FINAL REPORT

DECONTAMINATION OF EXPLOSIVES-CONTAMINATED RANGE SCRAP USING A TRANSPORTABLE HOT GAS DECONTAMINATION SYSTEM

U.S. Army Environmental Center
U.S. Army Aberdeen Test Center
Parsons Corporation

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List of Acronyms

AAP	Army Ammunition Plant
ABR-9	Air Base Range 9
AD-3	Ammunition Dump 3
AEC	Army Environmental Center
AEDA	Ammunition, Explosives, and Dangerous Articles
APG	Aberdeen Proving Ground
ATC	Aberdeen Testing Center
ATIRS	Automated Test Incident Reporting System
BCS	burner control system
BRAC	Base Realignment and Closure
BRACO	BRAC Office
CAA	Clean Air Act
CCTV	closed circuit television
CEM	continuous emissions monitor
C&P	Cost and Performance
COTS	commercial off-the-shelf
CRREL	Cold Regions Research and Engineering Laboratory
CTT	Closed, Transferred, and Transferring
DoD	Department of Defense
DRMO	Defense Reutilization and Marketing Office
DSHE	Directorate of Safety, Health, and Environment
ECP	Explosives Contaminated Property
ECAM	Environmental Cost Analysis Method
ESTCP	Environmental Security Technology Certification Program
FUDS	Formerly Used Defense Sites
IDL	Instrument Detection Limit
IG	Inspector General
GC/MS	gas chromatograph/mass spectrometer
HGD	hot gas decontamination
HMX	Octahydro-1,2,5,7-tetranitro-1,3,5,7-tetrazocine
HQDA	Headquarters Department of the Army
HPLC	high performance liquid chromatography
IDL	instrument detection limit
I/O	input/output
IOC	Industrial Operations Command
IOP	Internal Operating Procedures
IPR	In-Process Reviews
JHA	Job Hazard Analysis
LCS	laboratory control sample
MDE	Maryland Department of Environment
MHE	material handling equipment
MMR	Military Munitions Rule
MPPEH	Material that Presents the Potential for Explosives Hazard

MSDS	Material Safety Data Sheets
NAAQS	National Ambient Air Quality Standards
NEMA	National Electric Manufacturers Association
NIST	National Institute of Standards and Technology
NFPA	National Fire Protection Agency
NO_x	oxides of nitrogen
OEESCM	Operational and Environmental Executive Steering Committee
OW	operator workstation
PAHs	polycyclic aromatic hydrocarbon compounds
PETN	Pentaerythritol tetranitrate
PLC	programmable logic controller
$PM_{2.5}$	particulate matter with an aerodynamic diameter less than or equal to 2.5 microns
PM_{10}	particulate matter with an aerodynamic diameter less than or equal to 10 microns
PPE	personal protective equipment
QA	quality assurance
QAPP	Quality Assurance Project Plan
R3	Resource Recovery and Recycle
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
REC	Record of Environmental Consideration
RPD	relative percent difference
SOP	standard operating procedure
SSHSP	Site-Specific Health and Safety Plan
SVOC	Semi-volatile organic compounds
TCLP	Toxic Characteristic Leaching Procedure
TIR	Test Incident Report
TNT	Trinitrotoluene
TSOP	Temporary Standing Operating Procedures
USAEC	U.S. Army Environmental Center
USAGAPG	U.S. Army Garrison Aberdeen Proving Ground
USEPA	U.S. Environmental Protection Agency
UXO	unexploded ordnance
VOC	volatile organic compounds
Yellow D	Ammonium Picrate

1.0 INTRODUCTION

This report documents the results of the field demonstration of a transportable hot gas decontamination (HGD) system for decontamination of explosives-contaminated range scrap. Under management of the U.S. Army Environmental Center (USAEC), a low-cost HGD process configuration was selected by the Environmental Security Technology Certification Program (ESTCP) for full-scale demonstration of field decontamination of explosives-contaminated range residue at the U.S. Army Aberdeen Test Center (ATC), located on Aberdeen Proving Ground (APG), Maryland. In addition to funding by ESTCP, additional financing has been provided by the USAEC to perform this field demonstration. This report documents the performance of the decontamination system, provides design and operational details and performance of the materials and equipment, and provides a performance assessment of operational data, including air emissions monitoring and test coupons.

1.1 BACKGROUND

The Department of Defense (DoD) has numerous target, bombing, test, and firing ranges that have accumulated a substantial amount of high-value recyclable scrap metal in the form of ammunition, explosive, and dangerous articles (AEDA), range residue, Explosives-Contaminated Property (ECP), and Materials that Present the Potential for Explosive Hazard (MPPEH). This scrap metal includes practice bombs, expended artillery, small arms and mortar projectiles, aircraft bombs and missiles, rockets and rocket motors, hard targets, grenades, incendiary devices, experimental items, demolition devices, and other materials fired on or upon a military range (See Figure 1.1-1). These articles include various expended primers, flash tubes, stub bases, and other items and present a unique problem to generating activities. This material is collected in range sweeps and removal operations at active and inactive ranges, and unexploded ordnance (UXO) removal operations at Closed, Transferred, and Transferring (CTT) sites. Contrary to popular belief, these items often have explosives residue after detonation. Explosive incidents involving scrap metal from training and firing ranges have occurred over the years and recently have come under close scrutiny.

A safe, environmentally conscious alternative to decontaminate firing range scrap is a low-temperature thermal desorption process called the hot gas decontamination (HGD) technology developed by the U.S. Army Environmental Center (USAEC). The HGD technology uses controlled heat to volatilize and thermally decompose the explosives contamination. A low-cost HGD process configuration was demonstrated in which the scrap metal is placed in piles and covered with an insulated thermal blanket. Propane-fired portable burners inject heat at a controlled rate to meet the time and temperature criteria (up to 600°F for up to a 6-hour holding time), to reach a decontamination level which can be certified as inert. Range residue has not previously been decontaminated in this manner. Although not used on range residue, many Army facilities have flashed range scrap to make it safe for sale before the range residue problem developed. Although this method did not use propane as the heat source, the use of wood or petroleum-based fuel was used to heat-treat metal scrap.

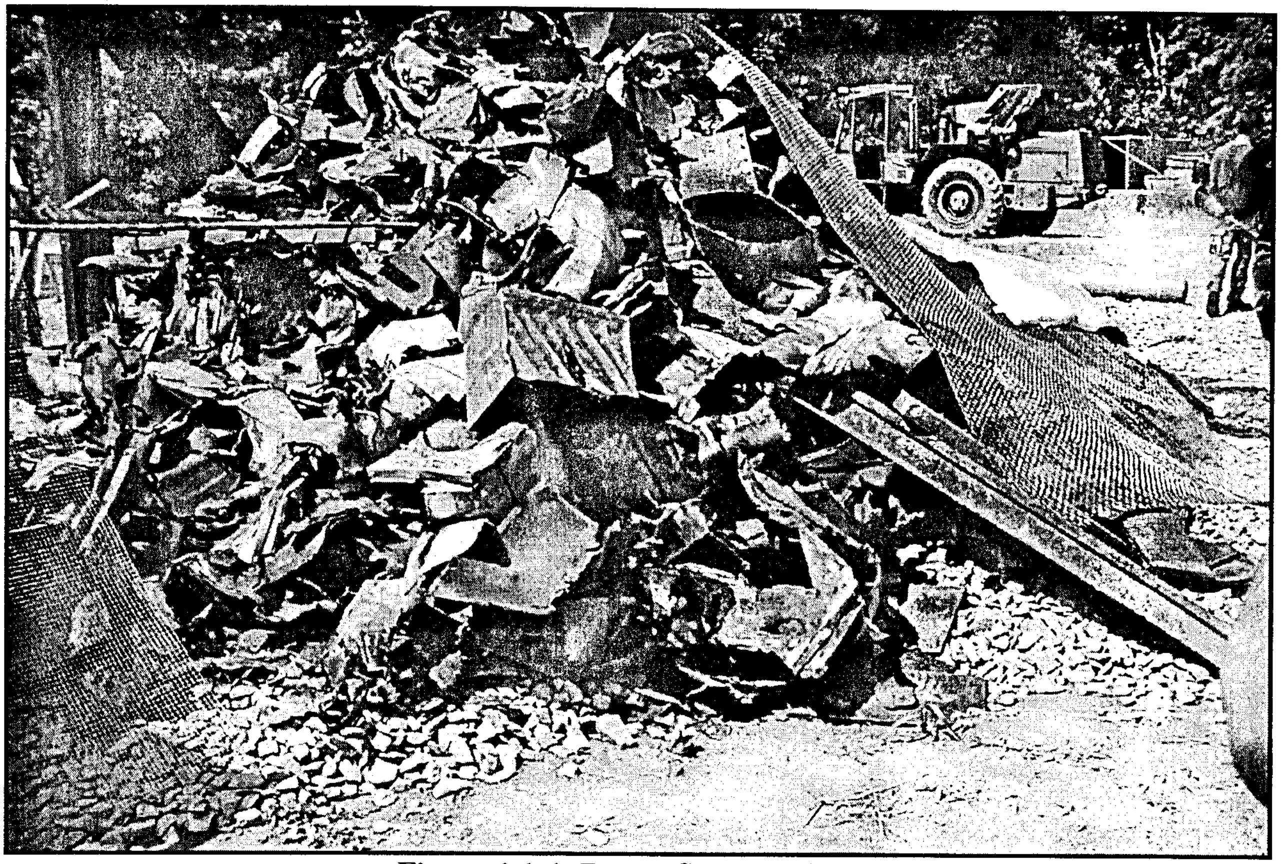

Figure 1.1-1 Range Scrap at ATC

1.2 OBJECTIVE OF THE DEMONSTRATION

The objective of this project is to demonstrate the safe and effective decontamination of range scrap materials at the lowest possible cost. Using commercially available equipment and materials, this project demonstrated an effective, safe, temporary, and portable hot gas system for decontaminating explosives-contaminated range scrap materials. Currently, the high costs associated with establishing and maintaining permanent hot-gas decontamination structures has made the technology unattainable for many installations. This project implements the HGD technology at APG using the design criteria developed by USAEC and Parsons, as detailed in the technical report "Design Guidance Manual for Low Cost Disposable Hot Gas Decontamination System for Explosives-Contaminated Equipment and Facilities," November 1998[1].

1.3 REGULATORY ISSUES

The promulgation of the U.S. Environmental Protection Agency (USEPA) Military Munitions Rule has brought a new focus to the topic of range scrap removal on active, inactive, and Closed, Transferred and Transferring (CTT) ranges.

Range scrap is high value metal and an outstanding resource for recycling. As such, if recycled the range scrap falls into the RCRA exemption for recycling (i.e. it is not a RCRA waste if recycled). These means that that a range scrap demilitarization system should not fall under the RCRA generator rules or the RCRA Treatment, Storage, and Disposal rules.

Explosives contamination from range residue potentially can leach into the soil, surface water, and groundwater during rainfall on military firing ranges. Soil erosion around blast holes caused by detonations can accelerate and magnify this effect. Without decontamination of the range residue, the explosive-contaminated scrap has historically been shipped to scrap recyclers, with potential for more spread of explosive contamination on transport trucks and to soil and water at outdoor recyclers' scrap yards.

Previous demonstrations of HGD technology used an off-gas treatment system to treat volatilized emissions. Generally speaking, it is the off-gas treatment system which is very expensive and drives the overall system cost upwards. The off-gas treatment system typically can be 25 to 40 percent of the overall system cost. As a one-time decontamination action, off-gas treatment is not an absolute requirement by regulators at all locations. This was demonstrated by recent (1996) permission by the Oregon Department of Environment Quality[2] to open burn (flash flame) the Explosives Washout Building at Umatilla Chemical Depot, Umatilla, Oregon without emissions control or treatment. The requirement for an off-gas treatment system must be evaluated on a case-by-case basis considering the site location and distance away from populated areas and off-site receptors, and local and state regulatory standards. Environmental permitting requirements, emissions limitations, and monitoring (continuous or intermittent) requirements will be determined on a case-by-case basis. Use of emissions estimates, air modeling, and fate and transport models may be used to make a case for HGD with no off-gas treatment. Operational controls (such as wind speed and direction restrictions) can be placed on the system to further promote the concept of HGD processing without off-gas treatment. For example, in a remote location with a reasonable regulatory oversight and no nearby receptors, a HGD system with no off-gas treatment may be judged acceptable as a quick, low-cost method to remove contamination.

1.4 DOD POLICY ISSUES

A recent DoD Range Sustainability initiative has placed urgency on maintenance of active and inactive ranges, including detection and removal of ordnance and explosives (and range residue). Also, there is an immediate need for clearance and removal of firing range scrap at Base Realignment and Closure (BRAC) sites and Formerly Used Defense Sites (FUDS) sites, where public use and redevelopment priorities, and other economic issues such as ongoing maintenance, security, and care-taking costs are driving factors. Some ranges from BRAC '88 are still not fully cleaned up, and there is great incentive for DoD to clean up and close these ranges prior to the next round of base closures (preliminarily planned for 2005).

The disposal of range residue has recently been a matter of heightened interest among Congress and DoD officials. Each year, the Services expend more than 200,000 tons of munitions. In the Department of Defense Office of the Inspector General (DoD IG) Audit, "Review of Policies and Procedures Guiding the Cleanup of Ordnance on DoD Lands"[3], DoD IG reported that expended ordnance and explosive waste cleanup requirements and guidance developed by DoD and the Military Departments were incomplete, vague, and inconsistent.

Three years later, the Office of the Secretary of Defense requested the Inspector General, DoD, to evaluate the munitions disposal process after a commercial scrap worker was killed by a live anti-tank munitions shell. DoD IG responded with a separate audit entitled "Evaluation of the Disposal of Munitions Items" (Report No. 97-213, September 5, 1997)[4]. The primary objective was to determine whether DoD procedures and controls adequately ensured the safe disposal of ammunition, explosives, and other dangerous articles (AEDA) residue. The audit specifically evaluated the adequacy of the policies, procedures, and management controls associated with the disposal of DoD managed munitions. The audit report contained 25 separate recommended actions and concluded that the DoD needs to improve management controls to prevent public access to live AEDA. Specifically, DoD controls for the disposal of AEDA residue by the Military Departments were ineffective. As a result, the public was sold or had access to either discarded live AEDA or AEDA residue that had not been properly certified as inert. Management controls at the Defense Reutilization Marketing Service to prevent the sale of live AEDA to the public were not fully effective. As a consequence, Defense Reutilization and Marketing Offices received and sold uncertified and improperly certified and stored AEDA residue to the public. DoD policies and procedures for AEDA disposal contracts, Direct Sales Programs as part of the Qualified Recycling Programs, reporting and investigating AEDA incidents, and demilitarization were inadequate. As a result, AEDA disposal service and sales contracts varied by installations and included disparate levels of safety and oversight.

A follow-up audit, "Disposal of Range Residue" (Report No. D-2000-170 August 4, 2000)[5], revisited the status on the recommended actions of the 1997 audit report by reviewing current operations at eight military installations and their servicing Defense Reutilization and Marketing Offices. To address recommendations in Report No. 97-213, the Under Secretary of Defense for Acquisition, Technology, and Logistics convened a review team. A draft report contained recommendations to improve the disposal process, but did not contain standard DoD-wide guidance for managing the disposal of range residue, as recommended in the 1997 report. In early FY 2000, the Under Secretary directed a far-reaching and comprehensive review of munitions by the Operational and Environmental Executive Steering Committee for Munitions (OEESCM). The objective was to determine whether the Services were disposing range residue in a safe manner. Specifically, the adequacy of the policies, procedures, and management controls associated with the disposal of range residue generated on DoD terrestrial firing ranges. DoD IG recommended that the Under Secretary of Defense for Acquisition, Technology, and Logistics have the OEESCM address the policy and procedural weaknesses and develop implementing guidance. As a result of the findings of the DoD IG audit, the Office of Deputy Under-Secretary of Defense for Installations and Environment is currently preparing an instruction for handling and disposition of Material that Presents a Potential for Explosives Hazards (MPPEH). A draft DoD instruction for handling and disposal of MPPEH is under preparation by an OEESCM subcommittee and planned for issue in 2002.

1.5 SAFETY ISSUES

The uncertainties associated with certification by visual inspection present unacceptable risk to human health for inspectors, range personnel removing scrap, and to transporters and commercial recyclers. In the past several years, explosive incidents involving scrap metal from firing ranges have occurred during handling operations, resulting in death or serious injuries, and forcing the DoD to review current scrap metal disposal practices. The advantage of remote operation of the HGD system as demonstrated lowers risk to range workers in the event of explosive incident, and eliminates off-site risk to the general public, including commercial recyclers.

1.6 PREVIOUS TESTING OF THE TECHNOLOGY

The HGD technology is well developed and supported by considerable research and demonstration. The USAEC began conducting bench-scale studies in the late 1970s to evaluate HGD technology for treatment of equipment, piping, metallic debris, and building materials contaminated with both explosive materials and chemical warfare agents. Successful pilot studies were followed by demonstration testing to define and refine the performance parameters. HGD technology is now available for field implementation and treatment of installations contaminated with explosive materials or chemical warfare agents.

HGD technology was developed and demonstrated as follows:

- In 1987, a pilot-scale study[6] for HGD technology using samples spiked with chemical warfare agent was conducted at Dugway Proving Ground, Utah. This controlled study successfully demonstrated the ability of the HGD technology to decontaminate agent from concrete and steel.
- Based on these results, pilot-scale tests[7] using the HGD technology to treat contamination with explosive materials were conducted at the Cornhusker Army Ammunition Plant in 1989. The Cornhusker test results indicated that the HGD technology seemed to be effective, but more studies were needed for application to explosive materials.
- Successful pilot-scale tests[8] were conducted in 1990 at Hawthorne Army Ammunition Plant for equipment, piping, and metal debris, including shell casings, contaminated with explosive materials. These studies defined HGD parameters for treatment of materials contaminated with explosive materials.
- Additional demonstration studies[9] were conducted in 1994 at Hawthorne for explosives contained within munitions, such as ship mines, depth bombs, and 106-mm and 5-inch projectiles. These latter Hawthorne results were successful, but indicated that equipment optimization should be further explored for explosive munitions applications.
- In 1994, a field demonstration[10] of HGD technology for facility and process equipment was successful in treating chemical warfare agent contamination at the Rocky Mountain Arsenal. This field demonstration provided HGD performance parameters for decontamination of former chemical agent installations.
- In 1995, validation testing for optimization of equipment using HGD technology for treatment of piping and debris contaminated with explosive material was conducted at the Alabama Army Ammunition Plant[11,12]. This validation testing provides HGD performance parameters for decontamination of former explosive materials installations.

Previous demonstrations of the technology have proven it effective both *in situ* (Cornhusker, Nebraska and Rocky Mountain Arsenal, Colorado) and *ex situ* by placing dismantled equipment and scrap metal in a furnace (Hawthorne, Nevada and Alabama Army Ammunition Plant, Alabama). The Hot Gas Decontamination technology has been proven effective in decontaminating explosives contamination for the following types of explosive materials:

- 2,4,6-Trinitrotoluene (TNT),
- Ammonium picrate (Yellow D),
- Royal Demolition Explosives or Research Department Explosives (RDX),
- Composition A-3 (RDX and wax),

- Composition B (TNT, RDX and wax),
- Tetryl,
- Smokeless Powder (Nitrocellulose/Nitrogylcerin), and
- HBX (TNT, RDX, aluminum, lecithin, and wax).

2.0 TECHNOLOGY DESCRIPTION

2.1 DESCRIPTION

The HGD technology was developed by the U.S. Army Environmental Center (USAEC), Aberdeen Proving Ground, Maryland as an environmentally safe alternative to decontaminate equipment (scrap metal) and buildings contaminated with explosives or chemical agents. The HGD process uses low temperature heat (500 to 600°F) to volatilize and decompose explosives residues in contaminated range scrap metal. Hot burner gas directly contacts the contaminated materials to elevate its temperature. The effectiveness of the process is both time and temperature dependent. Holding times between 1 and 6 hours have been shown to be effective at the prescribed soak temperature. Volatilization is the primary decontamination mechanism, but some in-place decomposition also takes place. Because of the type and character of the constituents of the off-gas, at some sites it may be necessary to contain, collect, and further treat the gaseous discharge to meet environmental regulatory stipulations.

The HGD System demonstrated in this test is a gas-fired burner system heating a pile of explosives-contaminated range residue covered by an insulation blanket as shown in Figure 2.1-1. The HGD system requires a heat source, thermal insulation and supports, a thermocouple array, a data acquisition system, a power supply, and a basic control system. This system can provide a heat-soak to the target contaminated area at a temperature of 500 to 600°F. This is inherently a low-cost method to decontaminate piles of explosives-contaminated scrap metal.

This configuration of the HGD system is applicable to piles of range scrap that are typical in size that may be found or that may be readily constructed on active ranges. A process schematic of the HGD system in the pile configuration as demonstrated is shown in Figure 2.1-2. An air heater is used to heat the pile of range residue. A standard air heater fueled by propane was used for process heating. To minimize heat losses and maintain heat in the scrap pile, fire-resistant thermal fabric and insulation is draped over equipment and pipe to contain the hot air. The thermal blanket is supported and held down by welded wire mesh to protect it from damage or displacement by wind.

Emissions from the HGD process vent around the edges of the thermal blanket at the base of the pile, through seams in the thermal blanket, and permeate through the blanket fabric. An extensive network of continuous air monitors was used to monitor the ambient air quality in the vicinity of the pile during demonstration test operations.

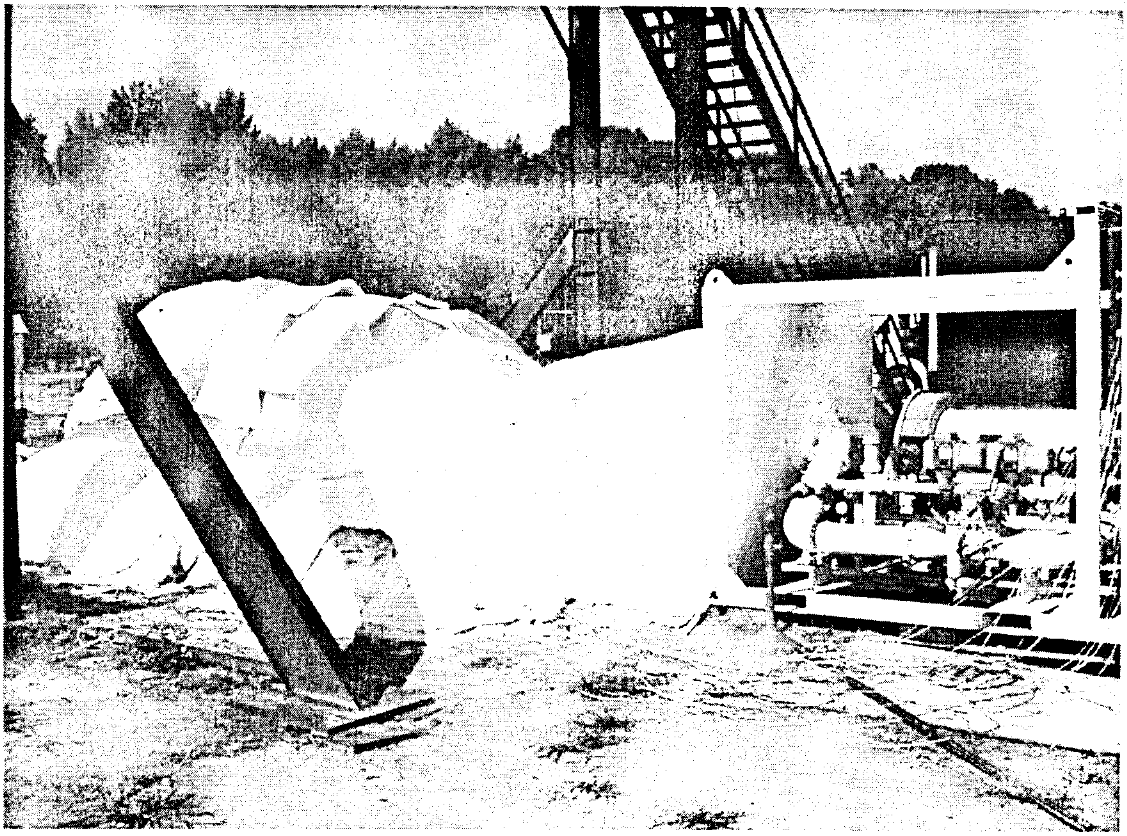

Figure 2.1-1 – Transportable Hot Gas Decontamination System and Insulation Blanket

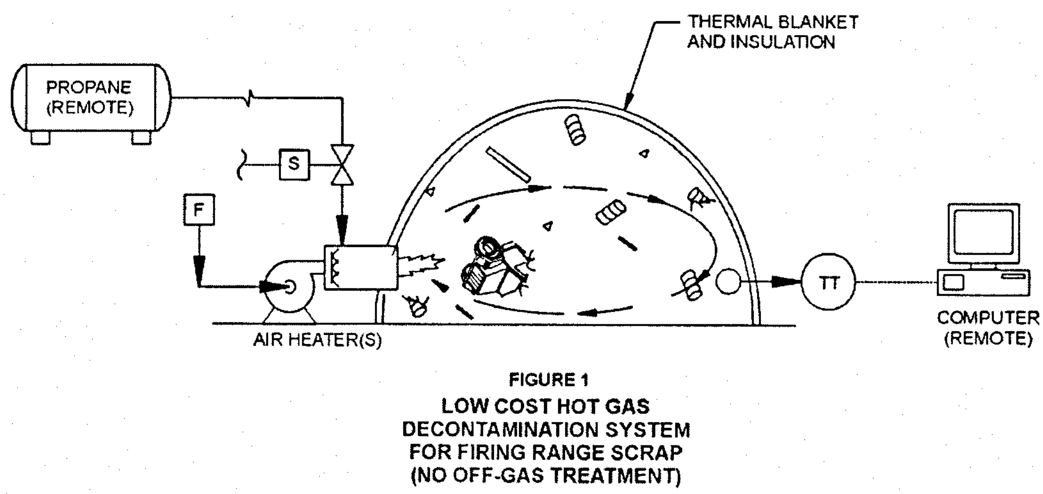

Figure 2.1-2 Process Schematic

Thermocouples with temperature transmitters are interlocked to the air heater fuel supply to control the programmed soak temperature of the scrap metal in the pile. The thermocouples are strategically placed at expected cooler locations (near the outside of the pile away from the burners). During heat up, the thermocouples indicate when their location has met the specified temperature criteria, and the heat soak can commence. When all of the thermocouples reach the soak temperature for the specified time, the decontamination process is complete.

The thermocouple signals are transmitted to a remote control station for recording and decision-making. Twelve thermocouples were used for the demonstration. A simple control process is employed for ease of operation and installation. Instrumentation is configured for remote read-out, with local read-out being used only for set up and test. Electrical power is provided by a leased diesel generator and fuel tank.

2.1.1 Design Criteria and Details

FUNCTIONAL DESIGN REQUIREMENTS

Based on the knowledge and experience gained from the field demonstrations, the following functional requirements ensure the cost-effective implementation of the HGD process:

- The system effectively meets decontamination requirements while ensuring the health and safety of workers and the general public, and protection of the environment;
- Regulatory agency approval and required permits are obtained. Ambient air monitoring is conducted as required to meet regulatory requirements. Monitoring requirements are developed on a case-by-case basis as required by the local regulatory agency;
- The system uses locally available stock items, standard equipment, and expendables and standard disposable materials of construction to minimize cost;
- Use of leased and/or disposable equipment for one-time use and short project life;
- Applicable to range residue that is free from live munitions; and
- Labor and utility requirements are minimized as much as possible.

PERFORMANCE CRITERIA

Previous demonstrations of the HGD technology explored the temperature-time relationship necessary for achieving 5X-equivalent decontamination of explosives-contaminated equipment and facilities. In accordance with Headquarters Department of the Army Technical Bulletin 700-4[14] "5X (XXXXX) level of contamination indicate that facilities and equipment have been completely decontaminated, are free of hazard, and may be released for general use or the general public", for facilities and equipment exposed to potential ammunition, explosives and explosives residue contamination. The HGD technology process utilizes low-temperature heat to decontaminate scrap metal that are contaminated with explosives. Under the heated conditions, the explosives residues in the material are volatilized or thermally degraded in place. Decontamination of the scrap metal is accomplished by maintaining the soak temperature over the specified time period required to meet the decontamination levels.

Results from tests at Hawthorne Army Depot[9] indicate a temperature between 550°F and 600°F for a six-hour soak was required. Test results from Alabama Army Ammunition Plant[11,12] indicate the optimum operating conditions for achieving complete destruction of TNT, RDX, tetryl, and their breakdown constituents (i.e., to levels below method detection limits) were 600° F with a one-hour soak. The current project further established time and temperature performance criteria that are reported in Section 5, Performance Assessment, of this report.

BURNER AND FUEL SYSTEM

The burner system is a skid-mounted assembly complete with combustion air fan, control panel, and burner shroud to direct the heat into the pile, as shown in Figure 2.1-3. The burner is placed adjacent to the pile but not directly contacting the pile (or in the pile). Hot burner gas is directed into the pile through the shroud. High temperature thermal insulation is draped around the burner shroud and onto the scrap pile to provide a seal around the burner interface with the scrap pile. The insulation is supporting by stainless steel wire mesh that stretches from the burner shroud to the pile and down to the ground. The burner interface is configured such that the burner flame is not permitted to contact the scrap from the pile or the insulation.

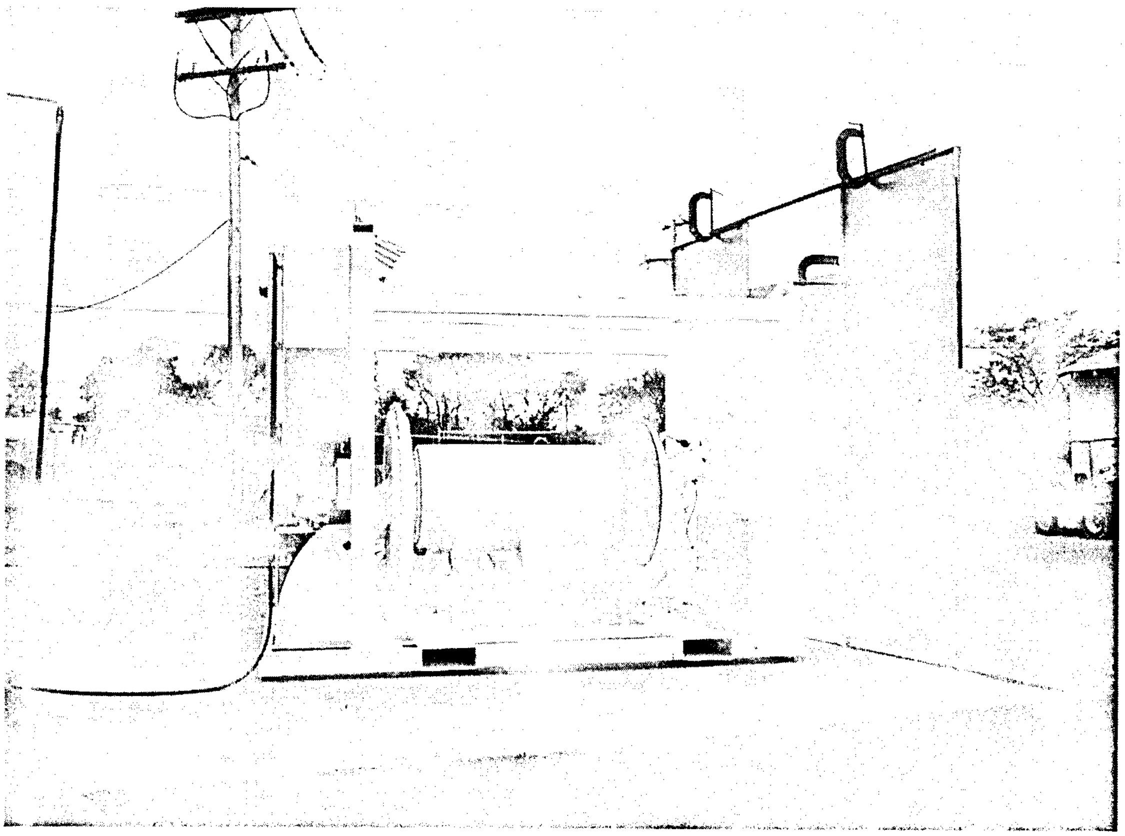

Figure 2.1-3 – Burner Assembly and Skid

The burner operates on propane gas with a maximum fuel usage of 1000 cu. ft./hr. The burner capacity is 2,500,000 BTU per hour, with a turn-down capability of 8:1 minimum. Temporary propane storage tanks are located approximately 100 feet from the pile (and burner) and are armor shielded. Propane from the tanks is supplied to the burner in a temporary configuration, using aboveground flexible hose.