are duration dependent. Normally, four changes of PPE clothing items (both disposable and reusable) are required for each crew member per day. Reusable PPE items were estimated to have a life expectancy of 200 hours. Disposable PPE items were assumed to have a life expectancy of 10 hours -

the length of the daily shift (see Appendix C). The cost of laundering reusable PPE clothing items is included in the analysis.

Costs for disposal of waste from the demonstrations were omitted from the analysis because both torches generated identical amounts of waste, and the disposal costs for the waste are not duration dependent.

The fixed cost elements (i.e. those independent of the quantity of D&D work, such as equipment mobilization – see Appendix C) were calculated as lump sums. The variable cost elements (i.e. those dependent on the quantity of D&D work, such as labor costs) were calculated for each metal thickness as the cost per inch of steel cut.

Measurement of Fuel Consumption

The demonstration data collected on each torch spanned a total working time of between seven and eight hours over a period of seven working days. During this period, the torches were in continuous use and it was not possible to collect accurate fuel consumption data during only those times when the torches were being demonstrated. However, since the total demonstration time for each torch was approximately one work day, fuel consumption was estimated to be a typical work day's usage which, in the case of the FEMP, is 2.5 gallons of gasoline and a cylinder of oxygen for the oxy-gasoline torch, and one 250-pound cylinder of acetylene and a cylinder of oxygen for the oxy-acetylene torch.

Amortization of Capital Cost of Equipment

Equipment costs were based on the cost of ownership. Hourly equipment rates were calculated using the method outlined in EP 1110-1-8*, Construction Equipment Ownership and Operating Expense Schedule, Region II*, US Army Corps of Engineers, August 1995. The hourly rate for each torch was based on the capital cost of the equipment, a discount rate of 5.6%, equipment life of 10,000 operating hours, and an estimated yearly usage of 1,040 hours. Based on these parameters, the hourly equipment cost of using the torches was estimated to be:

- $0.03 per hour for the Oxy-acetylene torch, and
- $0.09 per hour for the Oxy-gasoline torch.

Cost Conclusions

Mobilization costs were insignificant for both technologies. A technical representative from Petrogen provided the initial training on the use of the oxy-gasoline torch, but this was minimal and, therefore, no training costs were included in the analysis.

The cost of performing D&D work was lower for the oxy-gasoline torch due to its lower fuel cost and its higher productivity.

Neither torch generated secondary wastes other than PPE.

Demobilization costs were insignificant for both torches and were excluded.

Total PPE costs were identical for both torches, however, unit PPE costs were lower for the oxy-gasoline torch because of its higher productivity.

For the demonstrated application, the oxy-gasoline torch offers significant savings over the oxy-acetylene torch. For the material thicknesses cut during the demonstration, the oxy-gasoline torch had significant production rate advantages. Although the two torches performed identically when cutting materials up to 0.5 inches thick, the oxy-gasoline torch was still more cost effective due to its less costly fuel. In addition, as material thickness increased, the production rate of the oxy-gasoline torch relative to the oxy-acetylene torch increased and the payback time decreased.

Table 5 shows the unit cost and production rates for each torch and the pay back time for the capital cost difference between them. Anomalies in the production rate and operating cost trends were due to the differences in the geometry and the accessibility of the components that were segmented.

Table 5. Cost and performance data for the Oxy-acetylene and Oxy-gasoline Torches based on material thickness

Thickness (in.)	≤ 0.5in.	1.0in.	1.75in.	2.0in.	4.5in.**	Overall
Oxy-acetylene Torch						
Capital cost	$299					
Length of Cuts (in)	166.5	35	43	108	4.5	357
Time (min)	45	20	22	49	15	151
Production Rate (in/h)	222	105	117	132	18	142
Unit Cost ($/in)	$0.63	$1.05	$1.18	$1.12	$7.75	$1.19
Oxy-gasoline Torch						
Capital cost	$845					
Length of cuts (in)	166.5	35	43	120	4.5	369
Time (min)	45	14	19	33	5	116
Production Rate (in/h)	222	150	136	218	54	191
Unit Cost ($/in)	$0.62	$0.92	$1.01	$0.64	$2.53	$0.90
Pay-back Time (h) *	246	28	24	5	2	10
Break even point (in)	54,600	4,200	3,212	1,138	105	1,883

* The operating time over which the additional capital cost ($546) of the oxy-gasoline torch will be recovered.

** 4.5 in. diameter axle shaft.

Table 6 and Figure 4 show the major cost drivers associated with using the oxy-gasoline and oxy-acetylene torches for segmenting 2-inch thick steel at the FEMP. Details of the cost elements that comprise each major cost driver are presented in Appendix C. Also shown in Appendix C are detailed listings of the PPE used during the demonstration of each of the two systems.

Table 6. Costs associated with cutting 100 feet of 2-inch carbon steel

Cost Driver	Oxy-acetylene Torch	Oxy-gasoline Torch
Mobilization[1]	$0.00	$0.00
D&D Work		
Labor	$818.18	$495.41
Fuel	$121.18	$20.20
Amortized Capital Cost	$0.27	$0.50
Waste disposal	$0.00	$0.00
Demobilization[1]	$0.00	$0.00
PPE	$408.00	$247.05
Total Cost	$1,347.63	$763.16
Unit Cost ($/in)	**$1.12**	**$0.64**

[1] These are costs that are independent of the quantity of D&D work performed.

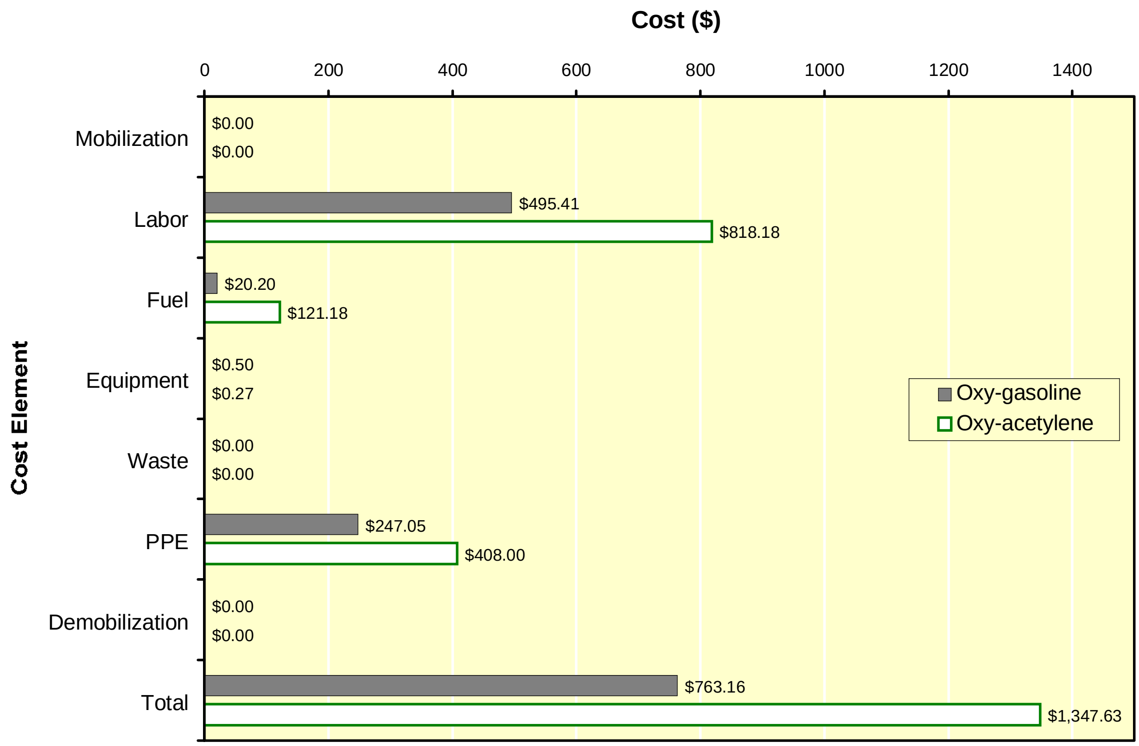


Figure 7. Estimated cost of cutting 100 feet of 2-inch carbon steel with the oxy-gasoline and oxy-acetylene torches.

Cost-Variable Factors

The DOE-Complex presents a wide range of working conditions at each site that directly affect the manner in which D&D work is performed and, consequently, the costs related to each job. The estimates for the technologies presented in this analysis are based on a specific set of factors and conditions found at the FEMP and these are presented in Table 7. This information is provided as an aid to D&D managers and other potential technology users who may need to make appropriate adjustments for differences between the operating conditions at their facilities and those at the FEMP.

Table 7. Summary of cost-variable factors

Cost-Variable Factor	Oxy-acetylene Torch	Oxy-gasoline Torch
Scope of Work		
Total length of cuts made with torch	357 in.	369 in.
Type of material cut	Large carbon steel components of varying thicknesses from 0.5 to 4.5 inches, including a shield wall, a drum crusher, a pulverizer base, and an axle shaft.	
Segmenting criteria	Components were segmented in accordance with the FEMP's waste acceptance criteria (see Appendix D).	
Work Area		
Work area access	Components were segmented in place and lowered using chain rigging. The test area was accessible by forklift for removal of debris.	
Ventilation	Emissions were collected by a vacuum/HEPA filtration system.	
Work Performance		
Work crew size	3	3
Worker training	Both torches were operated by experienced torch cutters. Minimal training was required to familiarize the cutters with the operation of the oxy-gasoline torch.	
Personal protective equipment	Cotton coveralls, hood and booties, Marmak fire-resistant coveralls rubber shoe covers, impermeable saranex disposable suit, nytrile gloves (two pairs), leather welding apron and gloves, full-face respirator and cartridges.	
Production rate: - 1-inch steel - 2-inch steel	105 in/h 132 in/h	150 in/h 218 in/h
Capital cost of equipment	$299	$845 (including gas tank)
Daily Cost of Fuel	Acetylene: 1 @ $32.00/cylinder Oxygen: 1 @ $8.00/cylinder Total: $40.00/day	Gasoline: 2.5 @ $1.20/gallon Oxygen: 1 @ $8.00/cylinder Total: $11.00/day
Equipment decontamination	None required	

SECTION 6

REGULATORY/POLICY ISSUES

Regulatory Considerations

The regulatory/permitting issues related to the operation of the oxy-gasoline torch at the FEMP are governed by 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
  - 1926.102 — Eye and Face Protection
  - 1926.103 — Respiratory Protection

- Occupational Safety and Health Administration (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
  - 1910.132 — General Requirements (Personal Protective Equipment)
  - 1910.133 — Eye and Face Protection
  - 1910.134 — Respiratory Protection

Safety, Risks, Benefits, and Community Reaction

The oxy-gasoline torch cutting system is safer to use and operate than the oxy-acetylene torch. It generates less airborne contamination and poses less risk to workers and the environment. The manufacturer of the oxy-gasoline torch has also gone to great lengths to incorporate extensive safety mechanisms, including redundant systems, into the torch to minimize risks to personnel, the work area and the environment, thereby reducing the potential for liability.

LESSONS LEARNED

Implementation Considerations

The Petrogen oxy-gasoline torch cutting system is a mature technology that performed exceedingly well during the FEMP demonstration, and there are no apparent areas of its performance or design that require improvement.

The operating principles of the oxy-gasoline torch are quite different from those of the oxy-acetylene torch and operators must first be trained to understand these principles and how to use the torch correctly. Particular attention should be paid to:

a) the proper procedures for lighting the torch and adjusting the flame.

b) the optimal placement of the torch tip relative to the material being cut to avoid clogging, overheating and excessive wearing of the tips.

c) establishing the correct pressure in the gasoline tank to compensate for the difference in altitude between the tank and the torch.

Technology Limitations and Needs for Future Development

During the demonstration, the oxy-gasoline torch performed well and did not appear to require any future improvements. It is a fully developed and mature technology that has seen use within the commercial sector, both in the United States and internationally.

Although stainless steel components were not segmented during the demonstration, empirical observations at the FEMP have shown that neither the oxy-gasoline nor the oxy-acetylene torch will readily cut through stainless steel due to its high resistance to oxidation. Both torches will cut through thin stainless steel up to a quarter inch thick mostly by melting through it. At higher thicknesses, however, the oxy-acetylene torch will not cut through most forms of stainless steel, but the oxy-gasoline torch will cut through some forms with varying degrees of success. Neither torch was able to cut cast iron.

Technology Selection Considerations

Based on the FEMP demonstration, the oxy-gasoline torch is better suited than the oxy-acetylene torch for cutting all thicknesses of carbon steel up to 4.5 inches (the boundary of the demonstration). For metal thickness less than 0.5 inches, the oxy-gasoline and oxy-acetylene torches perform comparably, however, the oxy-gasoline torch is still more economical to operate due to the lower cost of gasoline.

The factors that should be taken into consideration in selecting one of these torches are the amount of D&D work to be performed, production rates, the thickness of the metal to be cut, the lower cost of gasoline, and the higher initial cost of purchasing the oxy-gasoline torch. Based on these factors, Table 8 is a projection of the minimum hours of D&D work that would have to be performed to justify purchasing the more expensive oxy-gasoline system over the oxy-acetylene system i.e. the pay-back time. Beyond this time, it is more cost effective to purchase the oxy-gasoline torch.

Table 8. Payback-time for the Oxy-gasoline Torch based on material thickness

Metal Thickness (in.)	≤ 0.5in.	1.0in.	1.75in.	2.0in.	4.5in.
Pay-back Time (h)	246	28	24	5	2

APPENDIX A

REFERENCES

Petrogen International, Ltd., Oxy-gasoline Torch Reference Manual, Richmond, California.

Fluor Daniel Fernald, *Detailed Technology Report for the Oxy-gasoline Torch Technology, Large Scale Demonstration Project*, U.S. Department of Energy's Fernald Environmental Management Project, Cincinnati, Ohio, January 1998.

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

APPENDIX B

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Description
CFR	Code of Federal Regulations
D&D	Decontamination and Decommissioning
DDFA	Deactivation and Decommissioning Focus Area
Decon	Decontamination
DOE	Department of Energy
EP	Environmental Protection
ESH	Environment, Safety and Health
^{o}F	Degrees Fahrenheit
FDF	Fluor Daniel Fernald
FETC	Federal Energy Technology Center
FEMP	Fernald Environmental Management Project
FIU	Florida International University
ft^2	Square feet
H&S	Health and Safety
HCET	Hemispheric Center for Environmental Technology (at Florida International University)
h	Hour
HTRW	Hazardous, toxic, radioactive waste
in.	Inches
ITSR	Innovative Technology Summary Report
lbs	Pounds
LSDP	Large-scale Demonstration Project
OEM	Office of Environmental Management (of the DOE)
OSHA	Occupational Safety and Health Administration
OSDF	On-site disposal facility
OST	Office of Science and Technology
PPE	Personal Protective Equipment
psi	Pounds per square inch
USACE	United States Army Corps of Engineers

APPENDIX C

SUMMARY OF COST ELEMENTS

Table C-1. Breakdown of major cost elements

Fixed Costs

Description	Quantity	Unit	Man hrs	Labor	Equipm't	Materials	Other	Total
Oxy-acetylene Torch	357	in.						
Mobilization	1	ea.	0	$0	$0	$0	$0	$0
Demobilization	1	ea.	0	$0	$0	$0	$0	$0
Total Oxy-acetylene Torch	**357**	**in.**	**0**	**$0**	**$0**	**$0**	**$0**	**$0**
Oxy-gasoline Torch	369	in.						
Mobilization	1	ea.	0	$0	$0	$0	$0	$0
Demobilization	1	ea.	0	$0	$0	$0	$0	$0
Total Oxy-gasoline Torch	**369**	**in.**	**0**	**$0**	**$0**	**$0**	**$0**	**$0**

Variable Costs

Description	Quantity	Unit	Man hrs	Labor	Equipm't	Materials	Other	Total	Unit Cost
Oxy-acetylene Torch	357	in.							
D&D Work	357	in.	9	$265	$0	$41	$	$306	$0.86
Disposal	357	in.	0	$0	$0	$0	$0	$0	$0
PPE	357	in.	0	$0	$0	$0	$120	$120	$0.34
Total Oxy-acetylene Torch	**357**	**in.**	**9**	**$265**	**$0**	**$41**	**$120**	**$426**	**$1.19**
Oxy-gasoline Torch	369	in.							
D&D Work	369	in.	7	$203	$0	$9	$0	$212	$0.57
Disposal	369	in.	0	$0	$0	$0	$0	$0	$0
PPE	369	in.	0	$0	$0	$0	$120	$120	$0.33
Total Oxy-gasoline Torch	**369**	**in.**	**7**	**$201**	**$0**	**$9**	**$120**	**$330**	**$0.90**

Total Cost

Description	Quantity	Unit	Man hrs	Labor	Equipm't	Materials	Other	Total	Unit Cost
Oxy-acetylene Torch	357	in.							
Mobilization	1	ea.	0	$0	$0	$0	$0	$0	$0
D&D Work	357	in.	9	$265	$0	$41	$	$306	$0.86
Disposal	357	in.	0	$0	$0	$0	$0	$0	$0
Demobilization	1	ea.	0	$0	$0	$0	$0	$0	$0
PPE	357	in.	0	$0	$0	$0	$120	$120	$0.34
Total Oxy-acetylene Torch	**357**	**in.**	**9**	**$265**	**$0**	**$41**	**$120**	**$426**	**$1.19**
Oxy-gasoline Torch	369	in.							
Mobilization	1	ea.	0	$0	$0	$0	$0	$0	$0
D&D Work	369	in.	7	$203	$0	$9	$0	$212	$0.57
Disposal	369	in.	0	$0	$0	$0	$0	$0	$0
Demobilization	1	ea.	0	$0	$0	$0	$0	$0	$0
PPE	369	in.	0	$0	$0	$0	$120	$120	$0.33
Total Oxy-gasoline Torch	**369**	**in.**	**7**	**$203**	**$0**	**$9**	**$120**	**$332**	**$0.90**

Table C-2. Personal protective equipment costs and requirements per crew member

Cost Assumptions:

Daily Shift Length:	10 hours
Useful Life of Reusable PPE Items:	200 hours

Reusable PPE - Daily Requirements[1]			Segmentation using an Oxy-acetylene Torch (Baseline)		Segmentation using an Oxy-gasoline Torch (Innovative)	
Item	**Unit Cost**	**Unit**	**Quantity**	**Total Cost**	**Quantity**	**Total Cost**
Cotton coveralls (yellow)	$5.90	ea.	4	$23.60	4	$23.60
Cotton hoods (yellow)	1.16	ea.	4	4.64	4	4.64
Cotton shoe covers (yellow)	1.84	Pair	4	7.36	4	7.36
Leather welding apron	20.00	ea.	1	20.00	1	20.00
Leather welding gloves	7.00	Pair	1	7.00	1	7.00
Full-face respirators	174.00	ea.	4	696.00	4	696.00
Reusable PPE laundry costs[2]	1.39	Load	1	1.39	1	1.39
Hourly Reusable PPE Cost				**$ 3.80**		**$ 3.80**

Disposable PPE - Daily Requirements[3]			Segmentation using an Oxy-acetylene Torch (Baseline)		Segmentation using an Oxy-gasoline Torch (Innovative)	
Item	**Unit Cost**	**Unit**	**Quantity**	**Total Cost**	**Quantity**	**Total Cost**
Tyvek suits	$4.09	ea.	0	$0.00	0	$0.00
Saranex suits	23.77	ea.	0	0.00	0	0.00
Marmak fire-resistant coveralls	3.36	ea.	4	13.44	4	13.44
Cotton glove liners	0.28	Pair	4	1.12	4	1.12
Cotton work gloves	0.54	Pair	0	0.00	0	0.00
Nytrile gloves	0.24	Pair	4	0.96	4	0.96
Rubber shoe covers	12.28	Pair	4	49.12	4	49.12
Rubber boots	29.30	Pair	0	0.00	0	0.00
Ear plugs	0.12	Pair	0	0.00	0	0.00
Ear protectors	18.72	ea.	0	0.00	0	0.00
Respirator cartridges	11.74	Pair	4	46.96	4	46.96
Hourly Disposable PPE Cost				**$11.16**		**$11.16**
TOTAL HOURLY PPE COST				**$ 14.96**		**$ 14.96**

[1]Requires four changes per worker each day. Expected life = 200 hours.

[2]One day's reusable PPE for one crew member is one laundry load. Cost per laundry load is $1.39. Data provided by Fluor Daniel Fernald.

[3]Requires four changes per worker each day. Expected life = 10 hours (the length of one shift).

WASTE ACCEPTANCE CRITERIA FOR DISPOSAL OF DEBRIS IN THE FEMP'S ON-SITE DISPOSAL FACILITY

Debris Category	**Maximum Dimensions**			**Other**
	Length (ft)	**Width (ft)**	**Height (ft)**	
General criteria for all categories of debris	10	10	1.5	Maximum height = 1.5 ft. including projections. No dimension greater than 10 ft. including projections. No void spaces greater than 1 ft^3.
Accessible metals	10	4	1.5	
Inaccessible metals	10	4	1.5	
Painted light gauge metals	10	4	1.5	
Concrete	6	4	1.5	
Non-regulated asbestos containing material	8	4	1.5	Bundled stacks.
Regulated asbestos containing material	10	4	1.5	Maximum volume per piece = 27 ft^3 Pipes with diameter of 12 in. or more must be segmented so that no piece is greater than 12 in. in height.
Miscellaneous materials	8	4	1.5	All miscellaneous materials must be compacted.

APPENDIX E

CURRENT USERS OF THE OXY-GASOLINE TORCH (AS OF APRIL 30, 1998)

Deployment Site	**Number of units**
AEA Technology PLC, Cumbria, United Kingdom	1
American Electric Power, Waterford, Ohio	1
B&W Services Inc., Fernald Plant 4 D&D Project, Fernald Ohio	1
B&W Services Inc., Waterford, Ohio	1
Bechtel, Hanford, Washington	1
Defense Nuclear Agency, Russia	100
Fluor Daniel Fernald, Fernald, Ohio	4
General Public Utilities, Three-mile Island, Pennsylvania	1
Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho	1
Laguila Construction Co., Brooklyn, New York	1
Lockheed Martin Energy Systems, Oak Ridge, Tennessee	2
Mason & Hanger, Pantex Nuclear Plant, Amarillo, Texas	2
National Cleaning services, Fernald Plant 9 D&D Project, Fernald Ohio	1
Nuclear Waste Recyclers, Memphis, Tennessee	1
RMI, Ashtabula, Ohio	1
US Ecology, Oak Ridge, Tennessee	1
Total	**120**