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U.S. Army Toxic and Hazardous Materials Agency

Task Order - 2
Pilot Test of Hot Gas Decontamination of Explosives-Contaminated Equipment at Hawthorne Army Ammunition Plant (HWAAP) Hawthorne, Nevada

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19. ABSTRACT FOR THE HAWTHORNE ARMY AMMUNITION PLANT

This report outlines the operational aspects of a pilot study which evaluated the feasibility of Hot Gas Decontamination of Exposives-Contaminated Equipment. Nine test runs were conducted to evaluate the effectiveness of the Hot Gas Treatment on test items contaminated with TNT; one test run was conducted to evaluate ammonium picrate. Test conditions were set up in a matrix format. Three temperatures were evauated: 400°F, 500°F, and 600°F. The duration of each test evaluating TNT was 6 hours 12 hours, 24 hours, or 36 hours (after reaching steady state). A residence time of 48 hours was used for evaluation of ammonium picrate-contaminated test items. Stack testing was conducted to determine the destruction and removal efficiency (DRE) of the process for TNT.

The results of the pilot study indicate that a minimum temperature of 500°F and a residence time of 6 hours are required to effectively decontaminate test items contaminated with TNT. Operating conditions of 600°F for 48 hours are sufficient to treat items contaminated with ammonium picrate. Conditions apply to the system at HWAAP. Should modifications be made to the system to increase the overall efficiency, these conditions will change. Stack test results indicate that the DRE for TNT exceeds 99.99 percent when sufficient levels are emitted from the flash chamber.

Based on results of the pilot study, test items that are treated for 6 hours at a minimum temperature of 500°F are safe for public release as scrap. Items treated in the prescribed manner are not considered characteristically hazardous and are appropriate for disposal or potentially for resale as scrap.

Treated test items constructed of steel and aluminum that have no intricate or mechanical components should be appropriate for reuse in manufacturing or handling operations. Treated test items that are constructed of steel or aluminum and contain intricate or mechanical components would not be appropriate for reuse. Treated test items constructed of clay will be too severely altered and would not be appropriate for reuse of any kind.

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GLOSSARY

AP - Aluminum Pipe
Btus - British thermal units
CAAP - Cornhusker Army Ammunition Plant
CEM - Continuous Emission Monitor
CFR - Code of Federal Regulations
CO - Carbon Monoxide
CO_2 - Carbon Dioxide
CP - Clay Pipe
DNB - 1,3-Dinitrobenzene
2,4-DNT - 2,4-Dinitrotoluene
2,6-DNT - 2,6-Dinitrotoluene
DRE - Destruction and Removal Efficiency
DZB - Day and Zimmerman/Basil
EPA - Environmental Protection Agency
FID - Flame Ionization Detector
HWAAP - Hawthorne Army Ammunition Plant
HMX - Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
ID Fan - Induced Draft Fan
M - Motor
NB - Nitrobenzene
NDIR - Nondispersive Infrared Gas Analyzer
NO_x - Nitrous Oxides
O_2 - Oxygen
PB - Powder Boxes
PLC - Programmable Logic Controller
QA/QC - Quality Assurance/Quality Control
RDX - Hexahydro-1,3,5-trinitro-s-triazine
RE - Removal Efficiency
SHR - Steam Heated Risers
SHV - Steam Heated Valves
SM - Ship Mine
SP - Steel Pipe
SSR - Shell Support Rack

Tetryl - 2,4,6-Trinitrophenylmethylnitramine
THC - Total Hydrocarbons
TNB - 1,3,5-Trinitrobenzene
TNT - 2,4,6-Trinitrotoluene
T2 - Test Run 2
USATHAMA - United States Army, Toxic and Hazardous Materials Agency

SECTION 1

EXECUTIVE SUMMARY

The manufacture, handling, and loading of explosives at Army industrial facilities have resulted in the contamination of process equipment (piping, pumps, motors, powder boxes, etc.) and sewer systems. Because of this residual contamination, many process items cannot be reused or be disposed as scrap. Contaminated sewer lines are also a disposal problem after they are excavated.

The U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) is investigating technologies to effectively treat explosives-contaminated components. Previous pilot studies have shown that decontamination of structural components is possible using a heated gas to thermally decompose or volatilize explosives with subsequent incineration in an afterburner. To determine the feasibility of hot gas decontamination of explosives-contaminated equipment, a pilot study was conducted at the Hawthorne Army Ammunition Plant (HWAAP) from 10 July 1989 to 21 September 1989.

The primary objective of the pilot study was to determine the operating conditions that effectively decontaminate explosives-contaminated equipment. The major explosive and propellant compounds evaluated during the pilot study included 2,4,6-trinitrotoluene (TNT), ammonium picrate (yellow D), and smokeless powder (nitroglycerin (NG) and nitrocellulose (NC)).

The process equipment used during the pilot investigation was supplied by the government and consisted of an air preheater, flash chamber, and afterburner. Ten test runs were conducted: nine tests evaluated the feasibility of the process on TNT and smokeless powder; one test run evaluated ammonium picrate. The operating conditions of the test runs were selected to form a temperature-residence time matrix. Three temperatures were evaluated: 400°F, 500°F, and 600°F. The duration of tests evaluating TNT decontamination was 6 hours, 12 hours, 24 hours, or 36 hours (after reaching steady state). A residence time of 48 hours was used for evaluation of ammonium picrate; this extended residence time (and a temperature of 600°F) was selected to ensure the decontamination process would be complete and to avoid potential safety problems associated with partially decomposed ammonium picrate (picric acid).

To demonstrate the destruction and removal efficiency (DRE) of the process, stack testing was conducted at the afterburner inlet and outlet. Stack tests were conducted during the first three test runs for explosives and smokeless powder.

The following conclusions are drawn from the pilot study:

- The hot gas process is effective for treating items contaminated with TNT and ammonium picrate.

- Analytical results indicate that temperature is a key factor in explosives removal. It was determined that a minimum temperature of 500°F is required to remove TNT below measurable levels on the treated test items. Since relatively large temperature gradations were evaluated (±100°F), the minimum effective operating temperature may lie somewhere between 400°F and 500°F.

- Test items that are treated for 6 hours at a minimum temperature of 500°F are not characteristically hazardous and are appropriate for disposal or potentially for resale as scrap.

- Items with contamination on external surfaces were generally the least difficult to treat; three failures were observed (one failure was associated with soil/debris in clay pipe). Test items with contamination on internal surfaces or within porous media proved to be more difficult to treat. Although three test items were observed to fail, residual concentrations were generally higher.

- Calculations completed to determine the length of time required for test items (steel) to achieve a steady state temperature of 500°F indicate that the mass of test items only has a moderate effect on the total time required for treatment. A minimum system heatup time of 1 hour should be sufficient during normal operation to allow subject items to reach temperatures appropriate for steady state operations to commence.

- Based on the analyses from sampling at the flash chamber outlet, TNT was primarily removed from test items during the heatup period; however, removal continued throughout steady state operation and possibly into the cooldown period.

- Generally, items constructed of steel or aluminum showed no signs of damage due to treatment. For clay, however, exposure to the hot gas resulted in cracks throughout the entire pipe sections. The clay became very brittle and was easily broken.

- Treated test items that are constructed of steel or aluminum and have no intricate or mechanical components should be appropriate for reuse in manufacturing or handling operations.

- Treated test items that are constructed of steel or aluminum and contain intricate or mechanical components would not be appropriate for reuse. These items should be disposed as scrap.

- Based on a limited statistical model developed for the hot gas system at HWAAP, the heatup/steady state temperature should be at least 440°F to have better than a 50 percent probability of successful decontamination. Predicted temperatures for 85 percent and 95 percent probability of successful decontamination are 480°F and 490°F, respectively.

- Operating conditions of 600°F, coupled with a steady state time of 48 hours, were found to be effective for reducing levels of ammonium picrate below detection limits. Optimum conditions may include lower temperatures and/or decreased residence times.

- Due to the limited testing on smokeless powder and the variability in pre-test item contamination, it is not possible to analyze trends in the data for smokeless powder.

- The sampling and analytical methods employed for determination of smokeless powder emissions in the stack gases (and presence of smokeless powder on test items) were determined to be inappropriate. The method did not allow NC and NG to be distinguished from one another or from other nitrated esters. The stack sampling protocol was also questionable; the sampling media may not have captured NC and NG.

- During each test, a phenomenon consistent with autoignition was observed for the bulk explosives contained in the clay pipe.

- The gas phase heat transfer coefficient for the hot gas system was calculated to range from 1.17 Btu/hr ft^2 °F to 1.82 Btu/hr ft^2 °F.

- The thermal conductivity constant (K) for the composite flash chamber wall was determined to average 5.10 Btu/hr ft^2/(°F/ft) (±20 percent). The average thermal conductivity constant is between the conductivity constants associated with the major structural components of the flash chamber (steel and concrete have K values of 27 and 0.30 Btu/hr ft^2/(°F/ft), respectively).

- TNT emissions from the afterburner, as measured during the stack testing program, were never above detectable levels. In cases where TNT inlet concentration was sufficiently high, the DRE exceeded 99.99 percent.

- Combustion efficiency of the afterburner ranged from 99.9895 to 99.9933 percent during the stack testing program; efficiencies reflect the excellent performance of the afterburner.

- The emissions of particulate from the afterburner, as measured during the stack testing program, ranged from 0.000017 gr/dscf to 0.00093 gr/dscf (corrected to 7 percent oxygen). Emissions are two orders of magnitude lower than applicable regulations.

- Emissions of carbon monoxide and total hydrocarbons at the flash chamber inlet indicate that the existing air preheater at HWAAP is operating poorly. Emissions were one order of magnitude higher than emissions associated with typical gas-fired heaters. Combustion efficiencies for the air preheater ranged from 98.95 percent to 99.72 percent during the stack testing program.

- Due to extended heatup and cooldown periods, it is difficult to evaluate the effects of the 600°F test runs. During the 600°F test runs, before the steady state temperature was achieved, the system had operated at conditions that were very similar to the 500°F/6 hour test run. The results of the 500°F/6 hour test run indicate decontamination of TNT. Therefore, during the 600°F test run, the test items may have been adequately treated before the steady state temperature was even achieved.

The following recommendations are provided:

- The hot gas system modifications presented in Section 11 should be implemented to improve the overall efficiency of the decontamination system at HWAAP (i.e., flash chamber insulation, reduction of afterburner stack heat losses, air preheater chamber enlargement, upgrades in the monitoring system, and remote car removal).
- For operation at HWAAP, the modified system should be operated at a temperature of 550°F during heatup. The heatup period should be a minimum of 1 hour to assure all test items have reached a temperature of 500°F prior to steady state conditions.
- For the system at HWAAP, to overcome potential problems with nonuniform temperatures in the flash chamber, items that are more difficult to treat (such as steam-heated vessels and items with internal contamination) should be located at the rear of the rail cart near the diffusers. Items that are less difficult to treat, such as items with external surface area only, will likely be effectively treated when placed at the front of the cart, near the chamber door.
- All items to be treated by the hot gas process on a routine basis should have bulk contamination removed and vented to avoid potentially high pressure conditions caused by autoignition events.
- If explosive or propellant compounds (other than TNT) are to be treated in the hot gas system, stack testing should be conducted to determine the associated DREs.
- If items to be treated during future operations are radically different from those items evaluated during the pilot study, further testing (sampling and analysis) should be conducted to verify optimum conditions.
- The structural stability of all treated items that are appropriate for reuse in manufacturing or handling should be verified by means of nondestructive testing using one or a combination of the following tests:
    - Visual inspection.
    - Magnetic Particle Test.
    - Dry Penetrant Test.
    - Ultrasonic Test.
    - Radiographic Test.

  Testing should be conducted by qualified personnel.
- To develop a statistical model for a general operational system, a testing program similar to the pilot study should be conducted.

- The sampling protocol for smokeless powder should be redesigned to afford a more useful final sample for analysis. The sampling media should be selected to assure complete capture of NC and NG. The analytical method should be further developed in an effort to provide a distinction between NC, NG, and ambient nitrous oxides. Potential developments are summarized in Subsection 9.6.5.

SECTION 2

INTRODUCTION

2.1 BACKGROUND

The manufacture, handling, and loading of explosives at Army industrial facilities has resulted in the contamination of process equipment (piping, pumps, motors, powder boxes, etc.) and sewer systems. Because of this residual contamination, many process items cannot be reused or be disposed of as scrap. Contaminated sewer lines are also a disposal problem after they are excavated.

The U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) is investigating technologies to effectively treat explosives-contaminated components. Previous pilot studies[1] have shown that decontamination of structural components is possible using a heated gas to thermally decompose or volatilize explosives with subsequent incineration in an afterburner. To determine the feasibility of hot gas decontamination of explosives-contaminated equipment, a pilot study was conducted at the Hawthorne Army Ammunition Plant (HWAAP) from 10 July 1989 to 21 September 1989. This pilot study was based on a test plan that outlined the operational aspects of the pilot test[2]. Findings of the pilot study are included herein.

2.2 PURPOSE OF THE REPORT

The purpose of this report is to present the methodology, results, and conclusions of a pilot investigation that evaluated the feasibility of using the hot gas decontamination process for treating explosives-contaminated equipment items. Descriptions of the process equipment, test items treated, test variables, operational parameters, and monitoring results are contained herein.

2.3 OBJECTIVES OF THE PILOT STUDY

The primary objective of the pilot investigation was to determine the operating conditions that effectively decontaminate explosives-contaminated equipment (i.e., reduced explosives concentrations below detectable levels). Secondary objectives included determination of the following items:

- The effectiveness of the treatment on various types of equipment and equipment materials (including vitrified clay pipe) previously used in the manufacture, handling, and loading of explosives.

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[1] Arthur D. Little, Inc., Pilot Plant Testing of Caustic Spray/Hot Gas Building Decontamination Process. Prepared for USATHAMA (Task Order Number 5). USATHAMA Reference AMXTH-TE-CR-87112. August 1987.

[2] Test Plan - Task Order 2. Pilot Test of Hot Gas Decontamination of Explosives - Contaminated Equipment, at Hawthorne Army Ammunition Plant (HWAAP), Hawthorne, Nevada, August 1988.

- The effects, if any, that the treatment has on the reuse of equipment used in the manufacture, handling, and loading of explosives.

- The time-temperature dependencies for the decontamination of explosives on metal and clay surfaces.

- The operational parameters for future production decontamination systems.

2.4 EXPLOSIVE COMPOUNDS EVALUATED DURING PILOT STUDY

The primary explosive and propellant compounds evaluated during the pilot investigation include:

- 2,4,6-trinitrotoluene (TNT).
- Ammonium picrate (Yellow D).
- Smokeless powder (nitrogylcerin (NG) and nitrocellulose (NC)).

The analytical method for TNT determination also provided identification of the following compounds:

- Hexahydro-1,3,5-trinitro-s-triazine (RDX).
- Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX).
- Nitrobenzene (NB).
- 1,3-Dinitrobenzene (DNB).
- 1,3,5-Trinitrobenzene (TNB).
- 2,4-Dinitrotoluene (2,4-DNT).
- 2,6-Dinitrotoluene (2,6-DNT).
- 2,4,6-Trinitrophenylmethylnitramine (tetryl).

Consequently, the presence of these compounds was reported when detected.

A total of 10 test runs was conducted during the pilot study.

- Nine test runs were conducted to evaluate the feasibility of the hot gas process for items contaminated with explosives (primarily TNT) and smokeless powder.

- One test run was conducted to evaluate the feasibility of the hot gas process for equipment contaminated with ammonium picrate.

2.5 TERMS USED THROUGHOUT REPORT

To avoid confusion, definitions for the following terms are provided:

- Process equipment - Operational components of the hot gas system, including the air preheater, flash chamber and afterburner. These components are discussed in detail in Section 4.

- Test items - Equipment or items that were previously used in the manufacture, handling, and loading of explosives and are subject to treatment by the hot gas process.

  Test items were further categorized into:

  -- Control test items - Types of equipment items that were included in each of the nine test runs evaluating TNT.

  -- Observation test items - Types of equipment items that were included in a limited number of test runs due primarily to item unavailability.

A glossary that provides a summary of acronyms used throughout the report is presented on Page x.

SECTION 3

TEST SITE

3.1 TEST SITE LOCATION AND DESCRIPTION

The pilot study was conducted at HWAAP located in Hawthorne, Nevada. HWAAP was established in 1929 by the U.S. Navy. Current operations at HWAAP include the receipt, storage, inventory, maintenance, demilitarization, demolition, and testing of ammunition. HWAAP encompasses 246,000 acres of land situated in the west-central section of Nevada in Mineral County. Hawthorne is located approximately 160 miles southeast of Reno, Nevada along Route 95. A site location map for the installation is provided in Figure 3-1. The areas utilized for pilot study activities are shown.

The pilot study was conducted in the Western Area Demilitarization Facility (WADF), which is located in the northernmost section of HWAAP.

The following buildings were used during pilot study activities:

- Building 117-1 (Services and Support Building) - Laboratory for onsite analyses.
- Building 117-3 (Small Items Building) - Operation support area for personnel (i.e., lunch room, decontamination area, etc.).
- Building 117-15 (Flash Chamber) - Testing facility for hot gas decontamination of explosives-contaminated equipment.

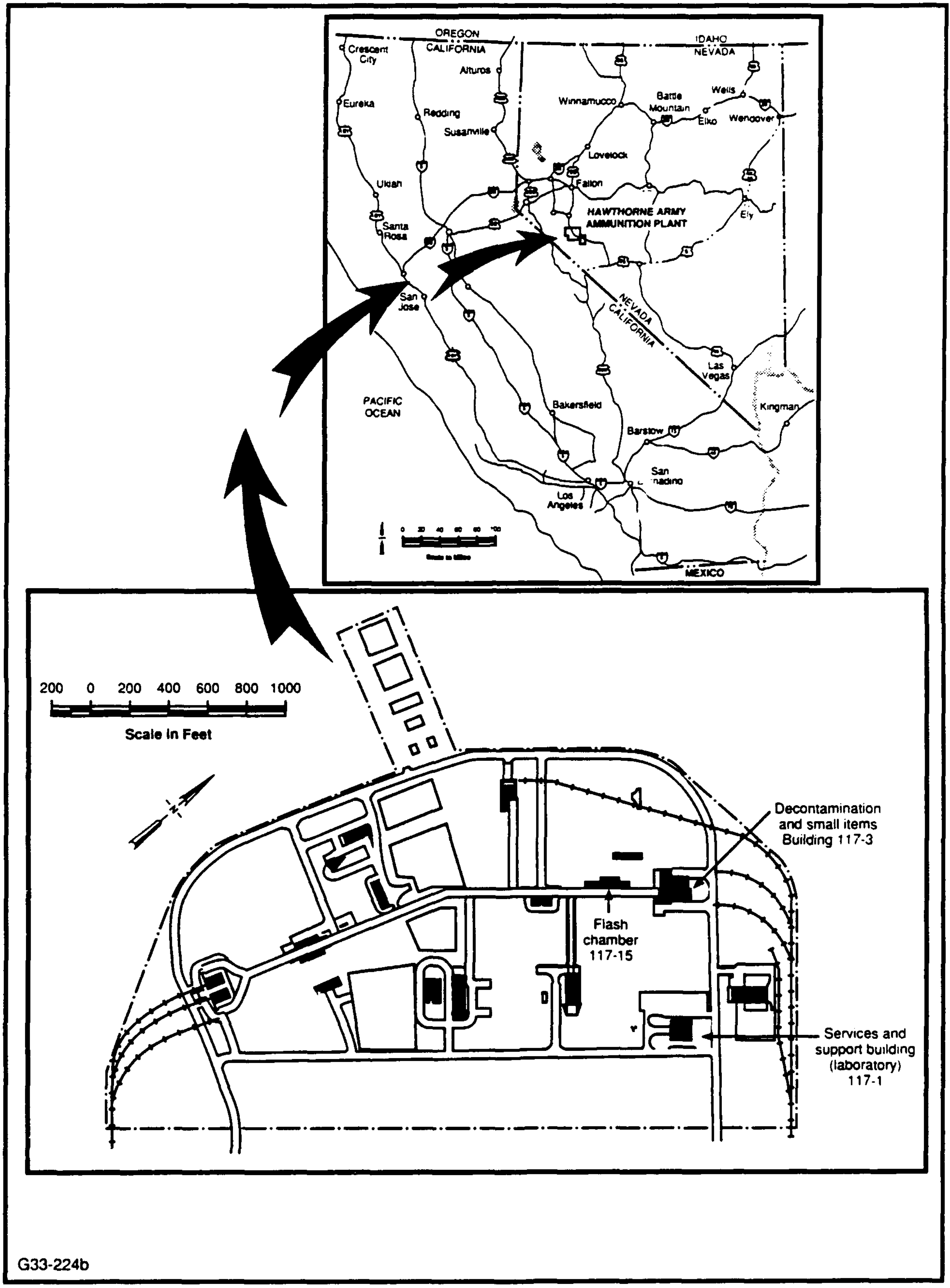


Figure 3-1. Location map of Hawthorne Army Ammunition Plant (HWAAP) with Pilot Study area identified.

SECTION 4

DESCRIPTION OF PROCESS EQUIPMENT

The process equipment used during the pilot investigation was supplied by the government and consisted of the following major items:

- Air preheater.
- Flash chamber.
- Afterburner.

A schematic diagram of the process equipment is shown in Figure 4-1. Photographs of the overall site are shown in Figure 4-2.

For each test run, explosives or propellent-contaminated test items were placed inside the flash chamber and the chamber was securely closed. The afterburner was brought up to the appropriate temperature (about 1800°F). Ambient air was blown into the air preheater by the combustion air blower. Propane fuel was used to fire the air preheater. The ambient air was heated to the appropriate target temperature. The hot gas was ducted into the flash chamber and distributed through gas diffusers. The hot gas thermally decomposed or volatilized the explosives and propellant from the test items. The contaminated vapor stream was withdrawn from the flash chamber through ducting. The induced draft (ID) fan directed gases to the afterburner. The afterburner incinerated the contaminants. Treated gases were then discharged to the atmosphere. Following a cooldown period, the treated test items were removed from the flash chamber and sampled.

The air preheater, afterburner, and control system were used previcusly in a pilot-scale demonstration of hot gas decontamination of process buildings at Cornhusker Army Ammunition Plant (CAAP) [Little, op cit.]. These items were transported from CAAP to HWAAP by the government.

The flash chamber (Building 117-15) is an existing facility at HWAAP. The facility was originally designed for flash powder decontamination of explosives-contaminated equipment.

A brief description of the process equipment is contained in the following subsections.

4.1 AIR PREHEATER

A horizontal air preheater, manufactured by the John Zink Company, is used to supply hot gas to the flash chamber. The air preheater is a refractory-lined combustion chamber which is 20 inches in diameter and 6 feet, 5 inches in length. The chamber is lined with 3 inches of lightweight castable refractory. It is propane-fired and rated for a total heat release of 3 million British thermal units (Btus) per hour. The preheater is equipped with a combustion air blower designed to deliver 2,000 standard cubic feet per minute (scfm) and driven by a 1.5-horsepower motor.

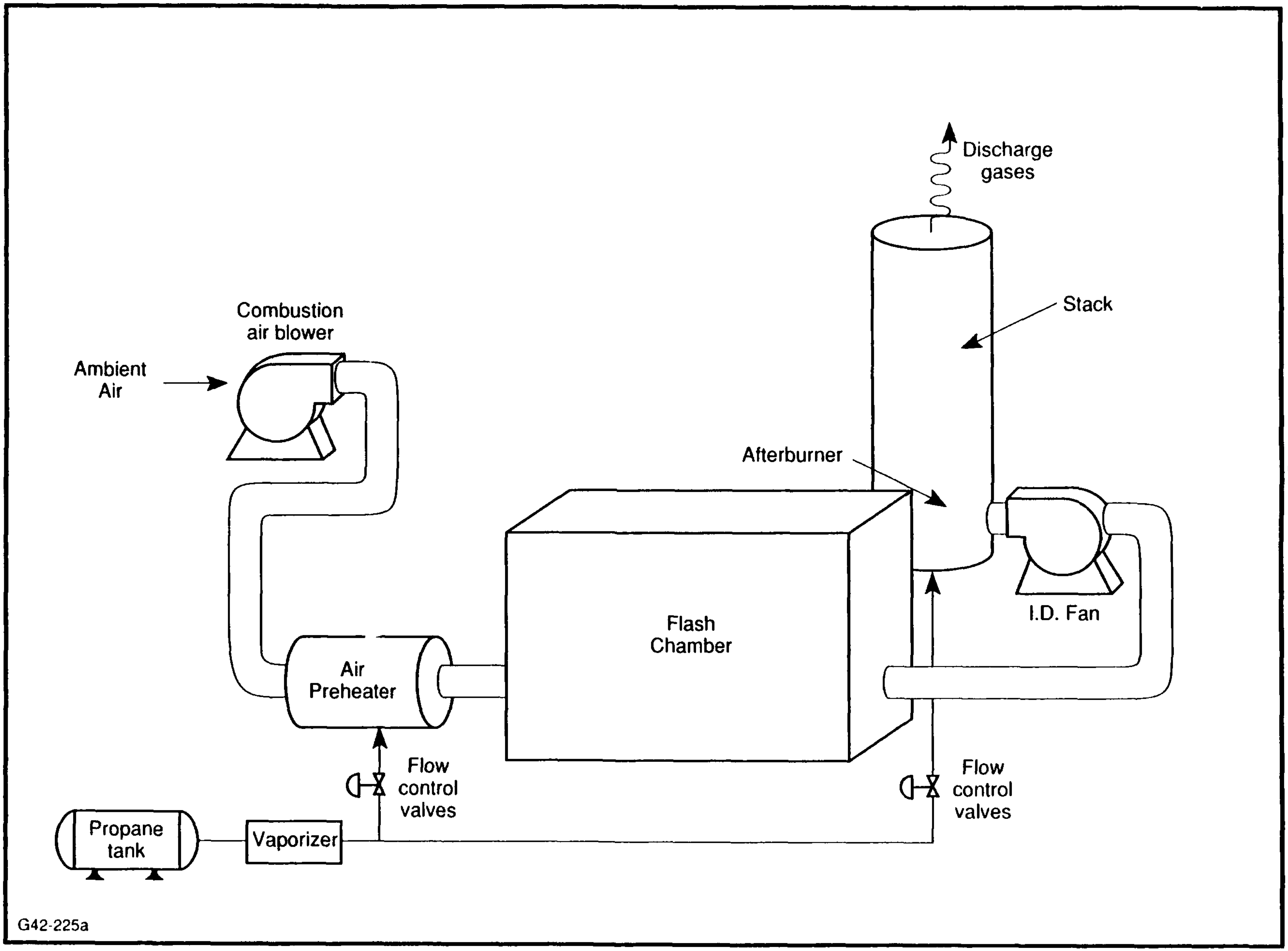
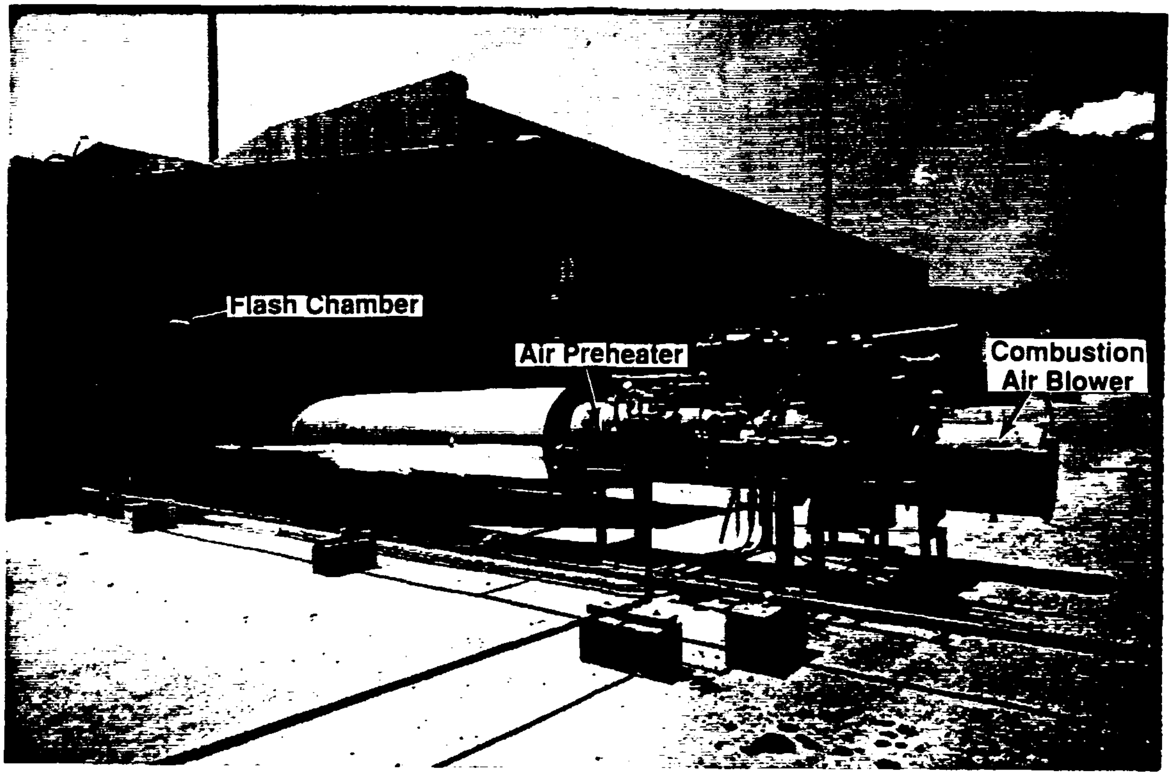


Figure 4-1. Schematic diagram for process equipment.



Photograph of Combustion Air Blower,
Air Preheater and Flash Chamber

Photograph of Flash Chamber,
Vent Fan and Afterburner

FIGURE 4-2 OVERALL VIEWS OF THE PROCESS EQUIPMENT

The temperature of the discharge gases can be controlled through a range of about 500°F to 1,150°F. The discharge gases are directed to the flash chamber through ducting that is 18 inches in diameter.

During startup, several attempts were generally required to ignite and maintain the preheater flame. To start the preheater, the fuel valve would typically have to be opened to its maximum allowable ignition setting (33 percent open). To maintain the flame, once ignition was achieved, the fuel valve was immediately opened to a 67 percent setting. The sudden increase of the gas flow (from 33 percent to 67 percent open) resulted in rapid heatup of the air preheater. Therefore, the temperature of the discharge gases was difficult to control at set points less than 600°F. In an attempt to reduce the heatup rate, the damper settings of the combustion air fan were adjusted to introduce more air into the system. Large increases in the damper setting increased the amount of air flow, however, and resulted in the flame being blown out.

The burner assembly from the preheater was routinely cleaned to remove excessive buildup of carbon and soot from the nozzles. The periodic cleaning resulted in a more uniform flame and fewer flame failures.

4.2 FLASH CHAMBER

The flash chamber is a steel structure 12.5 feet in diameter and encased in 4 to 6 feet of reinforced concrete. Two inches of fiberglass insulation are located between the steel and the concrete. The length of the flash chamber is 53 feet; however, a temporary false wall was installed to reduce the length to 30 feet. The false wall is constructed of carbon steel and lined with 6 inches of insulation. Entry to the chamber is controlled by a motor driven access door that is constructed of 16-inch-thick concrete and steel.

Hot gas is introduced to the rear of the flash chamber through ducting that is 18 inches in diameter. The inlet air ducts in the flash chamber were modified prior to pilot test activities to accommodate this ducting. The modification involved cutting two 18-inch diameter holes through the reinforced concrete wall surrounding the flash chamber. Hot gas is distributed throughout the chamber by diffusers, as shown in Figure 4-3. A photograph of the diffusers is shown in Figure 4-4.

During the planning stages of the pilot study, it was anticipated that there was sufficient insulation and it would take 2 to 4 hours to heat the flash chamber to target temperatures. Field activities indicated, however, that heatup times averaged 6 hours, 9 hours, and 17 hours for target temperatures of 400° F, 500° F, and 600° F, respectively. During system startup, several days were required to heat the chamber to 500° F. Heat was dissipating through the concrete walls of the chamber, as evidenced by moisture weeping from the concrete. The time period between test runs affected the heatup period, as shown in Table 4-1.

Similarly, although it was felt that the chamber could be cooled in less than 10 hours, field activities indicated that about 37 hours, 54 hours, and 69 hours were required to achieve target temperatures of 400° F, 500° F and 600° F, respectively.

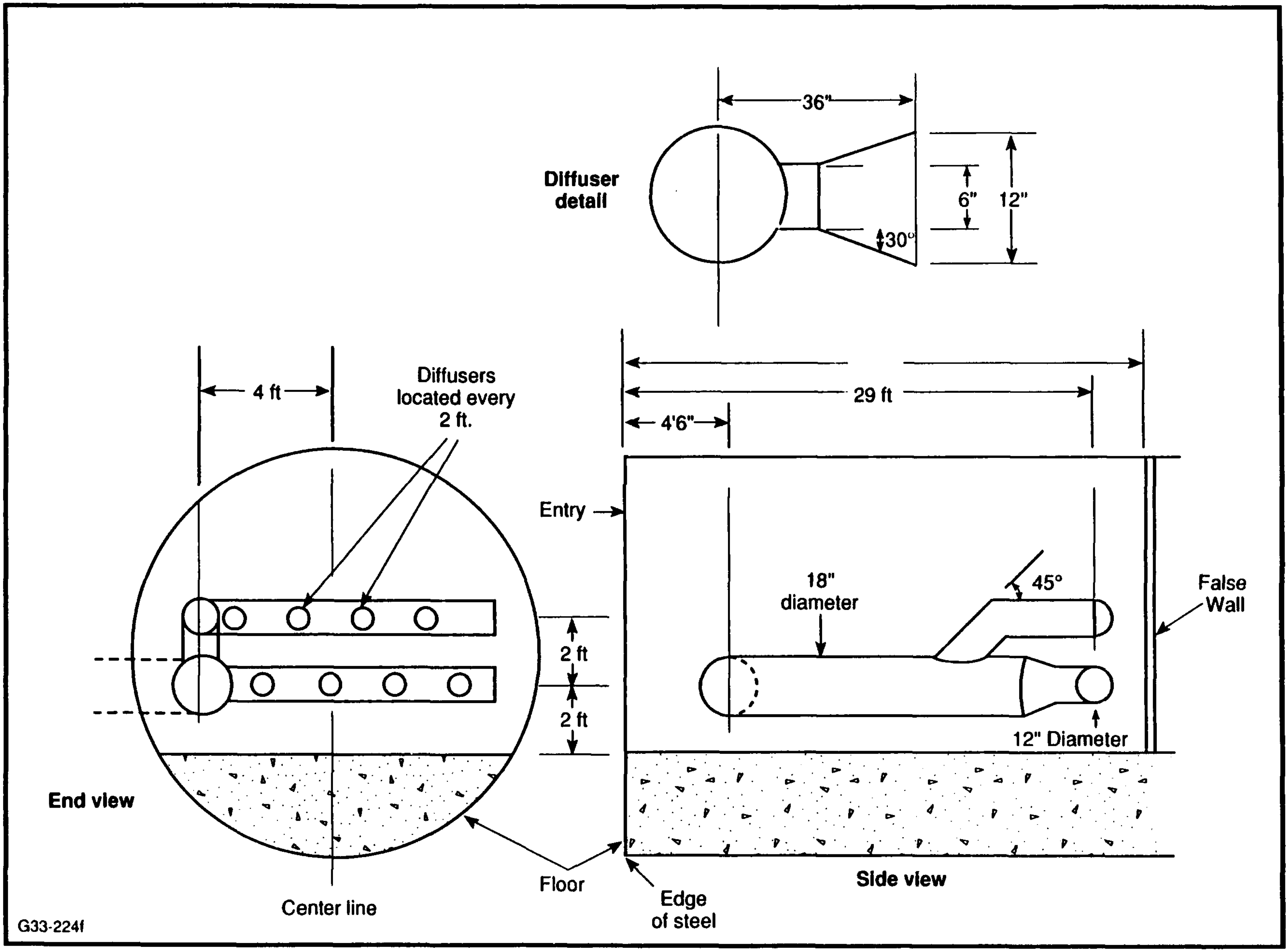


Figure 4-3. Schematic of diffusers used to distribute hot gas in flash chamber.

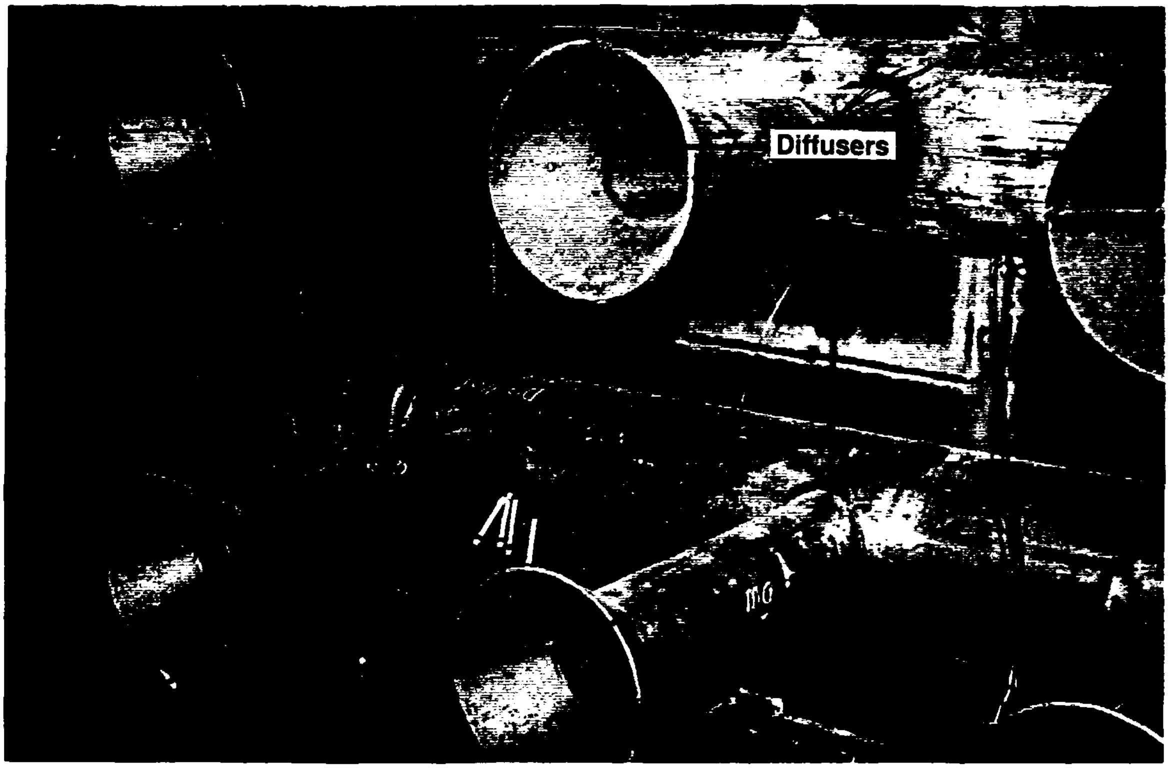


FIGURE 4-4 PHOTOGRAPH OF DIFFUSERS

Table 4-1

Heatup Period to Reach Target Temperature (Hours)

Target Temperature (°F)	Less than 2 Days Between Test Runs	More than 2 Days Between Test Runs
400	4	7
500	8	10
600	11	23

The long heatup and cooldown periods were primarily due to the lack of adequate insulation lining the steel structure within the flash chamber. The inadequate insulation resulted in a significant heat loss to the large thermal mass of concrete surrounding the flash chamber.

4.3 AFTERBURNER

A vertical afterburner, manufactured by the John Zink Company, is used to destroy contaminant vapors vented from the flash chamber. The afterburner chamber is 5 feet in diameter and 20 feet tall. It is lined with 3 inches of ceramic fiber insulation. The unit is propane-fired and rated for a total heat release of 4.5 million Btus/hour. The exhaust gases from the afterburner can be heated to reach a maximum temperature of about 2,000°F. The unit is preceded by an induced draft (ID) vent fan, which withdraws gases from the flash chamber. Rated to deliver 2,200 scfm of gases, the fan is driven by a 3-horsepower motor.

In general, operation of the afterburner was nonproblematic. Once ignited, the flame was easily maintained and controlled. The exit diameter of the stack is quite large; however, high winds occasionally blew down into the stack causing a back pressure on the system. The back pressure resulted in a slightly positive pressure in the flash chamber. The back pressure was never high enough to result in system shutdown.

The test plan originally indicated that an exit gas temperature of 2000°F would be maintained. The burner unit was undersized, however, and it was not possible to maintain the desired discharge temperature. Exit gas temperatures ranged from approximately 1760°F to 1997°F.

4.4 CONTROL SYSTEM

Operation of the air preheater and afterburner is monitored through a central control panel. The panel is 3 feet wide by 6 feet high by 2 feet deep. It contains motor controls, temperature and draft controllers, a programmable logic controller (PLC), warning lights, and an audible alarm.

The PLC provided safety interlocks that shut down the supply of fuel to the burners if any of the following conditions occurred:

- Low fuel gas pressure (i.e., less than 2 pounds per square inch gauge (psig)).
- High fuel gas pressure (i.e., greater than 15 psig).
- Flameout indication.
- Combustion air blower or vent fan motor failure.
- Draft pressure (DP) outside of control limits (-0.70 inwg < DP < + 0.02 inwg).

The control panel was upgraded to include a remote alarm system for unmanned operation (i.e., during night shift, weekends, and cooldown periods). The remote alarm automatically signaled the HWAAP guard station whenever the system shut down; WESTON personnel were subsequently notified. Operation of the remote alarm system was reliable and nonproblematic.

4.5 UTILITIES

Operation of the air preheater and afterburner required the following utilities:

- Electrical power.
- Propane fuel.

No water was required for process operations. Tap water from HWAAP was used for cleanup activities (personnel, sampling apparatus, etc.). Distilled water was used for sampling purposes (for instance, as a solvent for sampling ammonium picrate items).

4.5.1 ELECTRICAL POWER

The electrical power requirements for the pilot scale system were as follows:

- Air preheater and afterburner - 208 V/3-phase power for fan motors and 120 V/1-phase power for control circuits.

Electrical power for the system at HWAAP included:

- Continuous emission monitor (CEM) trailer - 240 V/3-phase power.

4.5.2 PROPANE FUEL

Propane fuel at 15 psig is required for the burners in the air preheater and afterburner. The maximum consumption rate for both burners is 7.5 million Btus per hour. Liquid propane was delivered to the site and stored in a tank located approximately 500 feet west of the flash chamber (Building 117-15). An evaporator is used to vaporize the liquid propane.

SECTION 5

TEST PROCEDURES

Process equipment was delivered from Cornhusker Army Ammunition Plant (CAAP) to the site in June 1988. The HWAAP operating contractor, Day and Zimmerman/Basil (DZB), was responsible for the modifications to the testing facility and installation of the process equipment. Modifications and installation were completed on 26 June 1989. The official testing program began on 11 July 1989 and continued through 21 September 1989 (10 weeks). A summary of the test run sequence is provided in Table 5-1. A brief description of the typical pretest, steady state, and post-test routine is contained in the following subsections. Detailed discussions of specific activities (selection of test items, sampling and analysis procedures, etc.) are contained in Sections 6 and 7. For illustration, the schedule corresponding to a 12-hour (steady state) test is presented in Figure 5-1.

5.1 DAILY ROUTINE

Typically, the regular test crew consisted of the following personnel:

- Site Engineer/Safety Officer.
- Continuous Emissions Monitor (CEM) System Operator.
- Analytical Chemist.
- Assistant Engineer.

Under special circumstances (e.g., stack sampling), additional personnel were required onsite.

5.1.1 PRETEST ACTIVITIES

Usually several days prior to a test, each test item to be treated was weighed, photographed, and measured. As discussed in Subsection 7.1, selected test items were prepared for treatment. Designated items were generally flushed with solvent (acetonitrorile and/or water, as appropriate) and rinse samples were collected to determine the initial concentrations of explosives. Test items were spiked with TNT or ammonium picrate. Spiking of the test items was conducted by representatives from HWAAP's onsite lab.

All pretest sampling was conducted on the loading dock of Building 117-15. Prepared test items remained on the loading dock for temporary storage.

On the day each test began, the test items were loaded onto a railroad car and moved into the flash chamber. Thermocouples were attached onto several test items to monitor temperatures. The chamber door was closed and testing was initiated.

WESTON personnel remained onsite during the entire heatup period, (beginning with the initial firing of the afterburner and continuing until the flash chamber reached steady state temperature). During this period, process equipment (propane gas supply tank, gas lines, and air preheater)

Table 5-1

Summary of Test Run Sequence

		Test Conditions		
Test Run Number	Testing Dates	Steady State Operating Temperature (°F)	Test Duration at Steady State (Hours)	Contaminants Evaluated
T14	15-18 August 89	400	12	Explosives/smokeless powder
T2	24-28 July 89	400	24	Explosives/smokeless powder
T8	3-8 August 89	400	36	Explosives/smokeless powder
T18	13-18 September 89	500	6	Explosives/smokeless powder
T13	9-14 August 89	500	12	Explosives/smokeless powder
T5	28 July 89 - 2 August 89	500	24	Explosives/smokeless powder
T3	16-21 July 89	500	36	Explosives/smokeless powder
T16	27-30 August 89	600	6	Explosives/smokeless powder
T15	22-27 August 89	600	12	Explosives/smokeless powder
T17	1-8 September 89	600	48	Ammonium picrate

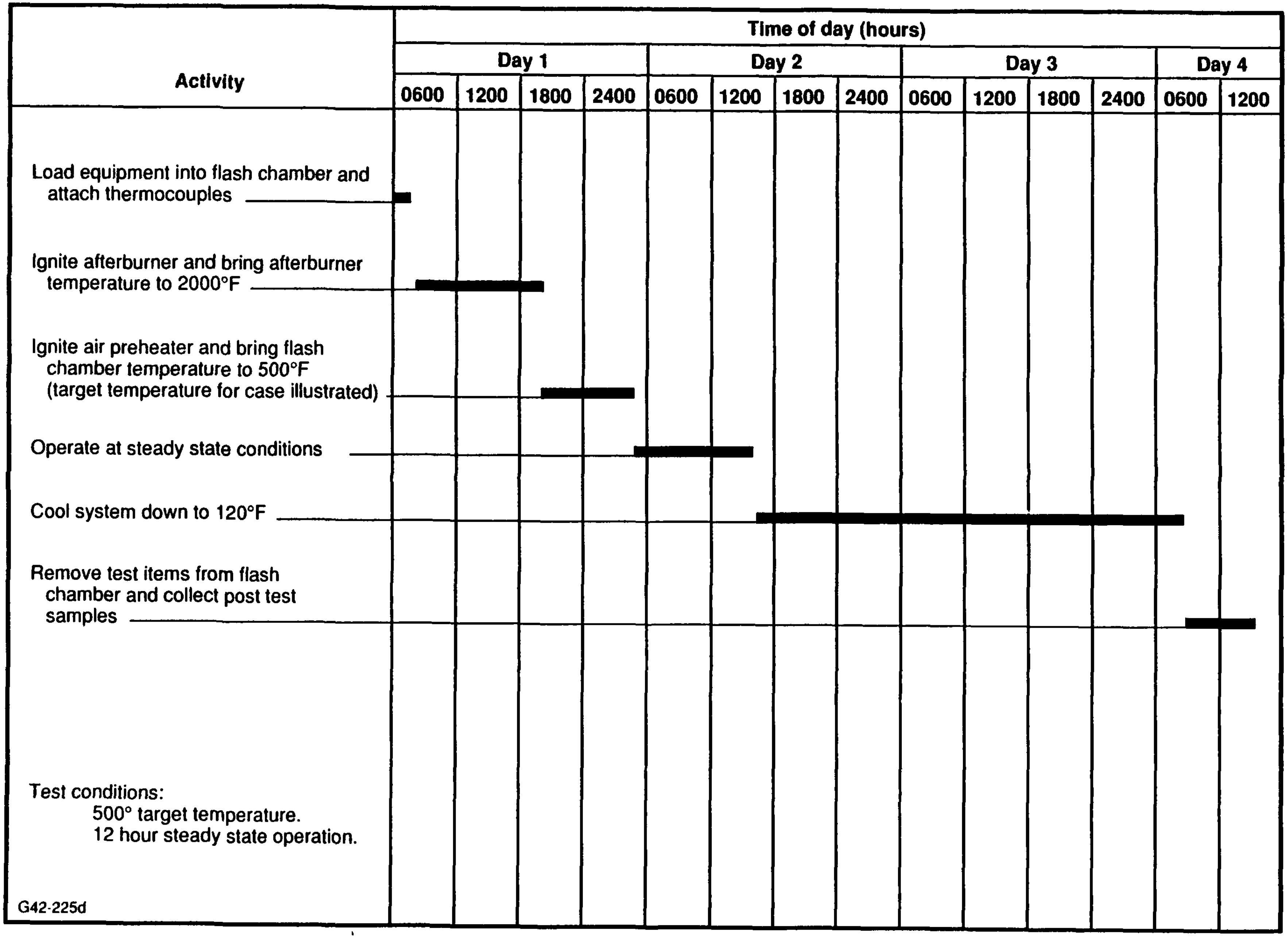


Figure 5-1. Typical schedule of onsite activities.

were inspected hourly to ensure proper operation. Monitoring data were also collected and recorded hourly (i.e., process temperatures, process pressures, damper positions, etc.).

5.1.2 STEADY STATE ACTIVITIES

WESTON personnel were not required to remain onsite and, therefore, departed the site after the flash chamber reached and maintained the target temperature. The automatic phone dialer was activated. The HWAAP security department was notified that the test site was being evacuated and that the automatic phone dialer was in operation. The system was typically left unattended until problems arose or the steady state test period was completed.

5.1.3 POST-TEST ACTIVITIES

At the end of the steady state time period, the air preheater was deactivated and the system cooldown period began. The combustion air blower introduced ambient air to the flash chamber to facilitate system cooldown. The afterburner continued to operate during the system cooldown period to ensure complete destruction of residual contaminants leaving the flash chamber.

For safety purposes, entry to the flash chamber was restricted until the temperature of the exit gas was below 120°F. The cooldown periods were usually unmanned. However, periodic checks were conducted to monitor internal chamber temperatures and to ensure proper operation of the system. Limited monitoring data were collected during the system cooldown period.

Once the internal chamber temperature was appropriate for safe entry, the afterburner was shut down and the flash chamber door opened. The thermocouples were removed from test items and the railroad car was removed from the chamber. Each test item was weighed, photographed, and measured. Post-test samples were collected on the loading dock of Building 117-15 and delivered to the lab for analysis.

After sampling, HWAAP personnel staged treated test items on concrete in a dedicated area located to the southwest of Building 117-15. Equipment was covered with plastic sheeting for protection from wind and rain.

SECTION 6

TEST VARIABLES

The variables of the pilot test were classified as follows:

- Independent variables - those whose values were not affected by test operations (e.g., ambient air temperature). No attempts were made to modify or control independent variables.
- Control variables - those whose values were selected and maintained during test operations (e.g., steady state temperature).
- Response variables - those whose values were a function of the selected operating conditions (e.g., residual contaminant concentration).

Table 6-1 provides a summary of test variables associated with the pilot study.

6.1 INDEPENDENT VARIABLES

As shown in Table 6-1, there were five independent variables associated with the pilot study system. These independent variables were the ambient air temperature and moisture content, the initial contaminant concentration, and initial weight and material of construction of the test items.

6.1.1 AMBIENT AIR TEMPERATURE

The temperature of the ambient (inlet) air varied with local weather conditions and time of day. The ambient air was routinely monitored during manned operation.

6.1.2 AMBIENT AIR MOISTURE CONTENT

The moisture content of the ambient air varied with the local weather conditions and time of day. The moisture content of the ambient air was routinely monitored during manned operation.

6.1.3 INITIAL CONTAMINANT CONCENTRATION OF THE TEST ITEMS BEING TREATED

The initial contaminant concentrations of explosives and smokeless powder varied based on previous uses of the test items and on previous spiking procedures. (Prior to pilot study activities, base personnel had spiked some test items with TNT and smokeless powder to determine the feasibility of flash powder decontamination.) In some cases, no attempts were made to change the initial contaminant concentration (those items that were grossly contaminated (e.g., clay pipe and motors) or previously spiked (e.g., ship mines).

Table 6-1

Summary of Test Variables for the Pilot Test

Independent Variables	Control Variables Held Constant At All Levels	Control Variables Held Constant At Various Levels	Response Variables
Ambient Air Conditions • Temperature • Moisture Content	Test Items Being Treated • Type of Control Test Items • Preparation and Handling • Location within Flash Chamber	Air Preheater Discharge Temperature	Heat-up Rate
Test Items Being Treated • Initial Contaminant Concentration • Initial Weight • Material of Construction		Preheater Air Flow Rate	Air Preheater Discharge Gas Composition
		Flash Chamber Discharge Gas Temperature	Test Items Being Treated • Final Contaminant Concentration • Structural Stability • Temperature (Internal and External) During Heat-Up, Testing, and Cool-Down Periods • Final Weight • TNT or Ammonium Picrate Removal Efficiency
	Flash Chamber Draft	Test Duration	
		Type of Observation Items Being Treated	
			Flash Chamber • Temperature (Walls and Floor) • Composition of Discharge Gases
			Afterburner • Composition of Discharge Gases • Flow Rate of Discharge Gases • Residence Time of Discharge Gases • Contaminant Destruction and Removal Efficiency • Discharge Temperature

However, for the remainder of the test items, spiking was accomplished as discussed in Subsection 7.1. Spiking was performed on test items with internal surface area for (which the only way to determine initial concentration was to flush the item) and those items for which no explosives contaminants were found by means of preliminary color reagent testing (ethylenediamine).

6.1.4 INITIAL WEIGHT OF THE TEST ITEMS BEING TREATED

The weight of each test item varied, depending on its configuration. The weight of each test item was recorded before each test.

6.1.5 MATERIALS OF CONSTRUCTION

Test items used in the pilot study were constructed of clay, aluminum, and steel. Test items were selected to evaluate the effectiveness of the hot gas process on a variety of construction materials.

6.2 CONTROL VARIABLES

As shown in Table 6-1, there were four control variables held constant at all levels throughout the entire test program. Five control variables were held at designated levels for appropriate test runs.

6.2.1 CONTROL VARIABLES HELD CONSTANT AT ALL LEVELS

6.2.1.1 Control Test Items Treated During the Study

Selected types of test items were included in each test run evaluating TNT. These items were characterized as "control test items". The selection of control test items was based primarily on their abundant availability from an onsite inventory of stockpiled equipment. Also, the selection was based on differing physical configurations (i.e., equipment with potentially contaminated internal surface areas, such as steam heated valves/risers; and equipment with external surface contamination, such as powder boxes and shell support racks).

The types and quantities of control test items included in the pilot study are shown in Table 6-2. Photographs of each type of control equipment are shown on Figure 6-1.

6.2.1.2 Preparation and Handling of Test Items Being Treated

Each test item was prepared and handled in the same general manner. Preparation and handling procedures included:

- Moving test items for loading, unloading, and sampling by a forklift, crane, or by hand.
- Screening for pre-test presence of explosives/ammonium picrate (using color indicating reagent).
- Spiking of test items (as necessary).
- Sampling of test items.

Table 6-2

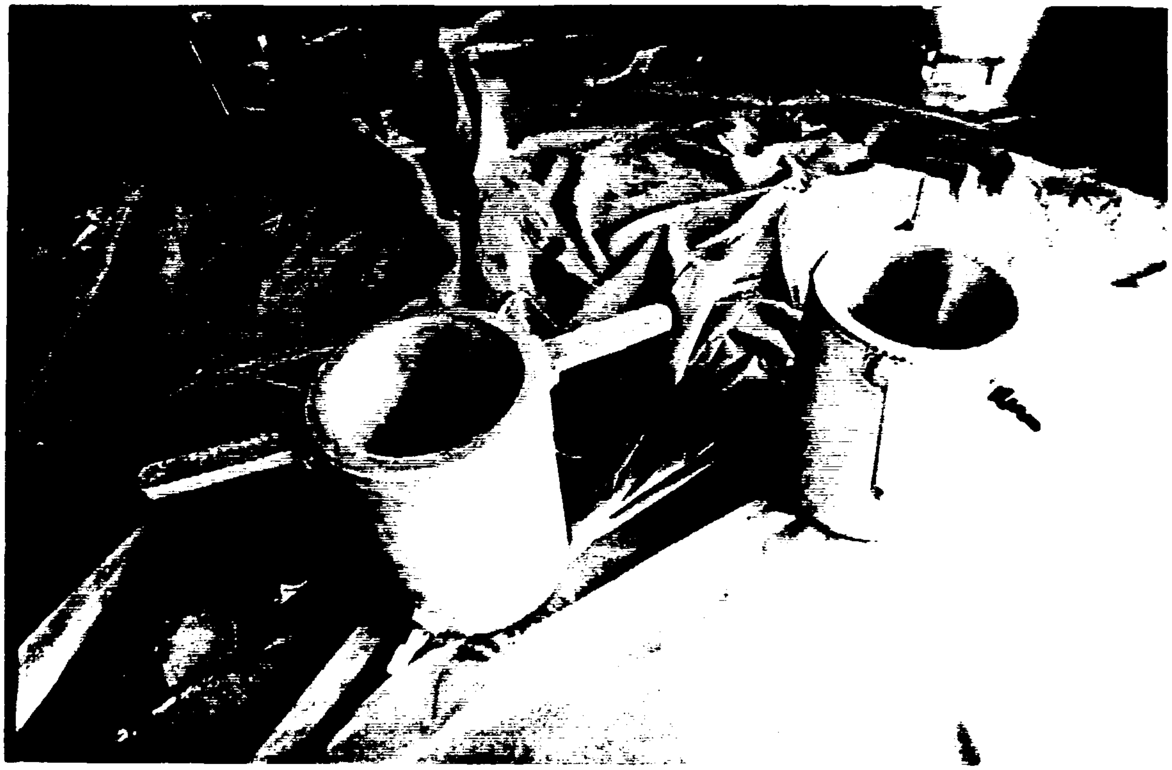
Types and Quantities of Control Test Items for Test Runs Evaluating TNT

Type of Control Test Item	Quantity Spiked with TNT[a]	 Contaminated With Explosives - No Spike Added
Powder Box	18	1
Steam-Heated Riser	18	0
Shell Support Rack	18	0
Vitrified Clay Pipe	0	9
Ship Mine	—	9[b]
Total	54	19

[a] Not all items included in study were analyzed; spare test items were included for evaluation in the event of problems (e.g., lab contamination,).

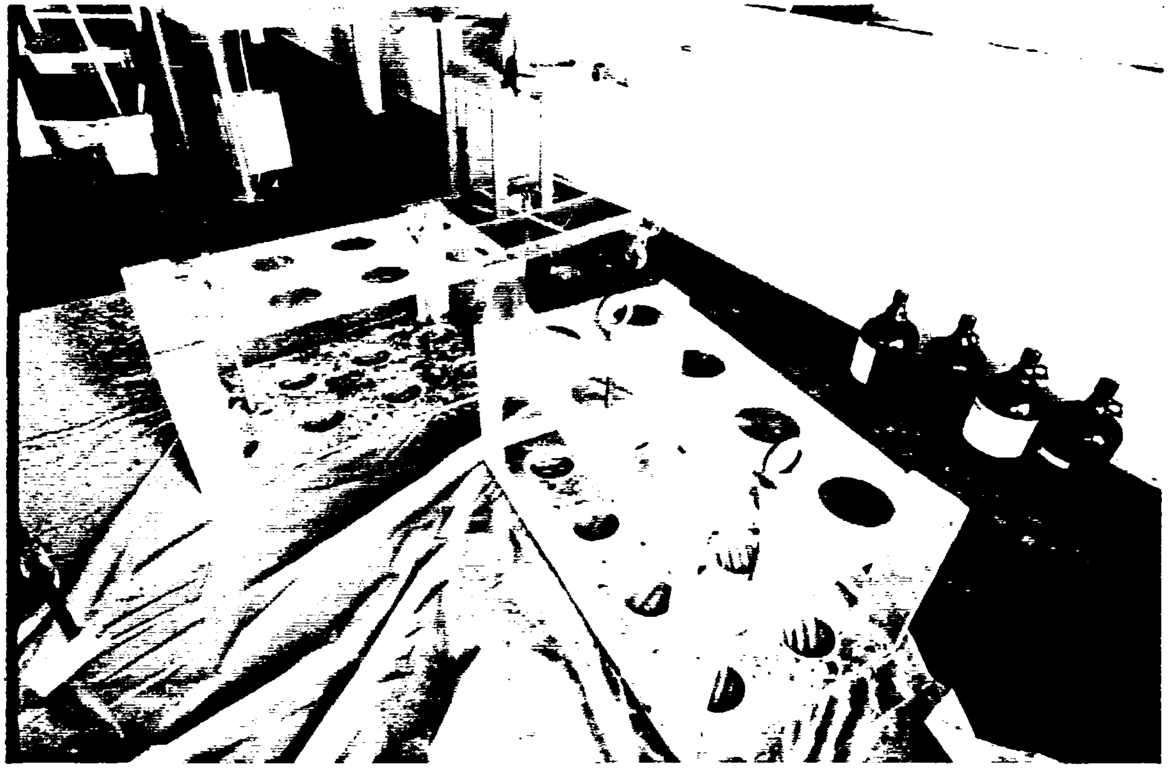
[b] Ship mines previously spiked with explosives and smokeless powder by Base Personnel (not spiked as part of pilot study). No additional spiking was conducted.

POWDER BOXES



STEAM-HEATED RISERS

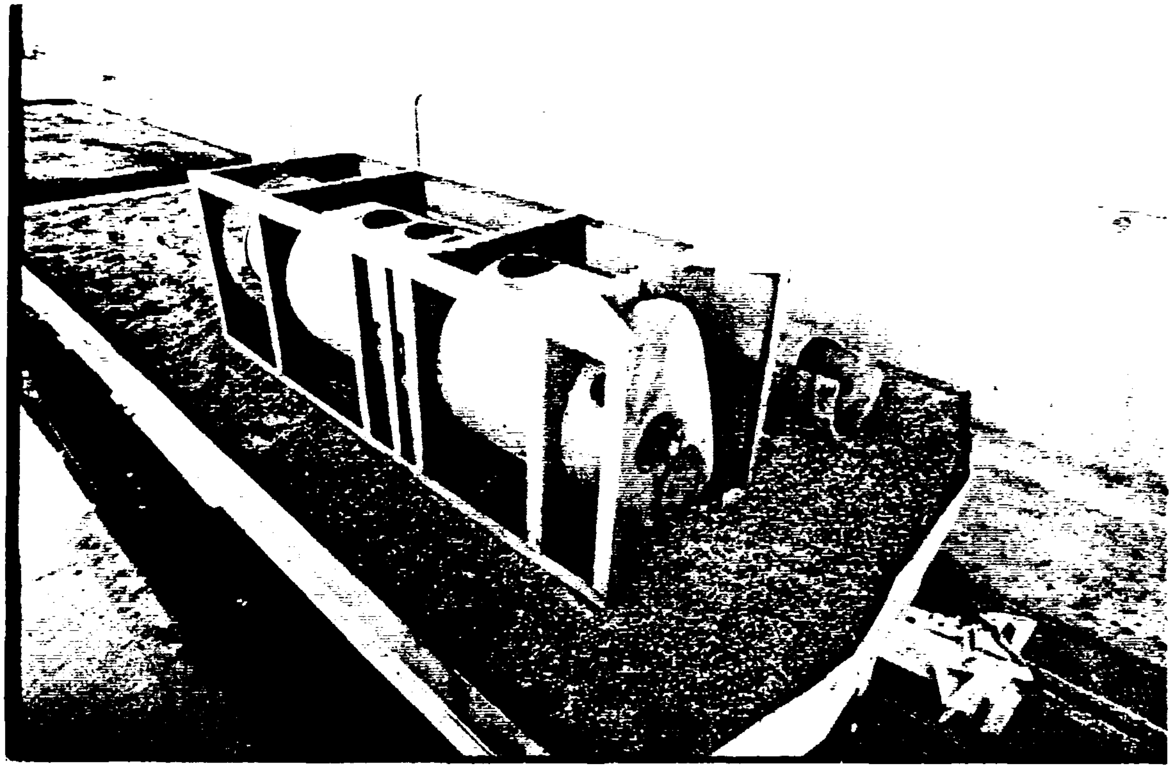
FIGURE 6-1 PHOTOGRAPHS OF CONTROL TEST ITEMS



SHELL SUPPORT RACKS

CLAY PIPE

FIGURE 6-1 PHOTOGRAPHS OF CONTROL TEST ITEMS (CONT'D)



SHIP MINE

FIGURE 6-1 PHOTOGRAPH OF CONTROL TEST ITEMS (CONT'D.)

Attempts were made to identify test items that were already contaminated with explosives or ammonium picrate. An identifier compound, ethylenediamine, was used as a color indicating reagent. When applied to a solid energetic material, an appropriate reagent will produce a coloration that is characteristic of the compound being tested. Color indicating reagents are used for preliminary identification and confirmation of the presence of a contaminant. In this application, ethylenediamine was applied to the test items through an eyedropper. Application of an ethylenediamine solution produced a maroon color if TNT was present and an orange color if ammonium picrate was present. Equipment that was not identified as being contaminated was spiked following the procedures outlined in Appendix A.

6.2.1.3 Location Within Flash Chamber

Temperature variations within the chamber were expected to occur due to: 1) the short circuiting of the hot air stream as it travelled from the diffusers to the exit duct, and 2) the loss of heat from the air stream as it traveled throughout the length of the chamber and was absorbed by the equipment and chamber walls. The location of test items within the chamber remained constant throughout the pilot study. Test items were placed on a railroad car for transport to and from the test chamber. Each type of test item was placed in the same position on the rail car for each test. For example, the vitrified clay pipe section was positioned in the northwestern corner of the car at a certain distance from the air diffusers for each test.

In general, larger, grossly contaminated test items, such as clay pipe and ship mines, were positioned on the rail car so that they would be closest to the diffusers. Test items with internal surface areas were positioned in the middle of the cart, while items containing external surface area only, such as powder boxes, were placed in the front of the rail cart near the door. A photograph of the test items loaded on a rail car for a typical test run is shown in Figure 6-2.

6.2.1.4 Flash Chamber Draft (Static Pressure)

To prevent the release of fugitive emissions from the flash chamber, a slight negative pressure was maintained. The negative pressure was controlled to limit the amount of infiltration air. During startup activities, air was drawn through the system to determine the desirable static pressure. A flash chamber draft of -0.1 inwg was maintained over the duration of the pilot study.

6.2.2 CONTROL VARIABLES HELD CONSTANT AT VARIOUS LEVELS

6.2.2.1 Air Preheater Discharge Temperature

The temperature of the air preheater discharge gases was controlled in order to maintain target temperatures in the flash chamber. Propane flow to the preheater was automatically adjusted to maintain temperatures in the preheater discharge gases.

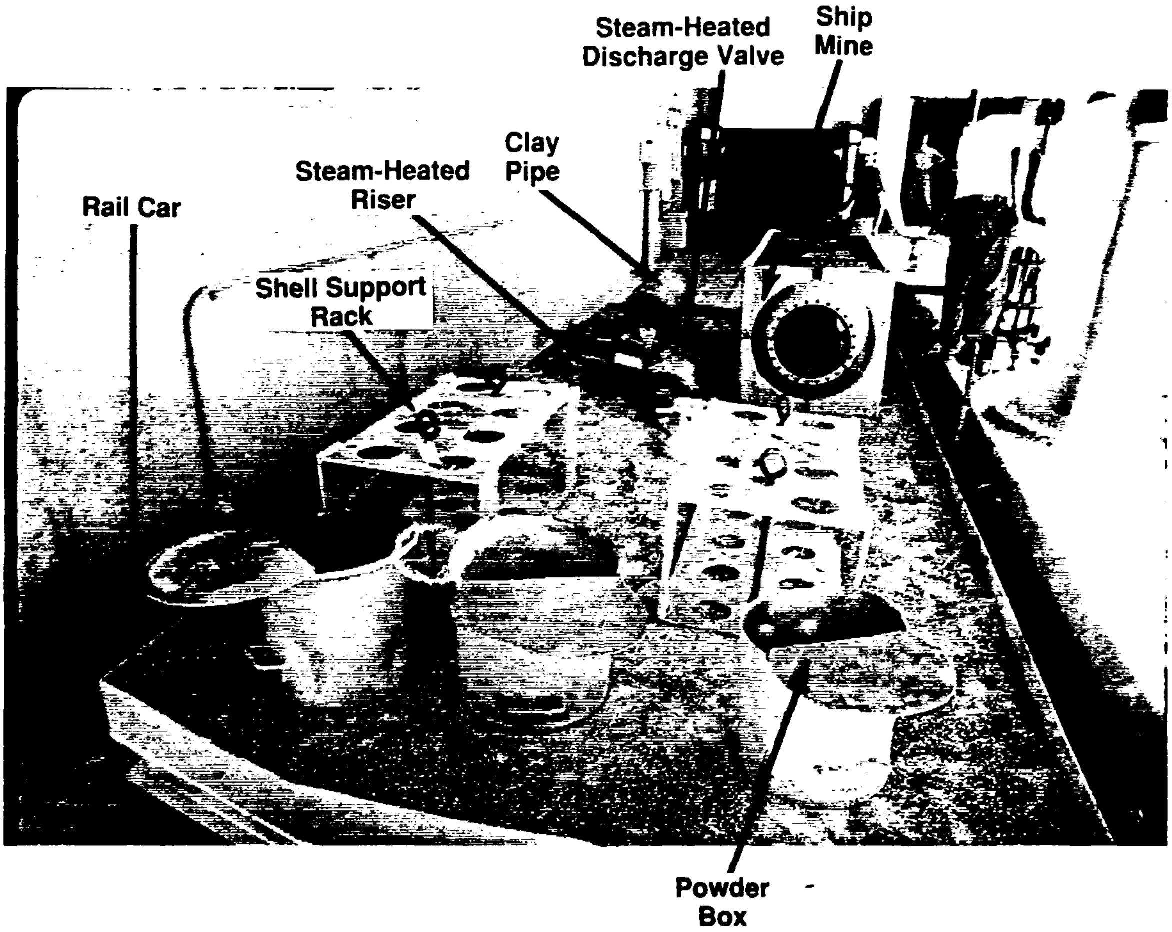


FIGURE 6-2 PHOTOGRAPH OF TEST ITEMS LOADED ON RAIL CART FOR TYPICAL TEST RUN

6.2.2.2 Preheater Air Flow Rate

The air flow rate through the preheater was controlled to maintain the target temperature in the flash chamber discharge gases.

6.2.2.3 Flash Chamber Discharge Gas Temperature

Three flash chamber target discharge temperatures were evaluated: 400°F, 500°F, and 600°F. These temperatures were selected based primarily on review of the final report from the pilot study for hot gas decontamination of process buildings [Little, op cit.]. Temperatures were verified to be appropriate during the initial testing program.

For pilot study purposes, the temperature of the discharge air from the flash chamber was used as an indication of target temperature. A thermocouple was placed at the outlet duct of the chamber. The thermocouple measured air temperature; it did not touch the walls of the duct. Selection of the discharge air temperature was necessary because during the heatup period, the temperatures of test items varied (± 100°F), depending upon location within the chamber, heatup rate for each material of construction, location of thermocouple (internal or external), etc.

6.2.2.4 Test Duration

Test conditions were set up in a steady-state format. As shown in Figure 6-3, the duration of tests evaluating TNT decontamination was 6 hours, 12 hours, 24 hours, or 36 hours. According to the Test Plan (see Subsection 2.2), the operating conditions for the first test run were originally proposed to be 600°F/48 hours. In the planning stage it was felt that about 7 hours would be required to bring the temperature in the flash chamber to 600°F. However, during the initial heat-up of the system (prior to the first test run with no equipment being treated), the temperature in the flash chamber was only 540°F after 36 hours. It was unknown at that time if 600°F could be achieved or how long a heat-up period would be required to achieve the operating temperature. After confirmation with USATHAMA, the operating conditions for the first test run were selected to be 500°F/36 hours.

Results of the first test run indicated that the selected operating conditions (500°F/36 hours) were sufficient to reduce the levels of TNT below detection limits. The matrix conditions were consequently changed to include residence times of 6, 12, 24, and 36 hours.

A residence time of 48 hours was used, however, for evaluation of ammonium picrate. The extended residence time (and higher temperature) were selected to ensure the decontamination process was complete and avoid potential safety problems associated with partially decomposed ammonium picrate (picric acid).

6.2.2.5 Type of Observation Test Items Being Treated

An objective of the pilot study was to evaluate a variety of types of equipment. Due to limited availability, some types of test items could not be

Steady State Temperature (°F)

Steady State Time (HR)	400	500	600
6		T-18 Explosives	T-16 Explosives
12	T-14 Explosives	T-13 Explosives	T-15 Explosives
24	T-2 Explosives	T-5 Explosives	
36	T-8 Explosives	T-3 Explosives	
48			T-17 Ammonium Picrate

Key: T = Test Run

G42-225c

Figure 6-3. Matrix of test conditions.

included in each test run (e.g., only three motors were available at HWAAP). These test items were characterized as "observation test items." They were included in randomly selected test runs.

The types and quantities of observation test items treated during the pilot study are shown on Table 6-3. Photographs of observation test items are shown on Figure 6-4.

6.3 RESPONSE VARIABLES

As shown in Table 6-1, there were 14 response variables measured. Each variable is discussed briefly in the following subsections.

6.3.1 HEATUP RATE

The test plan originally indicated that a total of 12 test runs would be conducted during the pilot study. A heatup rate of 50°F per hour was to be used to achieve the target temperature inside the flash chamber for the first 10 test runs (nine runs evaluating TNT and one run evaluating ammonium picrate). The selection of the 50°F per hour heatup rate was based primarily on review of the final report for the pilot study of hot gas decontamination of process buildings. The report indicated that, generally, higher heatup rates caused structural damage (i.e., cracks) to concrete and refractory. However, since the flash chamber was designed to accommodate high temperatures, a heatup rate of 100°F per hour was also to be evaluated. The last two test runs were planned to be conducted using a heatup rate of 100°F per hour until the target temperature was achieved.

Field operations, however, demonstrated that it was not possible to control the heatup rate. To maintain the flame on the air preheater, a large gas flow was required. The large gas flow resulted in rapid temperature increases which made control of heatup difficult below temperatures of 600°F. During the first test run, the heatup rate averaged about 6°F per hour. Although it was possible to increase the flash chamber temperature an average of 50°F per hour in subsequent test runs, short term temperature increases of 200°F per hour were not uncommon. A graphical representation of system heatup rates for a typical test run is shown in Figure 6-5 for illustration. It was also determined that during maximum firing of the air preheater, a heatup rate of 100°F per hour could not be maintained. The two test runs originally intended to evaluate a heatup rate of 100° per hour, therefore, were not conducted.

6.3.2 AIR PREHEATER DISCHARGE GAS COMPOSITION

The composition (carbon dioxide, carbon monoxide, and oxygen) of gases exiting the air preheater was monitored during the stack testing program (test runs T2, T3, and T5) to develop a mass balance for the system. The composition was dependent on the flow rate of air through the system and the amount of propane burned.

Table 6-3

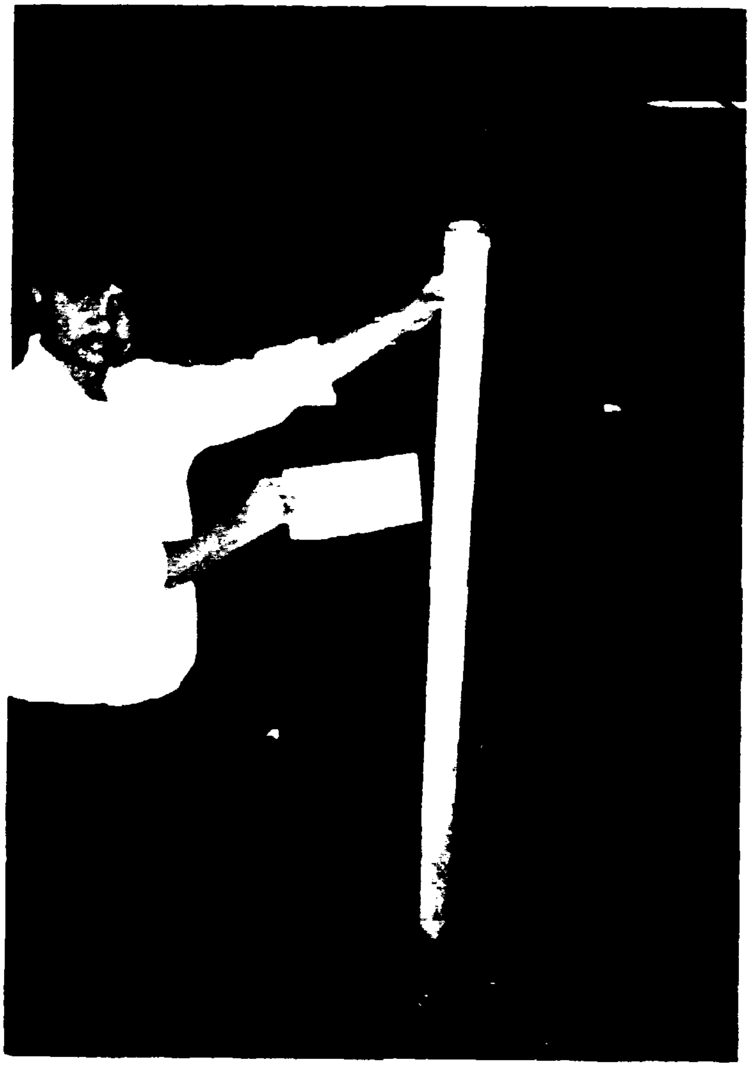
Types and Quantities of Observation Test Items for Test Runs Evaluating TNT

Type of Observation Test Items	Quantity	
	Spiked with TNT*	Contaminated With Explosives - No Spike Added
Steel Pipe	2	1
Steam-heated Discharge Valve	3	0
Aluminum Pipe	2	0
Motor	0	2
Total	7	3

*Not all items included in the study were analyzed; spare items were included for evaluation in the event of problems (e.g., lab contamination).

STEAM-HEATED DISCHARGE VALVE

FIGURE 6-4 PHOTOGRAPHS OF OBSERVATION TEST ITEMS

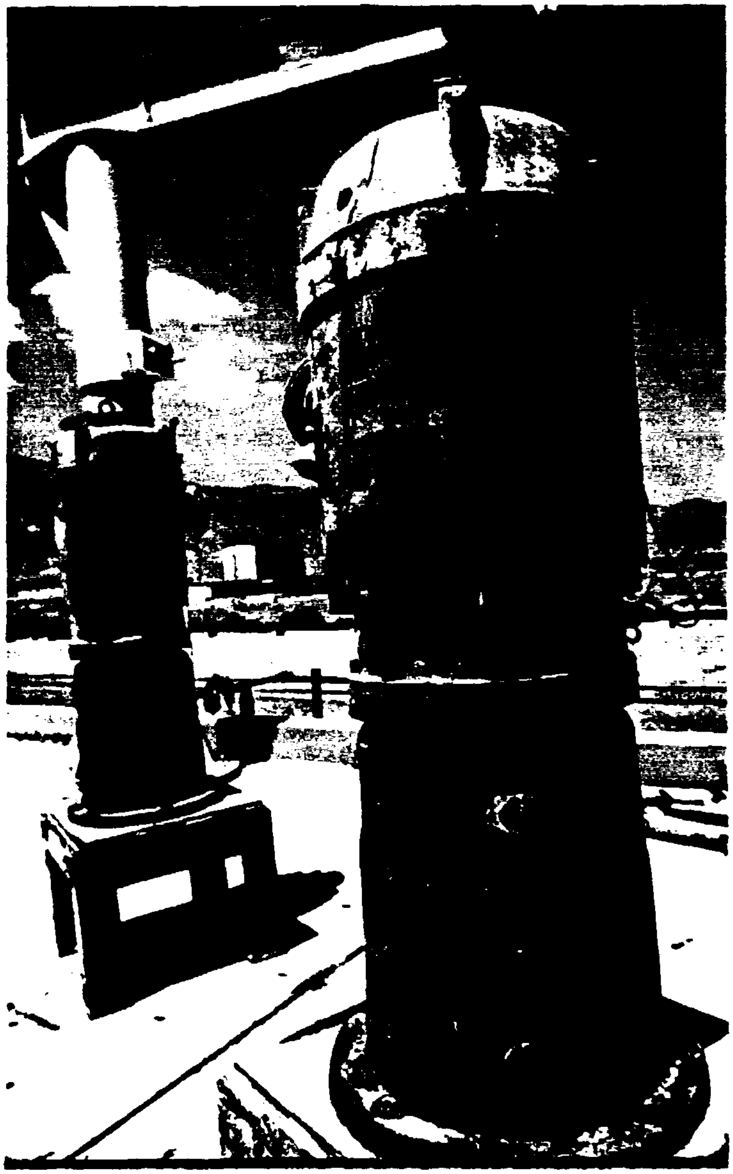


ALUMINUM PIPE

FIGURE 6-4 PHOTOGRAPHS OF OBSERVATION TEST ITEMS (CONT'D)

STEEL PIPE

FIGURE 6-4 PHOTOGRAPHS OF OBSERVATION TEST ITEMS (CONT'D)



MOTORS

FIGURE 6-4 PHOTOGRAPHS OF OBSERVATION TEST ITEMS (CONT'D)

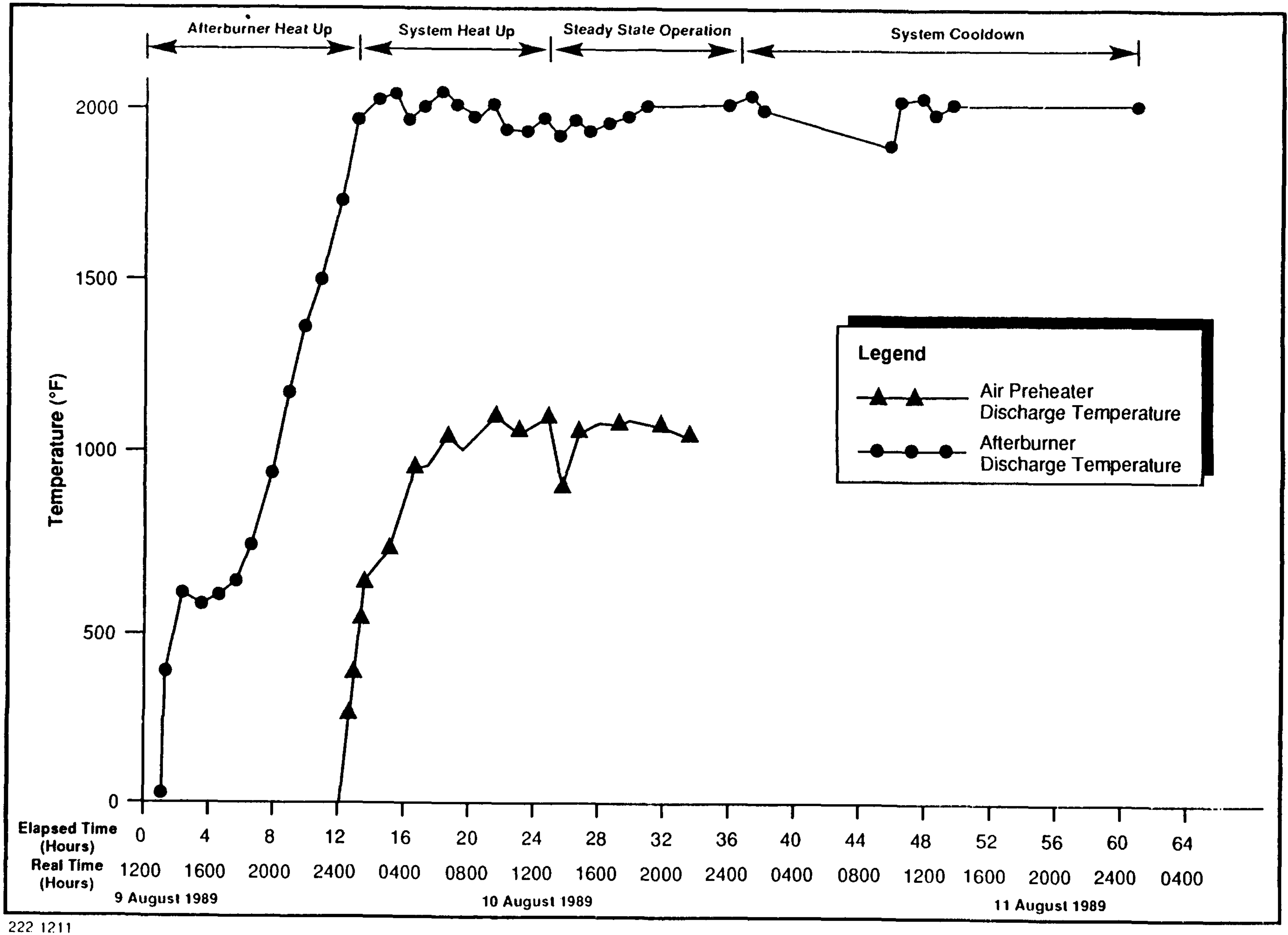


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FIGURE 6-5 GRAPHICAL REPRESENTATION OF TYPICAL SYSTEM HEAT-UP (STEADY STATE CONDITIONS OF 500° FOR 12 HOURS)

6.3.3 FINAL CONTAMINANT CONCENTRATION OF TEST ITEMS

The final contaminant concentration of the test equipment varied based on operating conditions. Test items were sampled after testing to determine the level of residual contamination.

6.3.4 STRUCTURAL STABILITY OF TEST ITEMS

After each test run, test items were visually inspected for warping, cracking, or other structural damage.

6.3.5 TEMPERATURE (INTERNAL AND EXTERNAL) OF TEST ITEMS

Thermocouples were used to monitor the internal and external temperatures of selected test items. The temperature of the test items varied based on the temperature of the chamber, location within the chamber, duration of time exposed to high temperature air, etc.

6.3.6 FINAL WEIGHT OF TEST ITEMS

The weight of each test item varied based on its configuration. Each test item was weighed after testing to determine if a weight change occurred.

6.3.7 FLASH CHAMBER TEMPERATURE (WALLS AND FLOOR)

The temperature of the walls and floor of the flash chamber varied based on the operating conditions. Temperatures were monitored at various locations within the chamber for each test.

6.3.8 COMPOSITION OF FLASH CHAMBER DISCHARGE GASES

The flash chamber discharge gases were monitored during the stack testing program (T2, T3, and T5) to determine the types and quantities of compounds present (contaminants, hydrocarbons, etc.).

6.3.9 COMPOSITION OF AFTERBURNER DISCHARGE GASES

The afterburner discharge gases were monitored during the stack testing program (T2, T3 and T5) to determine the types and quantities of compounds present (i.e., contaminants, hydrocarbons, etc.).

6.3.10 FLOW RATE OF AFTERBURNER DISCHARGE GASES

The flow rate of afterburner discharge gases varied based upon air flow rate through the system, air infiltration, and amount of propane burned. Discharge gases were monitored during the stack testing program (T2, T3, and T5) to determine the volumetric flow rate.

6.3.11 RESIDENCE TIME OF AFTERBURNER DISCHARGE GASES

The afterburner residence time for discharge gases has been calculated as follows:

$$T_r = \frac{V_a}{Q_a}$$

Where: T_r = Residence time of discharge gases in the afterburner (seconds).

V_a = Volume of the afterburner (cubic feet).

Q_a = Volumetric flow rate of the afterburner discharge gases at actual conditions (cubic feet per second).

6.3 12 AFTERBURNER CONTAMINANT DESTRUCTION AND REMOVAL EFFICIENCY (DRE)

The afterburner contaminant destruction and removal efficiency for TNT has been calculated as follows:

$$DRE = \frac{C_1 - C_2}{C_1} \times 100 \text{ percent}$$

Where: DRE = Afterburner contaminant destruction and removal efficiency (expressed as a percent).

C_1 = Mass of contaminant per unit time entering the afterburner (i.e., flash chamber discharge gas).

C_2 = Mass of contaminant per unit time discharging from the afterburner (or analytical detection limit).

The values for C_1 and C_2 are determined by sampling the afterburner inlet and outlet streams, respectively, for the mass of contaminant. In cases where the contaminant mass discharging the afterburner is below detection limits, the analytical detection limit is used for the value of C_2 in the above equation. DREs are reported as a minimum in these cases; actual DREs may be much higher.

The contaminant inlet mass feed rate must be sufficiently large to result in a desirable DRE. As an example, the methodology for determination of DRE for a hazardous waste incinerator is provided herein. (As discussed in Subsection 9.7.1, the hot gas system at HWAAP is not classified as a hazardous waste incinerator. The example is provided for illustration only since regulatory criteria exist).

Example: For a hazardous waste incinerator, a minimum DRE of 99.99 percent is required by federal regulations. During a stack test program for TNT, the following mass rates of contaminant were determined to be present:

Stack test 1 - C_1 = 0.0925 lb/hr
C_2 = <0.000000404 lb/hr

Stack test 2 - C_1 = 0.10 lb/hr
C_2 = <0.00000404 lb/hr

These values were used to determine associated DREs, as follows:

Stack test 1 - DRE = (0.0925 - 0.00000404)/0.0925
= 99.956%

Stack test 2 - DRE = (0.10 - 0.00000404)/0.10
= 99.996%

As shown, by nature of the calculation, if the mass of contaminant in the inlet stream (C_1) is not sufficiently high, the DRE will be less than 99.99 percent, even if contaminant levels in the discharge stream (C_2) are below detection limits.

6.3.13 AFTERBURNER DISCHARGE GAS TEMPERATURE

The afterburner temperature was maintained at the maximum controllable temperature to ensure complete combustion of flash chamber discharge gases. Temperatures ranged from about 1750°F to 1900°F, depending on the air flow rate and temperatures from the flash chamber. Lower afterburner temperatures (below 2000°F) were consistent with operations previously performed at CAAP.

SECTION 7

SAMPLING, MONITORING, AND ANALYTICAL METHODS

Samples of the test items and process streams were collected by WESTON personnel. The majority of samples were analyzed at the onsite laboratory. However, some samples (ammonium picrate, smokeless powder, stack gases, and quality assurance/quality control (QA/QC) samples) were returned for analysis to WESTON's Analytics Division in Lionville, Pennsylvania.

The locations of the sampling points are shown in Figure 7-1. A summary of the analytical parameters associated with each point is presented in Table 7-1. Table 7-1 also includes the following information:

- A summary of the test runs that were sampled for each parameter.
- An indication of whether the sample was manually collected (i.e., discrete sample) or collected by the continuous emission monitoring (CEM) system.

A brief discussion of the sampling and analysis methodology for each point is included in the following subsections.

7.1 SAMPLING METHODS

7.1.1 TEST ITEMS

Test items were generally sampled prior to each test run to determine initial concentration and after each test run to determine the residual explosives concentration. A brief discussion of the sampling methodology used for each type of equipment is included in the following subsections.

7.1.1.1 POWDER BOXES

Powder boxes were included for evaluation in each test run (nine tests for TNT and one test for ammonium picrate).

As a screening procedure, prior to testing, ethylenediamine indicator compound was applied to all powder boxes to determine the presence of TNT (or ammonium picrate, as applicable). Screening procedures only identified one powder box as being contaminated with TNT. To verify the presence of TNT, the contaminated powder box was wipe sampled prior to the test run using a Whatman Number 42 ashless, 9-centimeter filter soaked with acetonitrile. A wipe sample was collected (in a separate location) from the powder box following the test run to determine the residual concentration. No powder boxes were identified as being contaminated with ammonium picrate.

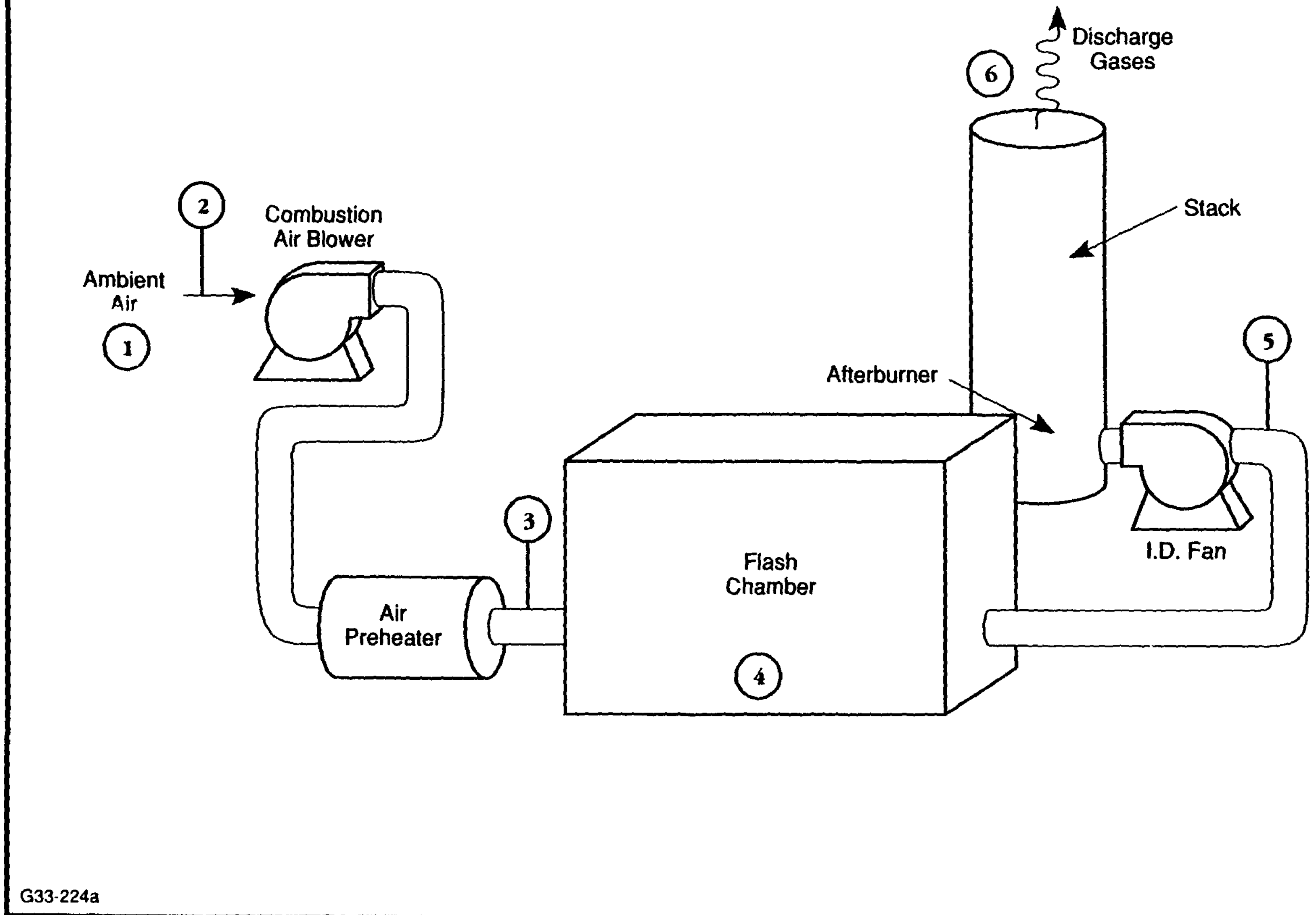


Figure 7-1. Location of sampling points.

Table 7-1

Summary of Sampling/Analytical Program for Each Test Run[a]

Parameter	1 Ambient Air	2 Combustion Air Blower Inlet Gases	3 Air Preheater Discharge Gases	4 Test Equipment	5 Flash Chamber Discharge Gases	6 Afterburner Discharge Gases
Explosives	---	---	---	All tests but T17	T2-T3-T5	T2-T3-T5
Smokeless Powder	---	---	---	All tests but T17	T2-T3-T5	T2-T3-T5
Ammonium Picrate (as picric acid)	---	---	---	T17	---	---
Total Hydrocarbons	---	---	All tests[b]	---	All tests[b]	All tests[b]
Carbon Dioxide	---	---	T2-T3-T5	---	T2-T3-T5	All tests[b]
Carbon Monoxide	---	---	T2-T3-T5	---	T2-T3-T5	All tests[b]
Oxygen	---	---	T2-T3-T5	---	T2-T3-T5	All tests[b]
Nitrous Oxides	---	---	---	---	---	All tests[b]
Particulates	---	---	---	---	---	T2-T3-T5
Semivolatile Compounds/ C_7-C_{17} Hydrocarbons	---	---	---	---	T3[c]	T3[c]
Volumetric Flow Rate	---	T0	T2-T3-T5	---	T2-T3-T5	T2-T3-T5
Moisture Content	All tests	---	T2-T3-T5	---	T2-T3-T5	T2-T3-T5

[a] Discrete sample unless noted.

[b] CEM System Sample.

[c] A portion of the extract from one of the EPA Modified Method 5 trains was analyzed for semivolatile compounds and C_7-C_{17} hydrocarbons.

Note: T = Test run.

The powder boxes that were determined to be uncontaminated were flushed with solvent as a conservative measure to remove any potentially low levels of contaminants. The flushing procedures were as follows:

- 1 liter of acetonitrile (or water for ammonium picrate) was applied in four equal fractions of 250 milliliters (mL) each.
- Each 250 mL fraction was placed into a separate sample jar and analyzed for explosives (or ammonium picrate, as applicable).

After flushing, powder boxes were spiked with a known quantity of TNT (or ammonium picrate, as applicable), according to the procedures outlined in Appendix A.

After each test run, the treated powder boxes were flushed with multiple rinses of solvent. Multiple rinsing was conducted to determine if residual contamination was removed during the first rinse or if contamination continued to be removed during subsequent exposure to fresh solvent. Each powder box was rinsed 4 times (1 liter per rinsate sample). The appropriate solvent was added to the powder boxes in four equal fractions of 250 mL each. The solvent was swirled around the bottom of sides of the box for about 2 minutes, and placed in a glass beaker to be composited with the other rinses. This procedure was repeated four times. A total of one liter of solvent was used per sample (4 liters per powder box).

7.1.1.2 Steam-Heated Risers

Steam-heated risers were included for evaluation in each test run (nine tests for TNT and one test for ammonium picrate).

Screening using ethylenediamine was not conducted on steam-heated risers since the internal surface area was not accessible (0.25-inch steam connections did not allow sufficient entry). Rather, the test plan indicated that during the first few test runs, steam-heated risers would be flushed with solvent (i.e., "decontaminated") and subsequently spiked with TNT. Following analysis of the rinsate, a decision would be made to continue flushing or to spike risers without further flushing, as follows:

- If analysis of the rinsate indicated that explosive compounds were present, pre-test flushing would be discontinued. Risers would be spiked on an "as-is basis" to evaluate the effectiveness of the process on existing contamination, as well as spiked contamination.
- If analysis of the rinsate indicated that no detectable levels of explosives compounds were present, risers would be flushed with acetonitrile to remove any low levels of explosives that might be present below detection levels. The risers would then be spiked with TNT, as discussed in Appendix A.

Preliminary flushing activities were conducted on the loading dock of Building 117-15. The bottom steam connection was sealed with parafilm wax. Three hundred mLs of acetonitrile were added to the jacket of the riser. The riser was gently agitated. A sample of the rinsate was collected for analysis. Preliminary flushes of the steam heated risers indicated the presence of RDX contamination. After the first test run (T3), based on conversations with USATHAMA, it was decided that for those test runs evaluating TNT, steam heated risers would be spiked without prior flushing since an objective of the pilot study was to evaluate items with existing contamination.

Prior to the test run that evaluated ammonium picrate, however, the riser was flushed with 1,200 mL of acetonitrile (in four equal fractions of 300 mL), followed by 1,200 mL of water (also in four equal fractions of 300 mL) to minimize any potential interference from other explosive compounds that may have been present. The riser was then spiked with ammonium picrate following the procedures outlined in Appendix A.

After each test run, the risers were rinsed with acetonitrile (or water, for ammonium picrate). Multiple rinsing was conducted as discussed in Subsection 7.1.1.1. Solvent was added to the jacket of the riser in fractions of 300 mL. The risers were agitated for about 2 minutes and samples were collected. This procedure was repeated four times (a total of four samples).

7.1.1.3 Shell Support Racks

Shell support racks were included for evaluation in all nine test runs evaluating TNT. Visual inspection suggested that contamination was present, as evidenced by relatively well distributed black dots present on the upper and lower shelves of the support racks. Ethylenediamine was applied to discrete areas on several of the racks to verify the presence of explosive compounds. Prior to each test run, wipe samples were collected from the bottom shelf. After each test run, a separate location on the bottom shelf was wipe tested to determine if detectable levels of explosives remained.

In addition to the wipe samples collected from the bottom shelf, the top shelf of each support rack was spiked following the procedures outlined in Appendix A. The area to be spiked was "decontaminated" prior to spiking. The area (5-inch by 5-inch square) was wiped several times with acetonitrile to remove existing contamination. A 4-inch by 4-inch area was spiked with TNT. After each test run, wipe samples were collected from the spiked portion of the rack using a 5-inch by 5-inch aluminum template. A larger template (5 inch by 5 inch) was used to ensure that the entire spiked area was included in the wipe sampling procedure.

7.1.1.4 Vitrified Clay Pipe

One section of vitrified clay pipe was used in each test run evaluating TNT. The clay pipe was known to be contaminated; therefore, screening and spiking were not necessary. However, ethylenediamine was applied to one section of pipe (clay pipe evaluated for T13) for verification. Shortly after application using an eye dropper, the sediment (in the area of application) began to smoke and then began to flame (yellow-orange flames). The flames were initially localized but began to spread. A fire extinguisher was then used to extinguish the flames.

The following types of contamination were evaluated:

- Sediment that had accumulated on the internal surface of the pipes.
- Contamination that had permeated into the clay wall (termed internal contamination).

To determine the initial concentration of explosives in the sediment, samples of the solid material were collected at three locations along the length of the pipe. Samples were composited for analysis. To determine the level of contamination after treatment, a sample of the explosives/debris was collected at the same three locations sampled prior to testing.

To determine the initial concentration of explosives that had permeated the pipe, one section of untreated clay pipe was ground for analysis. For safety purposes, the grinding operations were conducted inside of the flash chamber. The explosives/debris were first removed from the pipe section, using a teflon-coated scoop. The weight and volume of the debris were recorded. The pipe section was then placed inside a sturdy plastic bag and secured using rope. The bag was elevated inside the flash chamber (placed on coolers). A rope attached to the plastic bag was pulled through rail tracks. The chamber door was secured. The rope was pulled causing the section of pipe to fall and break. A piece of the broken pipe was collected and wiped to remove external explosives contamination. The wipe was retained for analysis. The wiped piece of pipe was placed inside a grinder. The grinder was located in the flash chamber, and its electrical cord was fed through the rail track gap and outside the chamber. The chamber door was secured and power to the grinder was initiated. The grinder operated through the timed cycle and stopped. The chamber door was opened and a ground sample was collected for analysis.

To determine the post-test concentrations of explosives remaining in the clay, sections of pipe from the following test runs were ground for analysis:

- 400°F/12 hours.
- 500°F/6 hours.
- 500°F/12 hours.
- 600°F/12 hours.

The pipe was ground using the same procedures described for pretest sampling.

7.1.1.5 Ship Mines

Ship mines were evaluated during nine test runs. The mines were contaminated with explosives (primarily TNT) and smokeless powder as a result of previous spiking activities by HWAAP personnel (not spiked as part of the pilot study). Since the mines were known to be contaminated, no screening or spiking was necessary.

To verify the presence of contaminants, wipe samples were collected before each test. Samples were collected from the inside of the ship mine (through access holes about 4 inches in diameter). A sampling template was not used to collect the wipe. The intent of sampling was not to quantify contaminants but to verify presence or absence. Acetonitrile was used for collection of explosives; ethanol was used for collection of smokeless powder. The test plan indicated that water would be used as the solvent for smokeless powder; however, based on conversations with HWAAP laboratory personnel, it was determined that ethanol would be the preferred solvent.

After each test run, wipe samples were collected for explosives and smokeless powder. Mines were sampled utilizing the same methodology as for pre-test samples, although different access holes were used. The test plan originally indicated that two ship mines would also be rinsed with solvent to determine the residual explosives and smokeless powder concentrations (1 gallon of water for smokeless powder followed by 1 gallon of acetonitrile for explosives). However, due to numerous access holes (top and both ends), it was determined that the mine could not contain the solvent.

7.1.1.6 Steel Pipe

Steel pipe was evaluated during four test runs (three tests evaluating TNT and one test evaluating ammonium picrate).

Numerous sections of steel pipe from the HWAAP inventory were screened using ethylenediamine. Only one section of steel pipe was determined to be contaminated with TNT. Contamination was present around the threaded ends of the 4-inch diameter pipe. This section of pipe was included for testing. A wipe sample was collected prior to the test to verify the presence of TNT. After the test run, a similar wipe sample was collected from a separate location on the threads to determine if detectable levels of TNT remained.

For the remaining tests, sections of steel pipe were purchased from a hardware store. Steel pipe from the inventory was not used primarily due to its length (15 to 20 feet), which would have made sampling activities cumbersome. The condition of most pipe was also poor (visible rust, dented, etc.). The purchased pipe varied in length from 5 to 10 feet and was 2 inches in diameter. The pipe sections evaluated in the TNT test runs were not flushed prior to the test. Prior to the test run that evaluated ammonium picrate, the pipe was flushed with 4 liters of acetonitrile (in four equal fractions of 1 liter) followed by 4 liters of water (in four equal fractions of 1 liter). One end of the pipe was sealed with parafilm wax. The solvent was added and the other end of the pipe was sealed. After flushing, the internal surface areas of the pipe sections were spiked following the procedures outlined in Appendix A.

After each test run, the pipe was sampled with acetonitrile (or water, as applicable). One end of the pipe was sealed with parafilm wax. Four successive 1-liter rinses of solvent were added to the pipe (multiple rinses as discussed in Subsection 7.1.1.1). The top end of the pipe was sealed with wax and the pipe was swirled. The top cover of wax was removed and the spent solvent for each rinse was collected for analysis.

7.1.1.7 Steam-Heated Discharge Valves

Steam-heated discharge valves were evaluated during four test runs (3 tests evaluating TNT and one test evaluating ammonium picrate). Screening using ethylenediamine was not conducted on steam-heated discharge valves, because the internal surface area was not accessible (1-inch steam connections did not allow sufficient entry). Rather, the test plan indicated that during the first few test runs, steam-heated discharge valves would be flushed with solvent (i.e., "decontaminated") and subsequently spiked with TNT. Following analysis of the rinsate, a decision would be made to continue flushing or to spike valves without initial flushing, as follows:

- If analysis of the rinsate indicated that explosive compounds were present, pre-test flushing would be discontinued. Valves would be spiked on an "as-is basis" to evaluate the effectiveness of the process on existing contamination, as well as spiked contamination.

- If analysis of the rinsate indicated that no detectable levels of explosive compounds were present, valves would be flushed with acetonitrile to remove any low levels of explosives and spiked with TNT, as discussed in Appendix A.

Preliminary flushing activities were conducted on the loading dock of Building 117-15. Due to the weight of the valves (about 225 pounds each), a crane was used in the flushing process. The valve was hoisted into the air and the *bottom steam connection* was sealed with parafilm wax. One-liter of acetonitrile was added to be jacket of the valve through the upper steam connection. The upper steam connection was sealed with parafilm wax and the valve was agitated. A sample of the rinsate was collected for analysis.

Preliminary flushes of the valves indicated the presence of HMX and DNT contamination. After the first test run (T3), based on conversations with USATHAMA, it was decided that for subsequent tests the valves would be spiked without prior flushing.

Prior to the test run that evaluated ammonium picrate, valves were flushed with 4 liters of acetonitrile (in four equal fractions of 1 liter) followed by 4 liters of water (in four equal fractions of 1 liter). This flushing was conducted to mitigate any potential interference from explosive compounds that may have been present (analytical results indicated that 2,4-DNT was present in the acetonitrile rinse). The valve was then spiked with ammonium picrate following the procedures outlined in Appendix A.

After each test run, the valves were rinsed with acetonitrile (or water, for ammonium picrate). Multiple rinsing was conducted as discussed in Subsection 7.1.1.1. Solvent was added to the jacket of the valve in fractions of 1 liter. The valves were agitated for about 2 minutes and samples were collected. This procedure was repeated four times (a total of four samples).

7.1.1.8 Aluminum Pipe

Aluminum pipe was evaluated during three test runs (two tests evaluating TNT and one test evaluating ammonium picrate). Aluminum pipe, measuring 6 feet in length and 2 inches in diameter, was evaluated. Two sections of aluminum pipe were available from the inventory at HWAAP. Screening activities with ethylenediamine did not indicate that the pipe sections were contaminated with explosives or ammonium picrate. One section of pipe was purchased from an outside vendor.

The procedures for flushing and spiking the aluminum pipe and for collecting post test samples were the same as those used for the steel pipe (Subsection 7.1.1.6).

7.1.1.9 Motors

Motors were tested during two test runs evaluating TNT. Prior to any testing, a motor (not one of the two used for testing) was soaked in acetonitrile to determine the initial explosives concentration. The motor was moved to the loading dock of Building 117-15. The gear reducer section of the motor was removed before soaking as it contained oil that would potentially present analytical interference. A portion of the oil from one of the three gear reducers was sampled to determine if explosive compounds were present. A crane was used to place the motor in a 55-gallon drum. Acetonitrile (108 liters or 28.5 gallons) was poured into the drum, covering approximately half of the motor. The lower half of the motor soaked for 24 hours. The motor was "flipped" so that the other portion could soak for the same time period. A sample of the motor soak was collected. The TNT concentration in this motor was assumed to be equivalent to the concentration in the remaining two motors since their industrial applications were similar. No pre-test spiking was conducted on the two remaining motors.

Following each test run, the treated motors were soaked following the same procedure used for pre-test characterization. Samples of the rinsate were collected for analysis.

7.1.2 AIR SAMPLING TECHNIQUES

7.1.2.1 Stack Testing Schedule

To demonstrate the destruction and removal efficiency (DRE) of the process, stack testing was conducted at the afterburner inlet and outlet. Stack tests were conducted during the first three test runs for explosives and smokeless powder. The operating conditions for stack testing were as follows:

- 500°F/36 hours.
- 400°F/24 hours.
- 500°F/24 hours.

Although the stack tests were not conducted during all phases of the test runs, they were conducted during the period over which emissions were highest (i.e., during combustion of the explosives in the vitrified clay pipe).

Based on conversations with USATHAMA, stack tests for the first test run were conducted over the following periods:

- Stack test 1
    - Six hours beginning when the temperature in the flash chamber was about 315°F.
    - Four hours after completion of stack test 1.
    - The last 6 hours of steady state conditions.

After the first test run, sampling times were changed based on field observations (combustion of material in clay pipe, and the appearance of the condensers from stack sampling trains, which seemed to indicate the majority of contamination was removed during the early portion of the test run). After discussions with USATHAMA, the remaining stack tests were conducted over the following periods:

- Stack tests 2 and 3
    - Six hours beginning when the air preheater was fired.
    - Six hours immediately following probe changeout from the first round of stack tests.
    - The last 4 hours of steady state conditions.

7.1.2.2 Ambient Air (Sample Point 1 in Figure 7-1)

Inlet air to the combustion air blower was sampled during all test runs to determine the moisture content. A sling psychrometer was used to measure the wet bulb and dry bulb temperatures. Temperatures were monitored every few hours during manned operation, beginning when the heat-up period commenced and ending at the completion of steady state conditions. Temperatures were used with a psychrometric chart to determine moisture content.

7.1.2.3 Combustion Air Blower Inlet Gases (Sample Point 2 in Figure 7-1)

Blower inlet gases were measured during startup (T0) to determine the volumetric flow rate to the air preheater. EPA Modified Methods 1 and 2 were used to determine the volumetric flow rate of blower inlet gases for damper settings of 25 percent, 50 percent, 75 percent, and 100 percent open. Copies of all sampling and analytical methods are contained in Appendix B. Corresponding flow rates were used to calibrate the existing flow indicator (i.e., piezometer) on the blower inlet. The piezometer was used during the remainder of test runs for determination of air flow rate. One reading from the piezometer was recorded (manually) every hour after startup of the air preheater during manned operation.

7.1.2.4 Air Preheater Discharge Gases (Sample Point 3 in Figure 7-1)

The air preheater discharge gases were sampled to determine the composition and gas flow rate to the flash chamber.

Total hydrocarbons (THC) in the preheater discharge gases were monitored during each test run by means of EPA Method 25A using a continuous emission monitor (CEM) employing a flame ionization detector (FID). Intermittent measurements between the air preheater discharge gases and the flash chamber discharge gases were taken every 5 to 15 minutes during manned and unmanned operation. A description of the CEM sampling system, calibration procedures, and data collection system is contained in Appendix C. The specifications for the FID are shown in Table 7-2.

Carbon dioxide (CO_2), carbon monoxide (CO), and oxygen (O_2) were monitored during the stack test program using a single point integrated EPA Method 3 sample train. A schematic of the sample train is shown in Figure 7-2. The Method 3 sampling trains consisted of the following components:

- A stainless steel or ceramic probe with a plug of glass wool to remove particulates.
- An air or water-cooled condenser to remove moisture from the sampled gases.
- A teflon-coated diaphragm pump to draw a sample of the gases.
- A Tedlar bag to contain the sample of the gases.

An Orsat apparatus was used to measure carbon dioxide and oxygen concentrations. Carbon monoxide content was determined through infrared absorption following EPA Method 10 procedures. The specifications for the nondispersive infrared (NDIR) gas analyzer are summarized in Table 7-3. Nine composite samples were collected and analyzed for carbon dioxide, carbon monoxide, and oxygen (i.e., one sample per train; three trains per test run sampled).

A modified EPA Methods 1 and 2 velocity traverse was performed during the stack test program to measure volumetric flow rate and to determine a point of average velocity across the traverse axis. During each stack test, the single point of average velocity was monitored continuously by means of a Type S pitot tube connected to a transducer. The transducer provided an electrical output signal (i.e., millivolts) to the CEM data recording system. The transducer was calibrated after each test run using a manometer. The average point of velocity was verified periodically during the stack testing program by conducting a complete EPA Method 2 velocity traverse. The moisture content of the air preheater discharge gases were measured using EPA Method 4 during each stack test.

7.1.2.5 Flash Chamber Discharge Gases

Flash chamber discharge gases were monitored to determine the destruction and removal efficiency (DRE) of the afterburner.

Table 7-2

Specifications for the CEM Flame Ionization Detector Used to Monitor Total Hydrocarbons (THC)

Analysis method:	Flame Ionization Detector
Sensitivity:	Maximum: 1 ppm methane (CH_4)
Response Time:	90 percent of full-scale in less than 1 second
Zero drift:	1 percent of full-scale per 24 hours
Span drift:	1 percent of full-scale per 24 hours
Linearity:	Less than 1 percent of selected range
Ranges:	Any three of the following: 0 to 10, 0 to 100, 0 to 1,000, 0 to 10,000, or 0 to 1,000,000 ppm
Outputs:	0 to 10 volts DC
Display:	Analog meter in ppm hydrocarbon

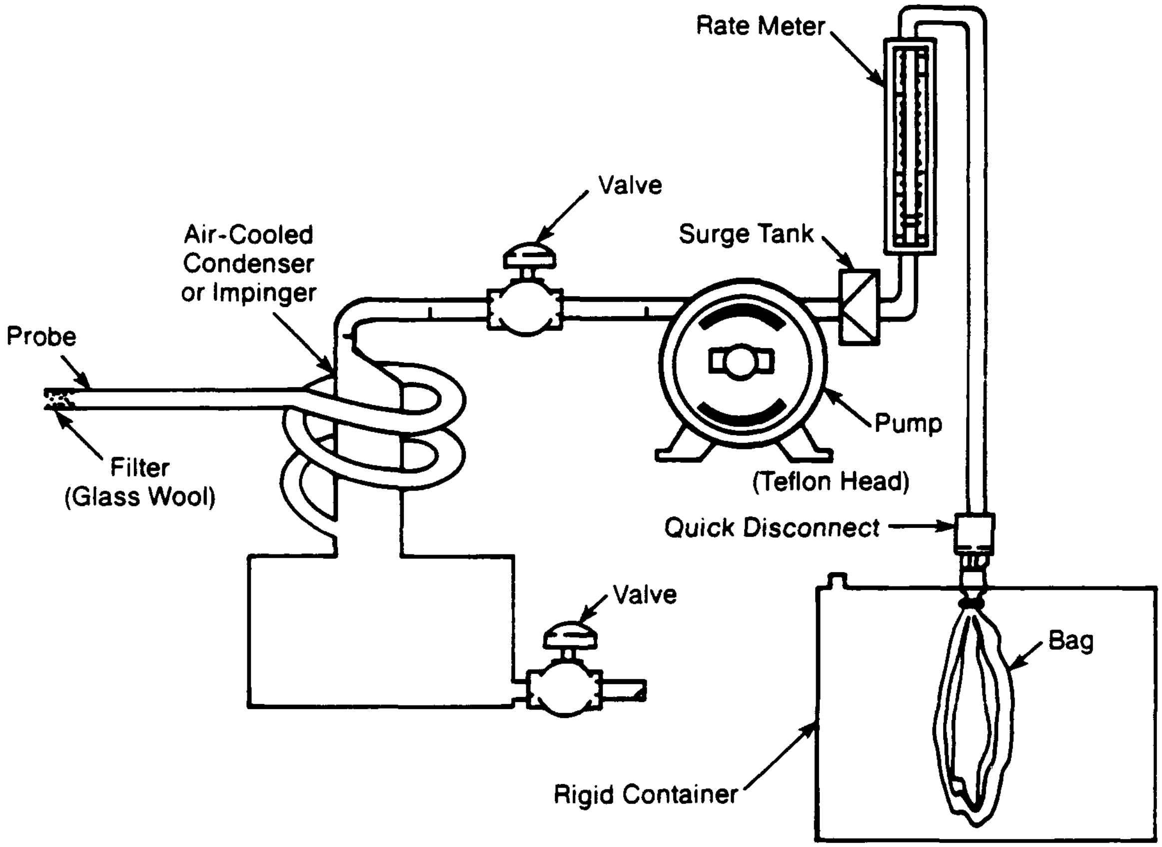


Figure 7-2. **Gas stream composition sampling train - EPA Method 3.**

Table 7-3

Specifications for the Nondispersive Infrared Gas Analyzer to Monitor Carbon Monoxide and Carbon Dioxide

Reliability/Accuracy:	±1 percent of full-scale*
Linearity:	±1 percent of full-scale
Noise level:	1 percent of full-scale
Zero drift:	±1 percent of full-scale/24 hours
Span drift:	±1 percent of full-scale/24 hours
Response time:	90 percent of reading in 1 second
Recorder output:	0 to 100 millivolts (mv)

*Full-scale adjustable.

Explosives were collected using an EPA Modified Method 5 sampling train. A schematic of the sample train is shown in Figure 7-3. The EPA Modified Method 5 sampling train consisted of the following components:

- A 316 stainless steel nozzle with an inside diameter sized to sample isokinetically.
- A heated, borosilicate-lined probe, equipped with a thermocouple to measure flue gas temperature and an S-type pitot tube to measure flue gas velocity pressure.
- A heated oven containing a borosilicate filter holder with a 90-millimeter Reeve Angel 934 AH glass fiber filter. A thermocouple was inserted in the filter box chamber.
- An impinger train consisting of a Grahm (spiral) type ice-water cooled condenser, two ice-water jacketed sorbent modules each containing approximately 40 grams of 30/60 mesh XAD-2 (preextracted), temperature sensors (thermocouples), a 1-liter condensate trap, two standard Greenberg-Smith impingers each containing 100 mL distilled water, and a final impinger containing 300 grams of dry, preweighed silica gel plus a thermocouple to detect sample gas exit temperature.
- A vacuum line (umbilical cord) to connect the outlet of the impinger train to a control module.
- A control module containing a 3 cubic foot per minute (cfm) carbon vane vacuum pump (sample gas mover); a calibrated dry gas meter (sample gas volume measurement device); a calibrated orifice (sample gas flow rate monitor); and inclined manometers (orifice and gas stream pressure indicators).
- A switchable calibrated digital pyrometer to monitor flue and sample gas temperatures.

Note that the train was further modified by the inclusion of an additional XAD-2 resin trap (total of two) to assure complete collection of target explosives. Sampling was conducted along the horizontal axis of the 18-inch inner diameter duct. A total of six points was sampled for 60 minutes each resulting in a total test time of 360 minutes.

Smokeless powder was collected during the stack test program on a separate EPA Method 5 sample train. A schematic of the sample train is shown in Figure 7-4. The Method 5 sample train consisted of the following components:

- A 316 stainless steel nozzle with an inside diameter sized to sample isokinetically.
- A heated, borosilicate-lined probe, equipped with a thermocouple to measure flue gas temperature, and an S-type pitot tube to measure flue gas velocity pressure.

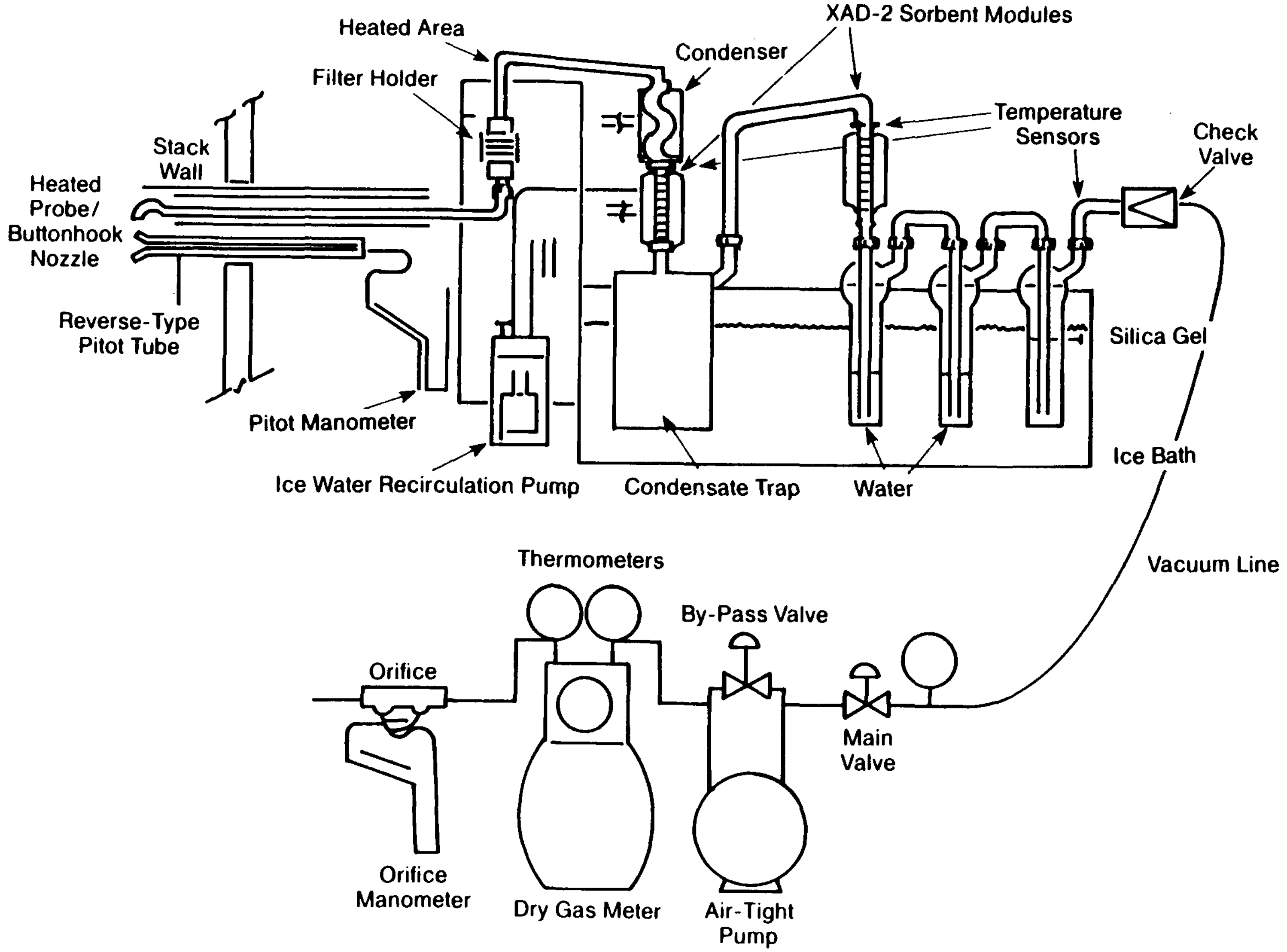
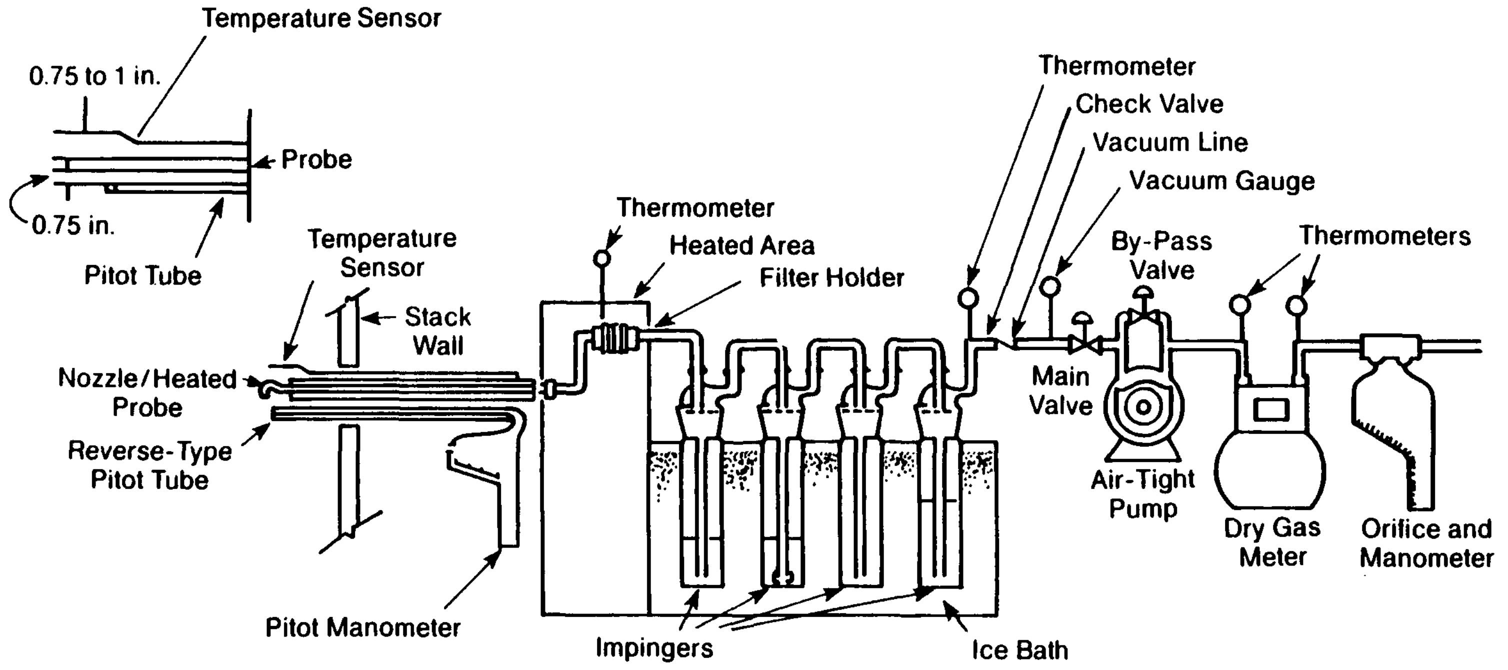


Figure 7-3. **EPA Modified Method 5 sampling train for collection of explosives.**



NOTES: A flexible sample line was used to connect the back half of the filter holder to the first impinger at the flash chamber outlet location for the collection of smokeless powder samples only.

Figure 7-4. **EPA Method 5 sampling train for collection of smokeless powder and particulate.**

- A heated oven containing a borosilicate filter holder with a 90-mm Reeve Angel 934 AH glass fiber filter.
- At the flash chamber outlet, a flexible teflon sample line was used to connect the back half of the filter holder to the first impinger.
- An impinger train containing four impingers: (1) 100 mL distilled water; (2) 100 mL distilled water; (3) dry; (4) 300 grams silica gel.
- A vacuum hose to connect the outlet of the impinger train to the control module.
- A control module containing a 3 cfm carbon vane vacuum pump (sample gas mover); a calibrated dry gas meter (sample gas volume measurement device); a calibrated orifice (sample gas flow rate monitor); and inclined manometers (orifice and gas stream pressure indicators).
- A switchable calibrated digital pyrometer to monitor flue and sample gas temperatures.

Total hydrocarbons in the flash chamber discharge gases were monitored during each test run by means of EPA Method 25A using a CEM FID. Intermittent measurements between the air preheater discharge gases and the flash chamber discharge gases were taken every 5 to 15 minutes during manned and unmanned operation.

Carbon dioxide and oxygen content was determined during the stack testing program using a multipoint integrated EPA Method 3 sampling train. A schematic of the sampling train for the air preheater discharge gases was shown in Figure 7-2. The method 3 probe was attached to the Modified Method 5 test train probe used for collection of explosives. An Orsat apparatus were used to measure carbon dioxide and oxygen concentrations. Carbon monoxide content was determined during the stack test program following Orsat analysis of the Tedlar bag by EPA Method 10 procedures. Nine composite samples were collected and analyzed for carbon dioxide, carbon monoxide, and oxygen (i.e., one sample per train, three trains per test run sampled).

Volumetric flow rate was determined by EPA Methods 1 and 2 during the stack test program. Moisture content was determined using the EPA Modified Method 5 sample train used for collection of explosives (one sample per train, nine trains total).

Semivolatile compounds and C_7-C_{17} hydrocarbons were also collected during the stack test program on the Modified Method 5 train used for collection of explosives. A portion of the extract from one of the Modified Method 5 trains was analyzed by means of gas chromatography.

7.1.2.6 Afterburner Discharge Gases

Afterburner discharge gases were monitored during the stack test program to determine the DRE and combustion efficiency of the afterburner.

Explosives were collected using an EPA Modified Method 5 sampling train. The train was further modified by the inclusion of an additional XAD-2 resin trap to assure complete collection of target explosives. A schematic of the sampling train for the flash chamber discharge gases was shown in Figure 7-3. Twenty-four test points were sampled during each test period (i.e., 12 per port axis). Each point was sampled for 15 minutes resulting in a total test time of 360 minutes. Readings (i.e., temperatures, pressures, etc.) were taken every 5 minutes during each test period.

Smokeless powder and particulates were collected during the stack test program using an EPA Method 5 sample train. A schematic of the sample train for the flash chamber discharge gases was shown in Figure 7-4.

Total hydrocarbons in the afterburner discharge gases were continuously monitored during each test run via EPA Method 25A using a CEM FID.

Carbon dioxide and carbon monoxide concentrations were measured continuously during each test run using a nondispersive infrared gas analyzer. Carbon dioxide was monitored following EPA Method 3A procedures. EPA Method 10 procedures were used to measure carbon monoxide content.

The concentration of oxygen in the afterburner discharge gases was monitored continuously during each test run using an electrochemical analyzer and following EPA Method 3A protocol. The specifications for the electrochemical analyzer are summarized in Table 7-4.

Nitrous oxides content was continuously monitored during each test run by means of a CEM analyzer using a chemiluminescent reaction and following the methodology outlined in EPA Method 7E. The specifications for the analyzer are summarized in Table 7-5.

Volumetric flow rate was determined during the stack test program using EPA Methods 1 and 2. Moisture content was determined using the EPA Modified Method 5 sample train used for collection of explosives.

Semivolatile compounds and C_7-C_{17} hydrocarbons were collected on the Modified Method 5 train used for collection of explosives. A portion of the extract from one of the Modified Method 5 trains was analyzed through gas chromatography.

7.2 MONITORING METHODS

An instrumentation diagram that illustrates the locations monitored is shown in Figure 7-5. A brief discussion of monitoring methods is included in the following subsections.

7.2.1 TEMPERATURE

Temperatures were monitored using Type J thermocouples (i.e., iron/constantan). A millivolt (mV) signal was transmitted from the thermocouples monitoring the vapor streams via a shielded pair conductor to the control panel. A real-time digital readout was provided. Temperatures of the streams were manually recorded once per hour during manned operation.

Table 7-4

Specifications for the Electrochemical Analyzer Used to Monitor Oxygen Content

Accuracy:	±2 percent of full-scale at 72°F - all ranges
Response time:	30 seconds for 90% response, 10 seconds typical for small step change
Stability:	2 percent of full-scale over 30 days typical

Table 7-5

Specifications for the Analyzer Used to Monitor Nitrous Oxide Content

Sensitivity:	0 to 2,500 ppm
Accuracy:	Derived from the NO or NO_2 calibration gas, ±1 percent of full-scale
Response time:	1.5 seconds - NO mode
(0 to 90 percent):	
Typical:	1.7 seconds - NO_x mode
Zero drift:	Negligible after 1/2-hour warm-up
Linearity:	±1 percent of full-scale

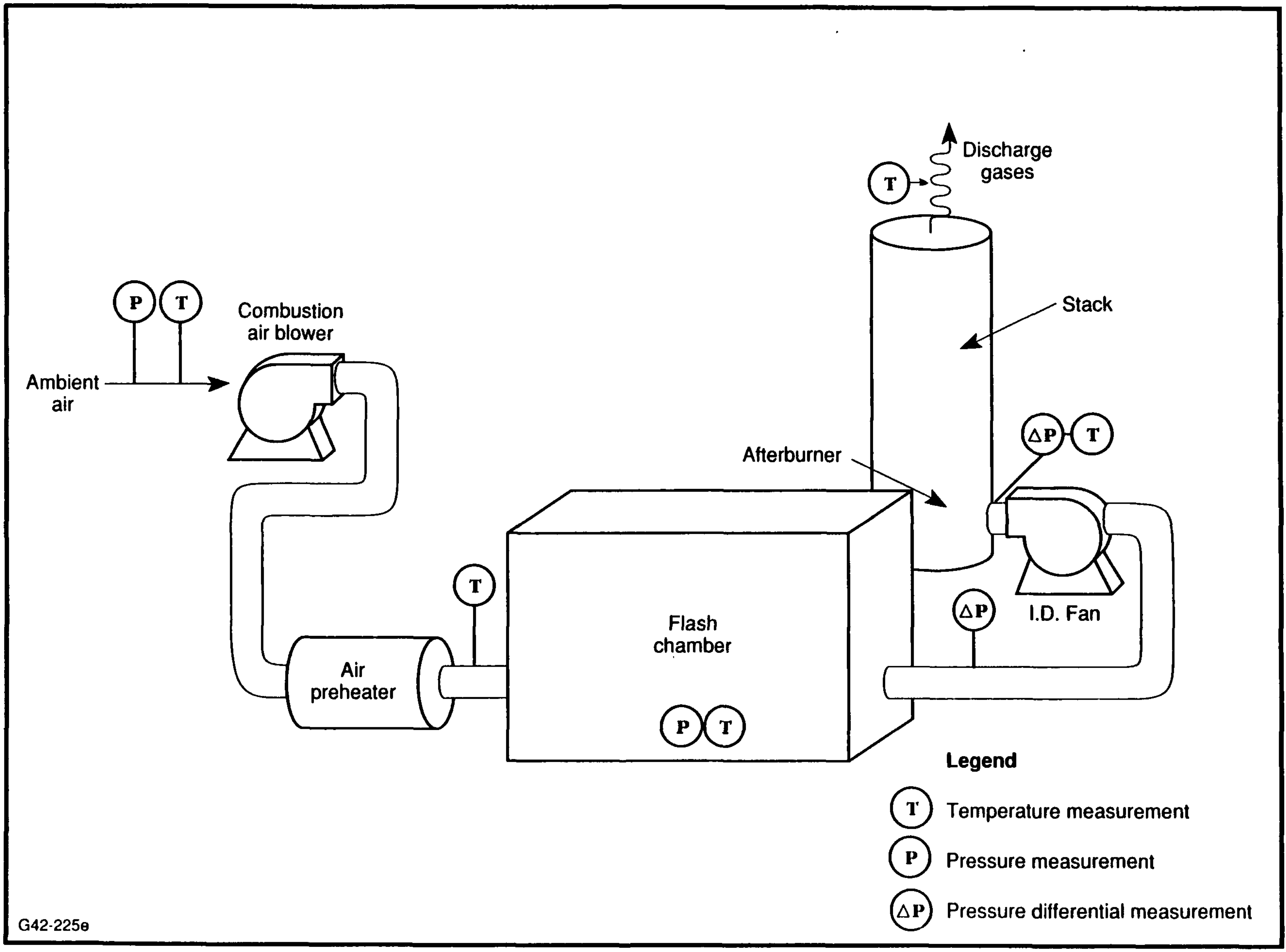


Figure 7-5. Instrumentation diagram.

Approximately 20 thermocouples monitored the internal and external temperatures of the equipment being treated, air temperature from the diffusers, the flash chamber walls, and the discharge air. The temperatures were recorded using a strip chart recorder.

7.2.2 PRESSURE

Pressure transmitters at the monitoring locations on the system transmitted a 4 to 20 mV signal to the control panel. A real-time readout was provided. Pressures were manually recorded once per hour during manned operation.

7.2.3 FLOW RATE

During start-up the piezometer on the combustion air blower was calibrated at various damper settings (i.e., 25, 50, 75, and 100 percent open) using a pitot tube. A curve that presented air flow rate versus piezometer reading was developed. During test runs, piezometer pressure readings were manually recorded during manned operation for conversion to flow rate.

7.2.4 WEIGHT

The mass of each test item was determined before and after each test run using a weigh scale. Readings were manually recorded.

7.2.5 DIMENSIONS

The dimensions of each test item were determined before and after each test run using a tape measure. Dimensions were manually recorded.

7.2.6 VISUAL MONITORING PLAN

7.2.6.1 Test Items

Prior to each test run, test items were visually inspected. Photographs of equipment were taken. Condition of the equipment was recorded (i.e., bumps, cracks, etc.). After testing, treated items were reinspected for deformation or damage, such as warping, cracking, spalding, splitting, peeling paint, and color change. Post-test condition was recorded. Damaged equipment was photographed.

7.2.6.2 Test Facility

Prior to field activities and after each test run, the interior of the flash chamber was inspected for signs of damage (i.e., warpage, deformation, cracking). Areas inspected included the walls (the false wall in particular), floor, and expansion joints. The door was also visually inspected for signs of leakage when closed. Any damage was photographed.

After several test runs, a small crack developed in the floor of the flash chamber near the entry door. The crack did not increase in size during subsequent test runs and did not affect, in any way, the loading or unloading of test items.

7.3 ANALYTICAL METHODS

A summary of the extraction/analytical methods used during the pilot study is contained on Table 7-6. Copies of all analytical methods are contained in Appendix B.

Table 7-6

Summary of Analytical Methods

Parameter	Ambient Air	Combustion Air Blower Inlet Gases	Air Preheater Discharge Gases	Test Equipment	Flash Chamber Discharge Gases	Afterburner Discharge Gases
Explosives	--	--	--	Modified Method LW02	EPA MM5 HPLC	EPA MM5 HPLC
Smokeless Powder (as nitrated esters)	--	--	--	Modified Method for NC, NG, and PETN in acetone	Spectra-Photometric Analysis	Spectra-Photometric Analysis
Ammonium Picrate (as picric acid)	--	--	--	Ammonium Picrate in water and wipe samples	--	--
Total Hydrocarbons	--	--	FID	--	FID	FID
Carbon Dioxide	--	--	Orsat	--	Orsat	Infrared Absorption
Carbon Monoxide	--	--	Infrared Absorption	--	Infrared Absorption	Infrared Absorption
Oxygen	--	--	Orsat	--	Orsat	Electrochemical Cell
Nitrous Oxides	--	--	--	--	--	Chemiluminescent Reaction
Particulates	--	--	--	--	--	Gravimetric
Semivolatile Compounds/C_7-C_{17} Hydrocarbons	--	--	--	--	EPA MM5 GC and GC/MS	EPA MM5 GC and GC/MS
Volumetric Flow Rate	--	MM1/MM2	M1/M2	--	M1/M2	M1/M2
Moisture Content	Sling psychrometer	--	M4	--	MM5	MM5

Notes: -- = Not monitored; N/A = monitored but an analytical method not applicable; FID = flame ionization detector; NC = nitrocellulose, NG = nitroglycerin; HPLC = high performance liquid chromatography; GC = gas chromatography; MS = mass spectrometry; MM5 = Modified Method 5; MM1 = Modified Method 1; MM2 = Modified Method 2; M2 = Method 2; M4 = Method 4.

SECTION 8

PRESENTATION OF DATA

The pilot investigation was conducted over a 10-week period from 10 July 1989 until 21 September 1989. Nine test runs were conducted to evaluate the time/temperature relationships for TNT decontamination; one test run was conducted to evaluate the effectiveness of the hot gas decontamination process for equipment contaminated with ammonium picrate.

Table 8-1 provides a summary of test conditions, contaminants evaluated, test items treated and test dates associated with each test.

8.1 SAMPLING AND MONITORING DATA

The test variables that were monitored during the pilot study were summarized in Table 6-1. Three types of data sheets were used to manually record data, as follows:

- Operational data (process temperatures, process pressures, damper positions, etc.).
- Test item temperatures (internal, external, etc).
- Test item general information (type, contaminant, dimensions, weight, etc).

Raw data sheets are contained in Appendix D. A hard copy printout of average values for parameters monitored by the continuous emissions monitor (CEM) system were provided once per minute. Hourly averages for these have been computed and are provided for each test run in Appendix E.

Data summaries are provided in the following Subsections. Summaries are presented for the following:

- Test items.
- Air preheater.
- Flash chamber.
- Afterburner.
- Stack test program.

8.1.1 TEST ITEMS

A summary of the variables monitored and recorded during manned operation for each test are presented in Table 8-2. Data summaries are provided for each test item evaluated.

Table 8-1

Summary of Test Conditions, Test Items Treated, and Test Dates

Test Run Number	Steady-State Testing Condition	Contaminant Evaluated	Test Items Treated	Start Date	End Date
T14	400°F/ 12 hrs	Explosives/ Smokeless Powder	Powder Box Steam-heated Riser Shell Support Rack Clay Pipe Steel Pipe Ship Mine	8/15/89	8/18/89
T2	400°F/ 24 hrs	Explosives/ Smokeless Powder	Powder Box Steam-heated Riser Shell Support Rack Clay Pipe Steel Pipe Ship Mine Steam-heated Discharge Valve	7/24/89	7/28/89
T8	400°F/ 36 hrs	Explosives/ Smokeless Powder	Powder Box Steam-heated Riser Shell Support Rack Clay Pipe Steel Pipe Ship Mine	8/3/89	8/8/89
T18	500°F/ 6 hrs	Explosives/ Smokeless Powder	Powder Box Steam-heated Riser Shell Support Rack Clay Pipe Ship Mine Motor	9/13/89	9/18/89
T13	500°F/ 12 hrs	Explosives/ Smokeless Powder	Powder Box Steam-heated Riser Shell Support Rack Clay Pipe Ship Mine Aluminum Pipe	8/9/89	8/14/89

Table 8-1

Summary of Test Conditions, Test Items Treated, and Test Dates
(continued)

Test Run Number	Steady-State Testing Condition	Contaminant Evaluated	Test Items Treated	Start Date	End Date
T5	500°F/ 24 hrs	Explosives/ Smokeless Powder	Powder Box Steam-heated Riser Shell Support Rack Clay Pipe Motor Ship Mine	7/28/89	8/2/89
T3	500°F/ 36 hrs	Explosives/ Smokeless Powder	Powder Box Steam-heated Riser Shell Support Rack Clay Pipe Steel Pipe Ship Mine Steam-heated Discharge Valve	7/16/89	7/21/89
T16	600°F/ 6 hrs	Explosives/ Smokeless Powder	Powder Box Steam-heated Riser Shell Support Rack Clay Pipe Ship Mine Steam-heated Discharge Valve	8/27/89	8/30/89
T15	600°F/ 12 hrs	Explosives/ Smokeless Powder	Powder Box Steam-heated Riser Shell Support Rack Clay Pipe Ship Mine Aluminum Pipe	8/22/89	8/27/89
T17	600°F/ 48 hrs	Ammonium Picrate	Powder Box Steam-heated Riser Steel Pipe Steam-heated Discharge Valve Aluminum Pipe	9/1/89	9/8/89

TABLE 8-2

INFORMATION ON TEST ITEMS
POWDER BOXES

	UNITS	TEST T2 400 F, 24 hr		TEST T3 500 F, 36 hr			TEST T5 500 F, 24 hr		TEST T8 400 F, 36 hr		TEST T13 500 F, 12 hr		TEST T14 400 F, 12 hr		TEST T15 600 F, 12 hr		TEST T16 600 F, 6 hr		TEST T17 600 F, 48 hr		TEST 118 500 F, 6 hr	
		#1	#2	#1	#2	#3	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
CONTAMINANT MASS (1)																						
Initial	g	10	10	10	10	BDL (2)	10	10	10	10	10	10	10	10	10	10	10	10	5		10	10
Final	mg	BDL	NA	BDL	NA	BDL	BDL	NA	2.41	BDL	BDL	NA	BDL	NA	BDL	NA	BDL	NA	BDL		BDL	NA
EQUIPMENT WEIGHT																						
Initial	lb	12	6	10	8	10	5	8	8	10.5	8	7.5	8	8.5	10.5	10.5	7.5	8.5	8		8.5	8
Final	lb	12	6	10	8	10	6	10	8.5	10.5	8	8	8	8.5	10.5	10.5	7.5	8.5	8		8.5	8
TIME TO REACH TEST TEMPERATURE	hr	18	NA	9	NA	NA	23	NA	7	NA	7	NA	7	NA	26	NA	NA	NA	16		7	NA
DURATION AT TEST TEMPERATURE	hr	14	NA	33	NA	NA	8	NA	36	NA	14	NA	2	NA	1	NA	NA	NA	21		9	NA
STEADY STATE TEMPERATURE																						
Internal (average)	F	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA
External (average)	F	392	NA	487	NA	NA	495	NA	439	NA	588	NA	387	NA	625	NA	554	NA	631		538	NA
HEAT-UP/STEADY STATE TEMPERATURE																						
Internal (average)	F	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA
External (average)	F	349	NA	446	NA	NA	444	NA	402	NA	501	NA	363	NA	456	NA	448	NA	551		442	NA
TOTAL TEST TEMPERATURE																						
Internal (average)	F	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA
External (average)	F	346	NA	433	NA	NA	369	NA	361	NA	400	NA	270	NA	415	NA	404	NA	551		266	NA
CHAMBER LOCATION		F1	F4	F4	F4	F1	M2	M5	F1	F4	F4	F2	F4	F1	F4	F1	F4	F1	R6		F1	F1

NA Not Evaluated for the test run.
BDL Below detection limit. The detection limit for TNT for powder boxes was 960 ug.
(1) TNT or Ammonium picrate (T17).
(2) Wipe sample collected following identification using ethylenediamine.
Wipe sample did not verify presence of TNT.
F-Front
M-Middle
R-Rear

Front	Middle	Rear	
1	2	3	DIFFUSERS
4	5	6	
	RAIL CAR		

TABLE 8-2 (cont'd)

STEAM-HEATED RISERS

	UNITS	TEST T2 400 F, 24 hr		TEST T3 500 F, 36 hr		TEST T5 500 F, 24 hr		TEST T8 400 F, 36 hr		TEST T13 500 F, 12 hr		TEST T14 400 F, 12 hr		TEST T15 600 F, 12 hr		TEST T16 600 F, 6 hr		TEST T17 600 F, 48 hr		TEST T18 500 F, 6 hr	
		#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
CONTAMINANT MASS (1)																					
Initial (2)	g	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	5		10	10
Final	mg	BDL	NA	BDL	BDL	BDL	NA	BDL	NA	BDL	NA	46.36	NA	BDL	NA	BDL	NA	BDL		BDL	NA
EQUIPMENT WEIGHT																					
Initial	lb	13	13	11	11	11	10	11	11.5	11.5	11.5	12	11.5	11.5	11.5	7.5	7	7.5		11.5	5.5
Final	lb	12	12	12	12	12	12	11.5	11.5	12	12	11.5	12	11.5	11.5	7.5	7.5	7.5		11.5	5.7
TIME TO REACH TEST TEMPERATURE	hr																				
Internal		24	NA	9	NA	23	NA	NA	17	NA	NA	8	NA	26	NA	NA	NA	12		8	NA
External		NA	NA	NA	NA	NA	NA	NA	15	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA
DURATION AT TEST TEMPERATURE	hr																				
Internal		8	NA	34	NA	8	NA	NA	27	NA	NA	8	NA	1	NA	NA	NA	NA		8	NA
External		NA	NA	NA	NA	NA	NA	NA	29	NA	NA	NA	NA	NA	NA	NA	NA	29		NA	NA
STEADY STATE TEMPERATURE																					
Internal (average)	F	382	NA	476	NA	484	NA	NA	399	NA	413	NA	NA	594	NA	590	NA	655		533	NA
External (average)	F	NA	NA	477	NA	486	NA	NA	402	NA	NA	398	NA	NA	NA	549	NA	NA		NA	NA
HEAT-UP/STEADY STATE TEMPERATURE																					
Internal (average)	F	333	NA	431	NA	412	NA	NA	352	NA	360	NA	NA	488	NA	474	NA	593		436	NA
External (average)	F	NA	NA	432	NA	425	NA	NA	358	NA	NA	367	NA	NA	NA	427	NA	NA		NA	NA
TOTAL TEST TEMPERATURE																					
Internal (average)	F	333	NA	419	NA	348	NA	NA	326	NA	303	NA	NA	451	NA	421	NA	590		265	NA
External (average)	F	NA	NA	420	NA	357	NA	NA	329	NA	NA	248	NA	NA	NA	392	NA	NA		NA	NA
CHAMBER LOCATION		F1	F4	M2	M5	M5	M5	M2	M2	M2	M5	M2	M2	M2	M2	F1	F4	M5		M2	M5

NA Not Evaluated for the test run.
BDL Below detection limit. The detection limit for TNT for steam-heated risers was 288 ug.

(1) TNT or Ammonium picrate (T17).
(2) Minimum contaminant mass; with the exception of T3, value represents minimum contaminant mass (riser not flushed prior to spiking). The riser in T3 was flushed prior to spiking as discussed in subsection 7.1.1.2.

F-Front
M-Middle
R-Rear

Front	Middle	Rear	
1	2	3	DIFFUSERS
4	5	6	

RAIL CAR

TABLE 8-2 (cont'd)

CLAY PIPE

	UNITS	TEST T0 UNTREATED	TEST T2 400 F 24 hr	TEST T3 500 F 36 hr	TEST T5 500 F 24 hr	TEST T8 400 F 36 hr	TEST T13 500 F 12 hr	TEST T14 400 F 12 hr	TEST T15 600 F 12 hr	TEST T16 600 F 6 hr	TEST T18 500 F 6 hr
SOIL/DEBRIS CONCENTRATION (1)		#1	#1	#1	#1	#1	#1	#1	#1	#1	#1
Initial	g/g		NA	0.15	0.57	0.06	0.51	0.55	1.25	0.2	0.04
Final	g/g		BDL	BDL	BDL	0.01	BDL	BDL	BDL	BDL	BDL
INTERNAL PIPE CONCENTRATION (1)											
Initial	mg/g	0.21	NA	NA	NA	NA	0.21	0.21	0.21	NA	NA
Final	mg/g	0.21	NA	NA	NA	NA	BDL	BDL	BDL	NA	NA
EQUIPMENT WEIGHT											
Initial	lb		88	90	100	141	72	97	93	147	127
Final	lb		87	90	96	120	69	92	95	125	113
TIME TO REACH TEST TEMPERATURE	hr										
Internal			11	9	13	10	9	8	9	7	8
External			10	NA	14	10	8	7	14	9	NA
DURATION AT TEST TEMPERATURE	hr										
Internal			21	36	18	33	12	8	18	7	8
External			22	NA	17	33	13	9	13	7	NA
STEADY STATE TEMPERATURE											
Internal (average)	F		411	507	518	444	588	420	656	609	359
External (average)	F		422	481	512	428	584	415	651	629	NA
HEAT-UP/STEADY STATE TEMPERATURE											
Internal (average)	F		348	459	453	361	486	377	503	439	450
External (average)	F		376	439	455	378	485	387	472	517	NA
TOTAL TEST TEMPERATURE											
Internal (average)	F		350	445	376	338	399	278	493	453	356
External (average)	F		372	426	378	347	400	286	464	515	NA
CHAMBER LOCATION			R3	R3	R3	R3	R3	R3	R3	R3	R3

NA Not Evaluated for the test run.
BDL Below detection limit. The detection limit for TNT for clay pipe was 1.92 ug/g.
(1) TNT.
F-Front
M-Middle
R-Rear

Front	Middle	Rear	
1	2	3	DIFFUSERS
4	5	6	
	RAIL CAR		

TABLE 8-2 (cont'd)

SHELL SUPPORT RACKS

	UNITS	TEST T2 400 F, 24 hr		TEST T3 500 F, 36 hr		TEST T5 500 F, 24 hr		TEST T8 400 F, 36 hr		TEST T13 500 F, 12 hr		TEST T14 400 F, 12 hr		TEST T15 600 F, 12 hr		TEST T16 600 F, 6 hr		TEST T18 500 F, 6 hr	
		#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
TOP SHELF CONTAMINANT MASS (1)																			
Initial (2)	g	0.88	0.86	0.84	0.87	0.60	0.65	0.79	0.79	0.62	0.91	0.46	0.65	0.67	0.73	0.85	0.84	1	1
Final (2)	mg	BDL	NA	BDL	NA	BDL	NA	BDL	NA	BDL	NA	0.07	NA	BDL	NA	BDL	NA	BDL	NA
BOTTOM SHELF CONTAMINANT MASS (1)																			
Initial (2)	mg	BDL	BDL	4.65	3.52	0.87	BDL	2.18	0.04	BDL	BDL	BDL	BDL	BDL	3.13	0.83	2.08	2.53	BDL
Final (2)	mg	BDL	NA	BDL	NA	NA	BDL	BDL	NA	BDL	NA	BDL	NA	BDL	NA	BDL	NA	BDL	NA
EQUIPMENT WEIGHT																			
Initial	lb	85	87	70	75	86	84	71	86	87	87	86	86	86	72	87	71	73	86
Final	lb	80	87	68	75	87	86	71	85	87	87	86	86	86	72	87	71	73	86
TIME TO REACH TEST TEMPERATURE	hr	13	NA	15	NA	14	NA	9	NA	NA	7	9	8	26	NA	NA	NA	NA	NA
DURATION AT TEST TEMPERATURE	hr	19	NA	36	NA	17	NA	35	NA	NA	14	2	8	1	NA	NA	NA	NA	NA
STEADY STATE TEMPERATURE																			
Internal (average)	F	NA	NA	NA	NA	NA	NA	NA	NA	NA	596	NA	NA	NA	NA	NA	NA	NA	NA
External (average)	F	402	NA	487	NA	512	NA	422	NA	622	508	383	397	630	NA	NA	NA	NA	NA
HEAT-UP/STEADY STATE TEMPERATURE																			
Internal (average)	F	NA	NA	NA	NA	NA	NA	NA	NA	NA	497	NA	NA	NA	NA	NA	NA	NA	NA
External (average)	F	359	NA	447	NA	453	NA	389	NA	537	467	354	371	476	NA	NA	NA	NA	NA
TOTAL TEST TEMPERATURE																			
Internal (average)	F	NA	NA	NA	NA	NA	NA	NA	NA	NA	404	NA	NA	NA	NA	NA	NA	NA	NA
External (average)	F	355	NA	434	NA	375	NA	348	NA	432	381	244	249	431	NA	NA	NA	NA	NA
CHAMBER LOCATION		M2	M2	M2	M5	M2	M5	M5	M2	M5	M2	M2	M5	M2	M5	M2	M5	M2	M2

NA Not Evaluated for the test run.
BDL Below detection limit. The detection limit for TNT for shell support racks was 19.2 ug.

(1) TNT.
(2) Mass corresponds to 5 inch by 5 inch sample area.
F Front
M Middle
R Rear

Front	Middle	Rear	
1	2	3	DIFFUSERS
4	5	6	

RAIL CAR

TABLE 8-2 (cont'd)

SHIP MINES

	UNITS	TEST T2 400 F, 24 hr		TEST T3 500 F, 36 hr		TEST T5 500 F, 24 hr		TEST T8 400 F, 36 hr		TEST T13 500 F, 12 hr		TEST T14 400 F, 12 hr		TEST T15 600 F, 12 hr		TEST T16 600 F, 6 hr		TEST T18 500 F, 6 hr	
		#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
A. TNT CONTAMINANT PRESENCE																			
Initial		NA		NO		NO		YES		YES		NO		YES		YES		YES	
Final		NO		NO		NO		NO		NO		NO		NO		NO		NO	
B. NITRATED ESTERS CONTAMINANT PRESENCE																			
Initial		NA		NO		NO		YES		YES		NO		YES		NO		YES	
Final		NO		NO		YES		YES		NO		NO		NO		NO		NO	
EQUIPMENT WEIGHT																			
Initial	lb	728		730		725		719		717		736		730		748		769	
Final	lb	732		730		722		719		714		741		724		747		728	
TIME TO REACH TEST TEMPERATURE	hr																		
Internal		14		6		23		13		NA		8		13		9		8	
External		8		5		10		7		10		7		12		9		6	
DURATION AT TEST TEMPERATURE	hr																		
Internal		18		38		8		31		0		8		13		7		8	
External		24		40		21		37		2		9		15		7		10	
STEADY STATE TEMPERATURE																			
Internal (average)	F	398		543		504		406		447		399		693		628		521	
External (average)	F	433		596		540		426		489		403		701		649		562	
HEAT-UP/STEADY STATE TEMPERATURE																			
Internal (average)	F	347		499		443		360		362		369		560		507		414	
External (average)	F	388		551		488		396		401		381		615		492		488	
TOTAL TEST TEMPERATURE																			
Internal (average)	F	348		483		371		334		302		255		510		446		257	
External (average)	F	385		533		400		355		329		262		563		472		296	
CHAMBER LOCATION		R6		R6		R6		R6		R6		R6		R6		R6		R6	

NA Not Evaluated for the test run.
BDL Below detection limit.
F-Front
M-Middle
R-Rear

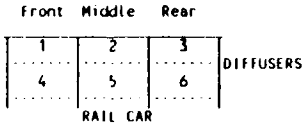


TABLE 8-2 (cont'd)

STEEL PIPE (1)

	UNITS	TEST T2 400 F, 24 hr		TEST T3 500 F, 36 hr			TEST T5 500 F, 24 hr		TEST T8 400 F, 36 hr		TEST T13 500 F, 12 hr		TEST T14 400 F, 12 hr		TEST T15 600 F, 12 hr		TEST T16 600 F, 6 hr		TEST T17 600 F, 48 hr		TEST T18 500 F, 6 hr	
		#1	#2	#1	#2	#3	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
CONTAMINANT MASS (2)																						
Initial	g	(3)							10				10	NA					5			
Final	mg	BDL							BDL				BDL	NA					BDL			
EQUIPMENT WEIGHT																						
Initial	lb	NA							21				21	NA					21			
Final	lb	NA							21				21	NA					21			
TIME TO REACH TEST TEMPERATURE	hr	(4)							9					(4)					(5)			
DURATION AT TEST TEMPERATURE	hr	(4)							34				(4)						(5)			
STEADY STATE TEMPERATURE	F	376							422				360	399					(5)			
HEAT-UP/STEADY STATE TEMPERATURE	F	334							385				332	370					(5)			
TOTAL TEST TEMPERATURE	F	333							346				233	277					(5)			
CHAMBER LOCATION		M5							M5				M5	M2					R5			

NA Not Evaluated for the test run.
BDL Below detection limit. The detection limit for TNT for steel pipe was 960 ug.

(1) Not included in test runs #3, 5, 13, 15, 16, and 18.
(2) TNT or Ammonium picrate (T17).
(3) Presence of TNT identified by testing with ethylenediamine.
Wipe sample did not verify presence of TNT.
(4) Test item did not reach test temperature.
(5) Temperatures not recorded due to malfunctioning thermocouple.
F-Front
M-Middle
R-Rear

Front	Middle	Rear	
1	2	3	DIFFUSERS
4	5	6	

RAIL CAR

TABLE 8-2 (cont'd)

STEAM-HEATED VALVES (1)

	UNITS	TEST T2 400 F, 24 hr		TEST T3 500 F, 36 hr		TEST T5 500 F, 24 hr		TEST T8 400 F, 36 hr		TEST T13 500 F, 12 hr		TEST T14 400 F, 12 hr		TEST T15 600 F, 12 hr		TEST T16 600 F, 6 hr		TEST T17 600 F, 48 hr		TEST T18 500 F, 6 hr	
		#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
CONTAMINANT MASS (2)																					
Initial (3)	g	10	10	10	10											10	10	5			
Final	mg	9.6	NA	BDL	NA											BDL	NA	BDL			
EQUIPMENT WEIGHT																					
Initial	lb	210	190	250	240											200	188	255			
Final	lb	210	190	250	240											200	191	254			
TIME TO REACH TEST TEMPERATURE	hr																				
Internal		24	NA	NA	10											NA	(4)	14			
External		NA	NA	NA	9											NA	(4)	13			
DURATION AT TEST TEMPERATURE	hr																				
Internal (2)		8	NA	35	NA											NA	(4)	22			
External		NA	NA	36	NA											NA	(4)	23			
STEADY STATE TEMPERATURE																					
Internal (average)	F	384	NA	488	NA											NA	578	636			
External (average)	F	NA	NA	494	NA											NA	456	621			
HEAT-UP/STEADY STATE TEMPERATURE																					
Internal (average)	F	324	NA	438	NA											NA	469	562			
External (average)	F	NA	NA	449	NA											NA	357	565			
TOTAL TEST TEMPERATURE																					
Internal (average)	F	327	NA	425	NA											NA	417	561			
External (average)	F	NA	NA	436	NA											NA	340	561			
CHAMBER LOCATION		M2	M2	M2	M2											M2	M5	F1			

NA Not Evaluated for the test run.
BDL Below detection limit. The detection limit for steam-heated discharge valves was 960 ug.

(1) Not included in test runs #5, 8, 13, 14, 15 and 18.
(2) TNT or Ammonium picrate (T17).
(3) Minimum contaminant mass; with the exception of T3, (valve not flushed prior to spiking). The remainder of valves were flushed prior to spiking as discussed in subsection 7.1.1.2.
(4) Test item did not reach test temperature.
F-Front
M-Middle
R-Rear

Front	Middle	Rear
1	2	3
4	5	6

DIFFUSERS

RAIL CAR

TABLE 8-2

ALUMINUM PIPE (1)

	UNITS	TEST T2 400 F, 24 hr		TEST T3 500 F, 36 hr			TEST T5 500 F, 24 hr		TEST T8 400 F, 36 hr		TEST T13 500 F, 12 hr		TEST T14 400 F, 12 hr		TEST T15 600 F, 12 hr		TEST T16 600 F, 6 hr		TEST T17 600 F, 48 hr		TEST T18 500 F, 6 hr	
		#1	#2	#1	#2	#3	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
CONTAMINANT MASS (2)																						
Initial	g										10	10			10				5			
Final	mg										BDL	NA			BDL				BDL			
EQUIPMENT WEIGHT																						
Initial	lb										5.5	5.5			5.5				14			
Final	lb										5.5	5.5			5.5				14			
TIME TO REACH TEST TEMPERATURE	hr										10	NA			26				32			
DURATION AT TEST TEMPERATURE	hr										2	NA			1				13			
STEADY STATE TEMPERATURE																						
Internal (average)	F										423	NA			594				601			
External (average)	F										NA	NA			NA				NA			
HEAT-UP/STEADY STATE TEMPERATURE																						
Internal (average)	F										372	NA			506				526			
External (average)	F										NA	NA			NA				NA			
TOTAL TEST TEMPERATURE																						
Internal (average)	F										300	NA			453				526			
External (average)	F										NA	NA			NA				NA			
CHAMBER LOCATION											M5	M2			M5				R3			

NA Not Evaluated for the test run.
BDL Below detection limit. The detection limit for TNT for aluminum pipe was 960 ug.

(1) Only evaluated for test runs #13, 15, and 17.
(2) TNT or Ammonium picrate (T17).
F-Front
M-Middle
R-Rear

Front	Middle	Rear	
1	2	3	DIFFUSERS
4	5	6	

RAIL CAR

TABLE 8-2 (cont'd)

MOTORS (1)

	UNITS	TEST T2 400 F, 24 hr		TEST T3 500 F, 36 hr		TEST T5 500 F, 24 hr		TEST T8 400 F, 36 hr		TEST T13 500 F, 12 hr		TEST T14 400 F, 12 hr		TEST T15 600 F, 12 hr		TEST T16 600 F, 6 hr		TEST T17 600 F, 48 hr		TEST T18 500 F, 6 hr	
		#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
CONTAMINANT MASS																					
Initial (2)	g					0.45														0.45	
Final	mg					BDL														BDL	
EQUIPMENT WEIGHT																					
Initial	lb					932														941	
Final	lb					919														942	
TIME TO REACH TEST TEMPERATURE	hr																				
Internal						23														(3)	
External						23														NA	
DURATION AT TEST TEMPERATURE	hr																				
Internal						8														(3)	
External						8														NA	
STEADY STATE TEMPERATURE																					
Internal (average)	F					489														434	
External (average)	F					500														NA	
HEAT-UP/STEADY STATE TEMPERATURE																					
Internal (average)	F					434														360	
External (average)	F					442														NA	
TOTAL TEST TEMPERATURE																					
Internal (average)	F					366														241	
External (average)	F					372														NA	
CHAMBER LOCATION						F2														M5	

NA Not Evaluated for the test run.
BDL Below detection limit. The detection limit for TNT for motors was 0.96 ug/ml.

(1) Only evaluated for test runs #5 and #18.
(2) Estimated contaminant mass.
(3) Motor did not reach test temperature.
F-Front

Front	Middle	Rear	
1	2	3	DIFFUSERS
4	5	6	

RAIL CAR

Duplicate pieces of some test items were included, where available, as a precaution so that a spare item could be sampled and analyzed in the event of field or laboratory contamination. The spare test item was not sampled unless warranted. Therefore, for each set of test conditions shown on Table 8-2, multiple test items are shown (i.e., 1, 2). Item 1 was generally used for sampling and analyses purposes. In some cases, thermocouples were attached to the spare item. For powder boxes, one box that was determined to be contaminated with TNT using ethylenediamine was included in Test 3 (T3). The box was not sampled or spiked prior to the test run. This item is represented by Item 3 on Table 8-2.

With the exception of ship mines, the initial and final mass of contaminants are provided. In the case of ship mines, the presence or absence of contaminants is noted since no attempts were made to quantify the pre- or post-test levels. Also, as discussed in Subsection 9.3, the method utilized by the laboratory for the analysis of wipe samples for smokeless powder (nitrocellulose (NC) and nitroglycerin (NG)) is a nonspecific method; it does not allow for NC and NG to be distinguished from one another or from other nitrated esters. Total nitrated esters, therefore, are reported as present or absent. In the cases where nitrated esters were present, the contaminant is presumed to be NC and NG; however, other nitrated esters may present a bias. Where possible, the initial mass of contaminant was determined through analysis and is provided on Table 8-2 (e.g., vitrified clay pipe). In some cases, however, the initial mass is unknown since some test items were spiked without prior flushing (to evaluate existing contamination). In those cases, the initial mass listed on Table 8-2 represents only the amount of TNT or ammonium picrate added during spike procedures. The actual initial mass may be higher. These cases are footnoted for reference.

The final contaminant mass was calculated based on the following information:

- The concentration as determined by the field laboratory and WESTON's Analytics Division (ug/g for solid samples, ug/L for rinsate samples or ug/square inch for wipe samples).
- The total mass, volume or surface area of the sample in question (gram of solid material, mL of rinsate, or template surface area).

BDL signifies that the concentration was below the analytical detection level. A further discussion of the analytical data, including detection levels, is discussed in Subsection 8.2 (Analytical Data). Spare items that were not analyzed for final contaminant mass show "not applicable" in the entry for final contaminant concentration.

The initial and final weight corresponding to each piece of equipment is shown. The accuracy of the scale was ± 1 pound.

As discussed in Subsection 6.2.2.3, the temperature of the discharge air from the flash chamber was used as an indication for when the target temperature was achieved. Once the chamber reached and maintained, the target temperature, steady state operation commenced. Although steady state conditions were maintained for each specific residence time, some test items reached target temperature before the discharge air. In these cases, the time that the test item was at or above target temperature was greater than the target residence time. For other items of equipment, target temperature was never achieved (probably due to location on the rail cart, potentially poor air circulation, etc.). The hours required for each test item to reach target temperature, as well as the hours the item remained at the test temperature, were determined and are provided on Table 8-2.

Personnel evacuated the site when steady state conditions commenced and the process was operating smoothly; operations were manned during afterburner and air preheater heat-up. Therefore, if an item reached target temperature shortly after steady state conditions commenced, the first record that the test item reached target temperature would not occur until manned operation resumed (8 to 12 hours later). The hours to reach steady state, as well as hours at steady state, therefore, are somewhat misleading. It was not possible to estimate the time that the target temperature was reached, based on an interpolation of recorded data.

Test item temperatures are presented for the following periods:

- Steady state (according to the discharge air temperature).
- Heat-up and steady state.
- Total test (heat-up, steady state and cooldown).

Average temperatures for each time period are shown; hourly temperatures recorded during manned operation were used in calculations.

Finally, the location of each test item on the rail car is provided. A schematic is shown on the bottom of Table 8-2; the key corresponding to each portion of the rail car is shown.

8.1.2 AIR PREHEATER

Data summaries for the air preheater are shown on Table 8-3. Information for each test run is provided.

The average dry bulb and wet bulb temperatures of ambient air monitored during manned operation are provided. These temperatures were used in conjunction with a psychrometric chart to determine the average ambient air moisture content.

Average volumetric flow rates to the air preheater are shown for steady state, heatup and steady state, and total test time. Flow rates represent the average values collected during manned and unmanned operation ("spot" checks).

The temperature of the discharge gas from the air preheater is shown for the same three time periods. Temperatures are average values corresponding to data recorded during manned and unmanned operation (extracted from strip chart recordings or recording during "spot" checks).

The composition of the discharge gas (concentration of carbon monoxide, carbon dioxide, and oxygen) was determined during the stack test program.

TABLE 8-3

DATA SUMMARY FOR AIR PREHEATER

	UNITS	TYPE OF VARIABLE	TEST T2 400 F, 24 hr		TEST T3 500 F, 36 hr		TEST T5 500 F, 24 hr		TEST T8 400 F, 36 hr	TEST T13 500 F, 12 hr	TEST T14 400 F, 12 hr	TEST T15 600 F, 12 hr	TEST T16 600 F, 6 hr	TEST T17 600 F, 48 hr	TEST T18 500 F, 6 hr
AMBIENT AIR TEMPERATURE		Independent													
Dry Bulb Temperature (average)	deg F		80		83		85		79	79	78	74	81	79	79
Wet Bulb Temperature (average)	deg F		66		57		59		59	65	53	57	59	62	59
AMBIENT AIR MOISTURE CONTENT *	lb H20/ lb dry air	Independent	0.1002		0.0035		0.004		0.0062	0.01	0.003	0.0054	0.0059	0.008	0.0062
VOLUMETRIC FLOW RATE		Response													
Steady State (average)	dscfm		1445		1445		1490		1525	1445	1395	1430	1445	NA	1375
Heat-Up/Steady State (average)	dscfm		1445		1430		1445		1490	1395	1375	1430	1430	NA	1395
Total Test (average)	dscfm		1445		1430		1375		1395	1375	1323	1395	1430	NA	1375
DISCHARGE GAS TEMPERATURE		Control, constant at various levels													
Steady State (average)	deg F		723		947		893		652	1084	737	1133	1048	NA	993
Heat-Up/Steady State (average)	deg F		733		907		842		642	1006	692	987	800	NA	894
Total Test (average)	deg F		671		837		530		351	676	692	890	766	NA	533
DISCHARGE GAS COMPOSITION		Response	CEM		CEM		CEM								
Total Hydrocarbons (THC)															
Steady State (average)	ppm/v		31.9	29.6	41.8	49	42.6	32.2	46.4	58.6	41.2	35.8	34.9	58	24.8
Heat-Up/Steady State (average)	ppm/v		31.7	39.8	41.8	33.1	37	50.8	45.8	52.5	35.9	40.2	42.8	52.5	26.8
Total Test (average)	ppm/v		12.9	45.6	40.6	38.2	26.1	45.8	29.5	43.3	25.1	33.6	42.8	35.8	5.95

* Generated from Psychometric Chart

NA Not analyzed
dscfm Dry standard cubic feet per minute
ppm/v Part per million by volume

The concentration of THC was monitored continuously by the CEM. The source of THC in the air preheater discharge gases is propane fuel. Hourly CEM averages are shown in Appendix E. Table 8-3 contains averages of data collected by WESTON personnel during manned operation and by the CEM system during unmanned operation (after reaching steady state). Average data values are provided for steady state, heatup and steady state, and total time (heatup, steady state, and cooldown).

8.1.3 FLASH CHAMBER

Data corresponding to the flash chamber are summarized on Table 8-4. Average data values corresponding to each test run are shown. Data represent average values recorded during manned and unmanned operation (extracted from strip chart recorder or recorded during "spot" checks). Average data values are provided for the following time periods:

- Steady state.
- Heat-up and steady state.
- Total time (heat-up, steady state and cooldown).

The draft (static pressure) in the flash chamber was maintained at a slight negative pressure to prevent potential fugitive emissions. As shown on Table 8-4, the average draft for the flash chamber was -0.1 inwg.

The discharge gas temperature from the flash chamber was used to determine the point at which the target temperature was achieved. The thermocouple used for this determination was located in the discharge duct leading from the flash chamber. Average values determined from data recorded during manned and unmanned operation (extracted from strip chart recorder or recorded during "spot" checks) are provided.

To evaluate the heat distribution in the flash chamber, thermocouples were attached to the walls and floor of the flash chamber. Average data values collected during manned operation and unmanned operation (extracted from strip chart recorder or recorded during "spot" checks) are shown on Table 8-3.

A summary of the composition of the flash chamber discharge gases (carbon dioxide, carbon monoxide, and oxygen) as determined during the stack test program is provided.

Average values corresponding to the THC concentration are also included. Values represent average data recorded during manned operation and hourly CEM averages. Hourly averages recorded by the CEM system are provided in Appendix E.

8.1.4 AFTERBURNER

Data summaries for the afterburner are presented in Table 8-5. Average values are provided for data recorded during manned operation and unmanned operation (extracted from strip chart recorder or recorded during "spot" checks) for the following time periods:

- Steady state.
- Heat-up and steady state.
- Total time (heat-up, steady state and cooldown).

TABLE 8-4

DATA SUMMARY FOR FLASH CHAMBER

	UNITS	TYPE OF VARIABLE	TEST T2 400 F, 24	TEST T3 500 F, 36	TEST T5 500 F, 24	TEST T8 400 F, 36 hr	TEST T13 500 F, 12 hr	TEST T14 400 F, 12 hr	TEST T15 600 F, 12 hr	TEST T16 600 F, 6 hr	TEST T17 600 F, 48 hr	TEST T18 500 F, 6 hr
FLASH CHAMBER DRAFT		Control, constant at all levels.										
Steady State (average)	inwg		-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Heat-Up/Steady State (average)	inwg		-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Total Test (average)	inwg		-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
DISCHARGE GAS TEMPERATURE		Control, constant at various levels.										
Steady State (average)	deg F		422	527	535	432	487	429	643	605	610	513
Heat-Up/Steady State (average)	deg F		385	490	491	403	429	415	510	494	524	240
Total Test (average)	deg F		378	475	393	360	329	277	465	434	524	190
INTERNAL FLASH CHAMBER TERMPERATURE		Response										
Middle Wall												
Steady State (average)	deg F		290	362	361	293	394	303	640	534	649	364
Heat-Up/Steady State (average)	deg F		255	328	312	260	340	289	475	384	567	418
Total Test (average)	deg F		256	321	281	255	288	227	429	381	567	326
Floor												
Steady State (average)	deg F		244	351	340	275	372	324	603	524	631	390
Heat-Up/Steady State (average)	deg F		212	315	289	242	292	301	431	399	549	307
Total Test (average)	deg F		215	308	270	243	273	225	400	369	545	203
DISCHARGE GAS COMPOSITION		Response										
Carbon Monoxide (CO)*												
Stack test 1	ppm		1.2	1.4	1.2	NA	NA	NA	NA	NA	NA	NA
Stack test 2	ppm		1.1	1.3	1.6	NA	NA	NA	NA	NA	NA	NA
Stack test 3	ppm		1.1	1.1	1.6	NA	NA	NA	NA	NA	NA	NA
Carbon Dioxide (CO2)*												
Stack test 1	%		86.7	19	1060	NA	NA	NA	NA	NA	NA	NA
Stack test 2	%		92.8	100.4	171.2	NA	NA	NA	NA	NA	NA	NA
Stack test 3	%		122.7	169	188.5	NA	NA	NA	NA	NA	NA	NA
Oxygen (O2)*												
Stack test 1	%		16.2	17.2	18.1	NA	NA	NA	NA	NA	NA	NA
Stack test 2	%		18.4	17.5	17.4	NA	NA	NA	NA	NA	NA	NA
Stack test 3	%		18.3	17.6	17.5	NA	NA	NA	NA	NA	NA	NA
Total Hydrocarbons (THC as propane)												
Steady State (average)	ppm/v		31.2	33.7	56.1	36	22.9	31.8	19.1	28	38.7	11.9
Heat-Up/Steady State (average)	ppm/v		29.2	31.9	47.6	35.8	29.6	29.7	22.5	25.2	35.6	9.5
Total Test (average)	ppm/v		26.3	30.7	34.6	23.8	26.6	22.1	21.0	25.2	25.8	16.4

* Measured during first three stack tests, data presented in Tables 8-5, 8-6, 8-7.
NA Not analyzed
** Due to malfunctioning thermocouple, discharge gas temperatures for T18 estimated from molytek strip chart recorder.
ppm/v part per million by volume.

TABLE 8-5

DATA SUMMARY FOR AFTERBURNER

	UNITS	TYPE OF VARIABLE	TEST T2 400 F, 24	TEST T3 500 F, 36	TEST T5 500 F, 24	TEST T8 400 F, 36 hr	TEST T13 500 F, 12 hr	TEST T14 400 F, 12 hr	TEST T15 600 F, 12 hr	TEST T16 600 F, 6 hr	TEST T17 600 F, 48 hr	TEST T18 500 F, 6 hr
DISCHARGE GAS FLOW RATE		Response										
Stack test 1 (average)	cfm		11800	10750	12350	NA	NA	NA	NA	NA	NA	NA
Stack test 2 (average)	cfm		12950	10950	13050	NA	NA	NA	NA	NA	NA	NA
Stack test 3 (average)	cfm		12750	11900	12450	NA	NA	NA	NA	NA	NA	NA
AFTERBURNER GAS RESIDENCE TIME		Response										
Stack test 1 (average)	sec		0.87	0.95	0.83	NA	NA	NA	NA	NA	NA	NA
Stack test 2 (average)	sec		0.79	0.94	0.79	NA	NA	NA	NA	NA	NA	NA
Stack test 3 (average)	sec		0.8	0.86	0.82	NA	NA	NA	NA	NA	NA	NA
AFTERBURNER DISCHARGE GAS TEMPERATURE		Response										
Steady State (average)	deg F		1828	1986	1805	1851	1951	1878	1998	1998	1996	2002
Heat-Up/Steady State (average)	deg F		1830	1988	1812	1852	1965	1884	1994	1960	1990	1934
Total Test (average)	deg F		1828	1986	1637	1819	1966	1904	1992	1972	1990	1900
DISCHARGE GAS COMPOSITION *		Response										
Total Hydrocarbons (THC as propane)*												
Steady State (average)	ppm/v		<0.1	<0.1	0.4	0.1	<0.1	<0.1	0.5	1.1	0.26	0.2
Heat-Up/Steady State (average)	ppm/v		<0.1	<0.1	0.5	0.1	<0.1	<0.1	<0.1	0.5	0.37	0.2
Total Test (average)	ppm/v		0.1	<0.1	0.5	0.1	<0.1	<0.1	<0.1	0.5	0.4	0.2
Carbon Dioxide (CO2)*												
Steady State (average)	%		6	6.3	6.2	6.2	6.4	6.8	8.9	9.5	8.86	6.7
Heat-Up/Steady State (average)	%		6.3	6.4	6.3	6.3	7.3	6.9	8.7	8	8.81	6.7
Total Test (average)	%		6.2	6.3	5.2	5.9	9.7	6.9	8.5	8	8.04	7.9
Carbon Monoxide (CO)*												
Steady State (average)	ppm/v		0.7	3.5	0.6	<0.1	<0.1	0.1	<0.1	0.9	3.09	5.3
Heat-Up/Steady State (average)	ppm/v		0.8	3.6	0.7	<0.1	<0.1	0.1	<0.1	0.1	3.11	4.6
Total Test (average)	ppm/v		0.9	3.5	3.1	<0.1	<0.1	0.1	<0.1	0.1	3.17	3.9
Oxygen (O2)*												
Steady State (average)	%		11	11.2	11.1	11.1	8.3	10.2	6.9	6.3	7.51	10.5
Heat-Up/Steady State (average)	%		10.7	11.1	10.9	10.7	8	10.1	7.2	8.1	7.51	10.8
Total Test (average)	%		10.8	11.1	12.4	11.5	8.3	10.1	7.5	8.1	8.56	9
Nitrous Oxides (NOx)*												
Steady State (average)	ppm/v		54.9	51.4	50.1	63.9	60.4	65.1	59.8	56.3	65.1	54.7
Heat-Up/Steady State (average)	ppm/v		55.4	51.4	52.3	61.8	60.4	61.1	66.5	58.9	64.1	56.8
Total Test (average)	ppm/v		57.8	52.1	46.9	62.1	73.8	73.2	69.3	58.9	77	62.3

* Hourly CEM values; data also collected during three stack tests, data presented in Tables 8-5, 8-6, 8-7.
** Afterbuner discharge gas temperature for T17 estimated from molytek strip chart recorder.
NA Not analyzed.
cfm cubic feet per minute.
ppm/v part per million by volume.

Average volumetric flowrates of discharge gases as determined during the stack test program are shown. This flowrate was used for determination of the residence time in the afterburner, as follows:

$$RT = (V / V_f) \times 60$$

Where,

RT = residence time (seconds)
V = volume of the afterburner (in this case, 171 cubic feet)
V_f = average gas stream volumetric flow (WACF/min)

For illustration, an example is provided for Test 2 (T2).

$$RT = (171 / 12{,}333) \times 60$$

$$= 0.83 \text{ seconds}$$

The setpoint for the afterburner discharge gas temperature was 2,000°F. However, the operating temperature was generally lower. The average values recorded during manned operation are provided.

The composition of the afterburner discharge gases (carbon dioxide, carbon monoxide, oxygen and THC) was monitored continuously by the CEM system. Hourly averages for these parameters are provided in Appendix E. Table 8-4 provides average values of data recorded during manned operation and by the CEM system during unmanned operation (after reaching steady state). Carbon dioxide, carbon monoxide and oxygen were also monitored during the stack test program; data are presented in Subsection 8.1.5.

8.1.5 STACK TEST PROGRAM

Stack tests were conducted during the first three test runs. The following parameters were sampled at each designated location:

- Flash chamber inlet
    - Carbon dioxide
    - Oxygen
    - Carbon monoxide
    - Nitrogen (calculated by difference)
    - Total hydrocarbons
- Flash chamber outlet
    - Carbon dioxide
    - Oxygen
    - Carbon monoxide
    - Nitrogen (calculated by difference)
    - Explosives

  - Nitrated esters*
  - Total hydrocarbons
  - Semivolatiles and hydrocarbons C_7-C_{17} (during T3 only)

- Afterburner outlet

  - Carbon dioxide
  - Oxygen
  - Carbon monoxide
  - Nitrogen (calculated by difference)
  - Explosives

  - Particulate
  - Nitrated esters
  - Total hydrocarbons
  - Nitrous oxides (NOx)
  - Semivolatiles and C_7-C_{17} hydrocarbons (during T3 only)

The results of the stack test program are shown on Table 8-6 (testing conducted during T2), Table 8-7 (testing conducted during T3) and Table 8-8 (testing conducted during T5). Tables consist of multiple pages. Each table contains the following data:

- Test run number (i.e., T2-1, T2-2, etc.), sampling location, test date, and test time period.

- General sampling data, such as nozzle diameters, meter temperature, etc.

- Information on the gas stream composition and velocity/volumetric flow rate.

Each table also contains information on specific parameters measured at each sampling location. Tables have been broken down as follows:

- Sheet A - Summarizes total hydrocarbon emissions monitored at the flash chamber inlet. Total hydrocarbon emissions were not monitored as part of the stack test program; data shown represent average values measured during each stack sampling event by the CEM system.

- Sheet B - Presents explosives emissions measured at the flash chamber outlet. If concentrations of parameters were not present at levels that were above the detection limit, the detection limit is reported with a "less than" sign.

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*As discussed in Subsection 9.6.2.3, the analytical method for smokeless powder is nonspecific; it does not allow NC and NG to be distinguished from one another or from other nitrated esters.

Table 8-6A

Summary of Data and Results from Stack Test Conducted during Test Run 2 at

Flash Chamber Inlet - Total Hydrocarbons

TEST DATA:			
Test run number	T2-1	T2-2	T2-3
Test location	FLASH CHAMBER INLET		
Test date	07-25-89	07-25-89	07-26-89
Test time period	0840-1345	1720-2200	0950-1400
SAMPLING DATA:(1)			
Sampling duration, min.	305.0	280.0	250.0
Nozzle diameter, in.	NA	NA	NA
Cross sectional nozzle area, sq.ft.	NA	NA	NA
Barometric pressure, in. Hg	26.44	26.44	26.40
Avg. orifice press. diff., in H2O	0.75	0.75	0.75
Avg. dry gas meter temp., deg F	100	97	99
Avg. abs. dry gas meter temp., deg. R	560	557	559
Total liquid collected by train, ml	112.0	89.0	59.0
Std. vol. of H2O vapor coll., cu.ft.	5.3	4.2	2.8
Dry gas meter calibration factor	0.999	0.999	0.999
Sample vol. at meter cond., dcf	164.255	143.865	125.622
Sample vol. at std. cond., dscf (2)	136.963	120.607	104.722
Percent of isokinetic sampling	NA	NA	NA
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	1.9	1.9	1.6
O2, % by volume, dry basis	17.0	17.0	17.5
CO, ppm by volume, dry basis (3)	131.3	175.1	200.3
N2, % by volume, dry basis	81.1	81.1	80.9
Molecular wt. of dry gas, lb/lb mole	29.0	29.0	29.0
H2O vapor in gas stream, prop. by vol.	0.037	0.034	0.026
Mole fraction of dry gas	0.963	0.966	0.974
Molecular wt. of wet gas, lb/lb mole	28.6	28.6	28.7
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	0.06	0.06	0.06
Static pressure, in. Hg	0.004	0.004	0.004
Absolute pressure, in. Hg	26.44	26.44	26.40
Avg. temperature, deg. F	881	812	743
Avg. absolute temperature, deg.R	1341	1272	1203
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	16	16	16
Avg. gas stream velocity, ft./sec.	41.1	41.1	41.5
Stack/duct cross sectional area, sq.ft.	1.77	1.77	1.77
Avg. gas stream volumetric flow, wacf/min.	4400	4400	4400
Avg. gas stream volumetric flow, dscf/min.	1500	1500	1700
Total Hydrocarbon Emissions: (3)			
Concentration, ppm/v dry basis as propane	29.6	39.8	45.6
Concentration, lb/dscf	3.39E-06	4.55E-06	5.22E-06
Mass emission rate, lb/hr	0.30	0.42	0.52

(1) Sampling data presented for EPA Method 4 (moisture) sampling train

(2) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)

(3) As measured by the WESTON CEM trailer

Table 8-6B

Summary of Data and Results from Stack Test Conducted during Test Run 2 at Flash Chamber Outlet - Explosives

TEST DATA:			
Test run number	T2-1	T2-2	T2-3
Test location	FLASH CHAMBER OUTLET		
Test date	7-25-89	7-25-89	7-26-89
Test time period	0830-1536	1558-2331	0945-1414
SAMPLING DATA:			
Sampling duration, min.	360.0	445.0	240.0
Nozzle diameter, in.	0.300	0.300	0.300
Cross sectional nozzle area, sq.ft.	0.000491	0.000491	0.000491
Barometric pressure, in. Hg	26.44	26.31	26.40
Avg. orifice press. diff., in H2O	1.11	1.41	1.36
Avg. dry gas meter temp., deg F	107	102	107
Avg. abs. dry gas meter temp., deg. R	567	562	567
Total liquid collected by train, ml	129.0	180.4	72.0
Std. vol. of H2O vapor coll., cu.ft.	6.1	8.5	3.4
Dry gas meter calibration factor	1.002	1.002	1.002
Sample vol. at meter cond., dcf	233.731	324.082	171.536
Sample vol. at std. cond., dscf (1)	193.327	269.096	141.794
Percent of isokinetic sampling	100.7	100.6	99.3
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	1.2	1.1	1.1
O2, % by volume, dry basis	16.2	18.4	18.3
CO, ppm by volume, dry basis	86.7	92.8	122.7
N2, % by volume, dry basis	82.6	80.6	80.6
Molecular wt. of dry gas, lb/lb mole	28.8	28.9	28.9
H2O vapor in gas stream, prop. by vol.	0.030	0.031	0.023
Mole fraction of dry gas	0.970	0.969	0.977
Molecular wt. of wet gas, lb/lb mole	28.5	28.6	28.7
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	-0.44	-0.56	-0.54
Static pressure, in. Hg	-0.032	-0.041	-0.040
Absolute pressure, in. Hg	26.41	26.27	26.36
Avg. temperature, deg. F	345	406	425
Avg. absolute temperature, deg.R	805	866	885
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	12	12	12
Avg. gas stream velocity, ft./sec.	32.3	39.4	39.4
Stack/duct cross sectional area, sq.ft.	1.77	1.77	1.77
Avg. gas stream volumetric flow, wacf/min.	3400	4200	4200
Avg. gas stream volumetric flow, dscf/min.	1900	2200	2100
EXPLOSIVES EMISSIONS:			
HMX			
Concentration, lbs/dscf	< 3.63E-08	< 2.61E-08	6.50E-11
Concentration, ppm/v	< 0.0472	< 0.0339	8.46E-05
Mass rate, lbs/hr	< 0.0042	< 0.0034	8.37E-06
RDX			
Concentration, lbs/dscf	< 2.79E-08	< 2.01E-08	< 3.81E-11
Concentration, ppm/v	< 0.0485	< 0.0348	< 6.61E-05
Mass rate, lbs/hr	< 0.0032	< 0.0026	< 4.91E-06
Trinitrobenzene (1 3 5 TNB)			
Concentration, lbs/dscf	< 5.96E-08	< 4.28E-08	< 8.13E-11
Concentration, ppm/v	< 0.1078	< 0.0775	< 1.47E-04
Mass rate, lbs/hr	< 0.0069	< 0.0056	< 1.05E-05
Dinitrobenzene (1 3 DNB)			
Concentration, lbs/dscf	< 1.69E-08	< 1.21E-08	6.93E-11
Concentration, ppm/v	< 0.0387	< 0.0278	1.59E-04
Mass rate, lbs/hr	< 0.0019	< 0.0016	8.93E-06
Nitrobenzene			
Concentration, lbs/dscf	< 1.20E-08	< 8.60E-09	< 1.63E-11
Concentration, ppm/v	< 0.0375	< 0.0270	< 5.11E-05
Mass rate, lbs/hr	< 0.0014	< 0.0011	< 2.10E-06
Tetryl			
Concentration, lbs/dscf	< 1.43E-07	< 1.02E-07	< 1.94E-10
Concentration, ppm/v	< 0.1914	< 0.1375	< 2.61E-04
Mass rate, lbs/hr	< 0.0164	< 0.0133	< 2.50E-05
2 4 6 Trinitrotoluene (TNT)			
Concentration, lbs/dscf	8.03E-07	3.24E-07	1.46E-09
Concentration, ppm/v	1.3628	0.5507	0.0025
Mass rate, lbs/hr	0.0925	0.0421	1.87E-04
2 4 Dinitrotoluene (2 4 DNT)			
Concentration, lbs/dscf	< 1.20E-08	< 8.60E-09	< 1.63E-11
Concentration, ppm/v	< 0.0253	< 0.0182	< 3.45E-05
Mass rate, lbs/hr	< 0.0014	< 0.0011	< 2.10E-06
2 6 Dinitrotoluene (2 6 DNT)			
Concentration, lbs/dscf	< 1.14E-08	< 8.19E-09	< 1.55E-11
Concentration, ppm/v	< 0.0241	< 0.0173	< 3.29E-05
Mass rate, lbs/hr	< 0.0013	< 0.0011	< 2.00E-06

(1) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)

Table 8-6C

Summary of Data and Results From Stack Test Conducted during Test Run 2 at

Flash Chamber Outlet - Nitrated Esters/Total Hydrocarbons

TEST DATA:			
Test run number	T2-1	T2-2	T2-3
Test location	FLASH CHAMBER OUTLET		
Test date	7-25-89	7-25-89	7-26-89
Test time period	0830-1536	1629-2331	0945-1444
SAMPLING DATA:			
Sampling duration, min.	360.0	420.0	240.0
Nozzle diameter, in.	0.310	0.310	0.310
Cross sectional nozzle area, sq.ft.	0.000524	0.000524	0.000524
Barometric pressure, in. Hg	26.44	26.31	26.40
Avg. orifice press. diff., in H2O	1.52	1.81	1.79
Avg. dry gas meter temp., deg F	114	109	115
Avg. abs. dry gas meter temp., deg. R	574	569	575
Total liquid collected by train, ml	127.0	175.0	89.0
Std. vol. of H2O vapor coll., cu.ft.	6.0	8.2	4.2
Dry gas meter calibration factor	1.002	1.002	1.002
Sample vol. at meter cond., dcf	248.942	315.669	180.476
Sample vol. at std. cond., dscf (1)	203.548	259.469	147.256
Percent of isokinetic sampling	97.7	97.8	98.3
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	1.2	1.1	1.1
O2, % by volume, dry basis	16.2	18.4	18.3
CO, ppm by volume, dry basis (2)	86.7	92.8	122.7
N2, % by volume, dry basis	82.6	80.5	80.6
Molecular wt. of dry gas, lb/lb mole	28.8	28.9	28.9
H2O vapor in gas stream, prop. by vol.	0.029	0.031	0.028
Mole fraction of dry gas	0.971	0.969	0.972
Molecular wt. of wet gas, lb/lb mole	28.5	28.6	28.6
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	-0.50	-0.57	-0.57
Static pressure, in. Hg	-0.037	-0.042	-0.042
Absolute pressure, in. Hg	26.40	26.27	26.36
Avg. temperature, deg. F	344	404	424
Avg. absolute temperature, deg.R	804	864	884
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	12	12	12
Avg. gas stream velocity, ft./sec.	32.7	38.7	38.8
Stack/duct cross sectional area, sq.ft.	1.77	1.77	1.77
Avg. gas stream volumetric flow, wacf/min.	3500	4100	4100
Avg. gas stream volumetric flow, dscf/min.	2000	2100	2100
Nitrated Esters Emissions:			
Nitrated esters catch, ug	30003.5	13601.49	1591.88
Concentration, gr/dscf	2.27E-03	8.77E-04	1.56E-04
Mass rate, lbs/hr	0.038	0.016	0.003
Total Hydrocarbon Emissions: (2)			
Concentration, ppm/v dry basis as propane	23.9	28.9	34.3
Concentration, lb/dscf	2.74E-06	3.31E-06	3.93E-06
Mass emission rate, lb/hr	0.320	0.423	0.496

(1) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)

(2) As measured by the WESTON CEM trailer

Table 8-6D

Summary of Data and Results From Stack Test Conducted during Test Run 2 at Afterburner Outlet - Explosives

TEST DATA:			
Test run number	T2-1	T2-2	[illegible]
Test location		AFTERBURNER OUTLET	
Test date	7-25-89	7-25-89	7-26-89
Test time period	0830-1537	1640-2340	0945-1444
SAMPLING DATA:			
Sampling duration, min.	340.0	360.0	240.0
Nozzle diameter, in.	0.760	0.800	0.800
Cross sectional nozzle area, sq.ft.	0.003150	0.003491	0.003491
Barometric pressure, in. Hg	26.44	26.31	26.40
Avg. orifice press. diff., in H2O	0.63	1.01	0.96
Avg. dry gas meter temp., deg F	112	109	115
Avg. abs. dry gas meter temp., deg. R	572	569	575
Total liquid collected by train, ml	323.0	375.0	207.0
Std. vol. of H2O vapor coll., cu.ft.	15.2	17.7	9.7
Dry gas meter calibration factor	0.995	0.995	0.995
Sample vol. at meter cond., dcf	167.991	224.444	144.556
Sample vol. at std. cond., dscf (1)	136.475	182.750	116.911
Percent of isokinetic sampling	100.4	100.4	97.0
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	7.1	6.5	6.0
O2, % by volume, dry basis	9.9	10.7	11.5
CO, ppm by volume, dry basis	7.5	6.0	7.0
N2, % by volume, dry basis	83.0	82.8	82.5
Molecular wt. of dry gas, lb/lb mole	29.5	29.5	29.4
H2O vapor in gas stream, prop. by vol.	0.100	0.088	0.077
Mole fraction of dry gas	0.900	0.912	0.923
Molecular wt. of wet gas, lb/lb mole	28.4	28.5	28.5
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	-0.10	-0.10	-0.10
Static pressure, in. Hg	-0.007	-0.007	-0.007
Absolute pressure, in. Hg	26.43	26.30	26.39
Avg. temperature, deg. F	1727	1790	1722
Avg. absolute temperature, deg.R	2187	2250	2182
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	24	24	24
Avg. gas stream velocity, ft./sec.	11.0	12.8	12.2
Stack/duct cross sectional area, sq.ft.	17.10	17.10	17.10
Avg. gas stream volumetric flow, wacf/min.	11300	13200	12500
Avg. gas stream volumetric flow, dscf/min.	2200	2500	2500
EXPLOSIVES EMISSIONS:			
HMX			
Concentration, lbs/dscf	2.02E-10	2.61E-11	< 2.39E-11
Concentration, ppm/v	2.63E-04	3.39E-05	< 3.12E-05
Mass rate, lbs/hr	2.63E-05	3.87E-06	< 3.54E-06
RDX			
Concentration, lbs/dscf	< 1.58E-11	< 1.18E-11	5.51E-11
Concentration, ppm/v	< 2.75E-05	< 2.05E-05	9.55E-05
Mass rate, lbs/hr	< 2.06E-06	< 1.76E-06	8.13E-06
Trinitrobenzene (1 3 5 TNB)			
Concentration, lbs/dscf	9.53E-11	< 2.52E-11	< 3.94E-11
Concentration, ppm/v	1.72E-04	< 4.56E-05	< 7.13E-05
Mass rate, lbs/hr	1.24E-05	< 3.75E-06	< 5.82E-06
Dinitrobenzene (1 3 DNB)			
Concentration, lbs/dscf	9.69E-12	2.90E-12	1.64E-11
Concentration, ppm/v	2.22E-05	6.64E-06	3.76E-05
Mass rate, lbs/hr	1.26E-06	4.30E-07	2.42E-06
Nitrobenzene			
Concentration, lbs/dscf	< 6.78E-12	< 5.07E-12	< 7.92E-12
Concentration, ppm/v	< 2.13E-05	< 1.59E-05	< 2.48E-05
Mass rate, lbs/hr	< 8.83E-07	< 7.53E-07	< 1.17E-06
Tetryl			
Concentration, lbs/dscf	< 8.08E-11	< 6.03E-11	< 9.43E-11
Concentration, ppm/v	< 1.08E-04	< 8.10E-05	< 1.27E-04
Mass rate, lbs/hr	< 1.05E-05	< 8.96E-06	< 1.39E-05
2 4 6 Trinitrotoluene (TNT)			
Concentration, lbs/dscf	< 3.10E-11	< 2.32E-11	< 3.62E-11
Concentration, ppm/v	< 5.27E-05	< 3.93E-05	< 6.15E-05
Mass rate, lbs/hr	< 4.04E-06	< 3.44E-06	< 5.35E-06
Destruction removal efficiency, %	> 99.996	> 99.992	> 97.139
2 4 Dinitrotoluene (2 4 DNT)			
Concentration, lbs/dscf	< 6.78E-12	< 5.07E-12	< 7.92E-12
Concentration, ppm/v	< 1.44E-05	< 1.07E-05	< 1.68E-05
Mass rate, lbs/hr	< 8.83E-07	< 7.53E-07	< 1.17E-06
2 6 Dinitrotoluene (2 6 DNT)			
Concentration, lbs/dscf	< 6.46E-12	< 4.83E-12	< 7.54E-12
Concentration, ppm/v	< 1.37E-05	< 1.02E-05	< 1.60E-05
Mass rate, lbs/hr	< 8.41E-07	< 7.17E-07	< 1.11E-06

(1) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)

Table 8-6E

Summary of Data and Results from Stack Test Conducted during Test Run 2 at

Afterburner Outlet - Nitrated Esters and Particulate

TEST DATA:			
Test run number	T2-1	T2-2	T2-3
Test location		AFTERBURNER OUTLET	
Test date	7-25-89	7-25-89	7-26-89
Test time period	0830-1537	1640-2340	0945-1414
SAMPLING DATA:			
Sampling duration, min.	340.0	360.0	240.0
Nozzle diameter, in.	0.860	0.860	0.810
Cross sectional nozzle area, sq.ft.	0.004034	0.004034	0.003578
Barometric pressure, in. Hg	26.44	26.31	26.40
Avg. orifice press. diff., in H2O	1.45	1.54	1.18
Avg. dry gas meter temp., deg F	110	106	110
Avg. abs. dry gas meter temp., deg. R	570	566	570
Total liquid collected by train, ml	389.0	396.0	233.0
Std. vol. of H2O vapor coll., cu.ft.	18.3	18.6	11.0
Dry gas meter calibration factor	1.003	1.003	1.003
Sample vol. at meter cond., dcf	235.949	256.203	151.815
Sample vol. at std. cond., dscf (1)	194.596	211.686	124.740
Percent of isokinetic sampling	98.2	99.6	96.2
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	7.1	6.5	6.0
O2, % by volume, dry basis	9.9	10.7	11.5
CO,ppm by volume, dry basis	7.5	6.0	7.0
N2, % by volume, dry basis	83.0	82.8	82.5
Molecular wt. of dry gas, lb/lb mole	29.5	29.5	29.4
H2O vapor in gas stream, prop. by vol.	0.086	0.081	0.081
Mole fraction of dry gas	0.914	0.919	0.919
Molecular wt. of wet gas, lb/lb mole	28.5	28.5	28.5
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	-0.10	-0.10	-0.10
Static pressure, in. Hg	-0.007	-0.007	-0.008
Absolute pressure, in. Hg	26.43	26.30	26.39
Avg. temperature, deg. F	1669	1709	1690
Avg. absolute temperature, deg.R	2129	2169	2150
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	24	24	24
Avg. gas stream velocity, ft./sec.	12.0	12.4	12.6
Stack/duct cross sectional area, sq.ft.	17.10	17.10	17.10
Avg. gas stream volumetric flow, wacf/min.	12300	12700	13000
Avg. gas stream volumetric flow, dscf/min.	2500	2500	2600
Particulate Emissions:			
Total particulate catch,g.	0.0074	0.0036	0.0044
Concentration, gr/dscf	5.87E-04	2.62E-04	5.44E-04
Mass rate, lbs/hr	0.012	0.006	0.012
Nitrated Esters Emissions:			
Nitrated esters catch, ug	< 1805	< 1660	< 1447
Concentration, gr/dscf	< 1.43E-04	< 1.21E-04	< 1.79E-04
Mass rate, lbs/hr	< 3.03E-03	< 2.60E-03	< 3.96E-03
Total Hydrocarbon Emissions: (2)			
Concentration, ppm/v dry basis as propane	0.2	<0.1	0.3
Concentration, lb/dscf	2.29E-08	<1.14E-08	3.43E-08
Mass emission rate, lb/hr	0.003	<0.002	0.005
NOx Emissions: (2)			
Concentration, ppm/v dry basis as NO2	58.9	54.6	54.8
Concentration, lb/dscf	7.03E-06	6.52E-06	6.54E-06
Mass emission rate, lb/hr	1.04	0.98	1.01
Carbon Monoxide Emissions: (2)			
Concentration, ppm/v dry basis	7.5	6	7
Concentration, lb/dscf	5.45E-07	4.36E-07	5.08E-07
Mass emission rate, lb/hr	0.081	0.065	0.079

(1) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)
(2) As measured by the WESTON CEM trailer
N.D. = None Detected

Table 8-7A

Summary of Data and Results from Stack Test Conducted during Test Run 3 at

Flash Chamber Inlet - Total Hydrocarbons

Test Data			
Run number	T3-1	T3-1	T3-1
Location	FLASH CHAMBER INLET		
Date	07-17-89	07-17-89	07-18-89
Time period	0450-1206	1449-1900	1440-2100
SAMPLING DATA:(1)			
Sampling duration, min.	436.0	251.0	380.0
Nozzle diameter, in.	NA	NA	NA
Cross sectional nozzle area, sq.ft.	NA	NA	NA
Barometric pressure, in. Hg	26.48	25.94	25.97
Avg. orifice press. diff., in H2O	1.00	0.75	0.70
Avg. dry gas meter temp., deg F	110	100	103
Avg. abs. dry gas meter temp., deg. R	570	560	563
Total liquid collected by train, ml	135.0	83.0	97.0
Std. vol. of H2O vapor coll., cu.ft.	6.4	3.9	4.6
Dry gas meter calibration factor	0.999	0.999	0.999
Sample vol. at meter cond., dcf	238.741	127.621	190.899
Sample vol. at std. cond., dscf (2)	196.012	104.408	155.502
Percent of isokinetic sampling	NA	NA	NA
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	2.4	2.2	1.8
O2, % by volume, dry basis	15.8	16.5	16.7
CO,ppm by volume, dry basis (3)	9.3	55.5	113.6
N2, % by volume, dry basis	81.8	81.3	81.5
Molecular wt. of dry gas, lb/lb mole	29.0	29.0	29.0
H2O vapor in gas stream, prop. by vol.	0.031	0.036	0.029
Mole fraction of dry gas	0.969	0.964	0.971
Molecular wt. of wet gas, lb/lb mole	28.7	28.6	28.6
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	0.06	0.06	0.06
Static pressure, in. Hg	0.004	0.004	0.004
Absolute pressure, in. Hg	26.48	25.94	25.97
Avg. temperature, deg. F	1128	1031	934
Avg. absolute temperature, deg.R	1588	1491	1394
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	16	16	16
Avg. gas stream velocity, ft./sec.	50.9	53.8	51.5
Stack/duct cross sectional area, sq.ft.	1.77	1.77	1.77
Avg. gas stream volumetric flow, wacf/min.	5400	5700	5500
Avg. gas stream volumetric flow, dscf/min.	1500	1700	1700
Total Hydrocarbon Emissions: (3)			
Concentration, ppm/v dry basis as propane	49	33.1	38.2
Concentration, lb/dscf	5.61E-06	3.79E-06	4.37E-06
Mass emission rate, lb/hr	0.52	0.38	0.46

(1) Sampling data presented for EPA Method 4 (moisture) sampling train

(2) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)

(3) As measured by the WESTON CEM trailer

Table 8-7B

Summary of Data and Results from Stack Test Conducted during Test Run 3 at

Flash Chamber Outlet Explosives

TEST DATA:			
Test run number	T3-1	T3-2	T3-3
Test location	FLASH CHAMBER OUTLET		
Test date	7-17-89	7-17-89	7-18-89
Test time period	0445-1226	1439-2221	1433-2134
SAMPLING DATA:			
Sampling duration, min.	360.0	240.0	360.0
Nozzle diameter, in.	0.300	0.300	0.300
Cross sectional nozzle area, sq.ft.	0.000491	0.000491	0.000491
Barometric pressure, in. Hg	26.48	25.94	25.97
Avg. orifice press. diff., in H2O	1.08	0.93	1.20
Avg. dry gas meter temp., deg F	96	113	112
Avg. abs. dry gas meter temp., deg. R	556	573	572
Total liquid collected by train, ml	156.0	105.0	173.0
Std. vol. of H2O vapor coll., cu.ft.	7.3	4.9	8.1
Dry gas meter calibration factor	1.002	1.002	1.002
Sample vol. at meter cond., dcf	229.737	146.867	243.272
Sample vol. at std. cond., dscf (1)	193.893	117.729	195.916
Percent of isokinetic sampling	101.2	101.0	98.8
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	1.4	1.3	1.1
O2, % by volume, dry basis	17.2	17.5	17.6
CO, ppm by volume, dry basis	19.0	100.4	169.0
N2, % by volume, dry basis	81.4	81.2	81.3
Molecular wt. of dry gas, lb/lb mole	28.9	28.9	28.9
H2O vapor in gas stream, prop. by vol.	0.037	0.040	0.040
Mole fraction of dry gas	0.963	0.960	0.960
Molecular wt. of wet gas, lb/lb mole	28.5	28.5	28.4
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	-0.48	-0.48	-0.56
Static pressure, in. Hg	-0.035	-0.035	-0.041
Absolute pressure, in. Hg	26.45	25.91	25.93
Avg. temperature, deg. F	440	510	513
Avg. absolute temperature, deg.R	900	970	973
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	12	12	12
Avg. gas stream velocity, ft./sec.	36.2	36.5	41.4
Stack/duct cross sectional area, sq.ft.	1.77	1.77	1.77
Avg. gas stream volumetric flow, wacf/min.	3800	3900	4400
Avg. gas stream volumetric flow, dscf/min.	1900	1700	2000
EXPLOSIVES EMISSIONS:			
HMX			
Concentration, lbs/dscf	< 3.62E-08	< 5.95E-10	< 1.43E-10
Concentration, ppm/v	< 0.0470	< 0.0008	< 1.86E-04
Mass rate, lbs/hr	< 0.0042	< 6.25E-05	< 1.70E-05
RDX			
Concentration, lbs/dscf	< 2.79E-08	< 4.59E-10	< 1.10E-10
Concentration, ppm/v	< 0.0483	< 0.0008	< 1.91E-04
Mass rate, lbs/hr	< 0.0032	< 4.81E-05	< 1.31E-05
Trinitrobenzene (1 3 5 TNB)			
Concentration, lbs/dscf	< 5.95E-08	< 9.79E-10	2.44E-10
Concentration, ppm/v	< 0.1075	< 0.0018	4.42E-04
Mass rate, lbs/hr	< 0.0068	< 1.03E-04	2.91E-05
Dinitrobenzene (1 3 DNB)			
Concentration, lbs/dscf	< 1.68E-08	< 2.77E-10	< 6.64E-11
Concentration, ppm/v	< 0.0386	< 0.0006	< 1.52E-04
Mass rate, lbs/hr	< 0.0019	< 2.91E-05	< 7.91E-06
Nitrobenzene			
Concentration, lbs/dscf	< 1.19E-08	< 1.97E-10	2.48E-10
Concentration, ppm/v	< 0.0374	< 0.0006	7.76E-04
Mass rate, lbs/hr	< 0.0014	< 2.06E-05	2.95E-05
Tetryl			
Concentration, lbs/dscf	< 1.42E-07	< 2.34E-09	< 5.63E-10
Concentration, ppm/v	< 0.1908	< 0.0031	< 7.55E-04
Mass rate, lbs/hr	< 0.0163	< 2.46E-04	< 6.70E-05
2 4 6 Trinitrotoluene (TNT)			
Concentration, lbs/dscf	1.01E-06	1.20E-09	1.92E-09
Concentration, ppm/v	1.7217	0.0020	0.0033
Mass rate, lbs/hr	0.1166	1.26E-04	2.29E-04
2 4 Dinitrotoluene (2 4 DNT)			
Concentration, lbs/dscf	< 1.19E-08	< 1.97E-10	< 4.73E-11
Concentration, ppm/v	< 0.0253	< 0.0004	< 1.00E-04
Mass rate, lbs/hr	< 0.0014	< 2.06E-05	< 5.63E-06
2 6 Dinitrotoluene (2 6 DNT)			
Concentration, lbs/dscf	< 1.14E-08	< 1.87E-10	< 4.50E-11
Concentration, ppm/v	< 0.0241	< 0.0004	< 9.52E-05
Mass rate, lbs/hr	< 0.0013	< 1.96E-05	< 5.36E-06

(1) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)

Table 8-7C

Summary of Data and Results from Stack Test Conducted during Test Run 3 at

Flash Chamber Outlet - Nitrated Esters/Total Hydrocarbons

TEST DATA:			
Test run number	T3-1	T3-2	T3-3
Test location	FLASH CHAMBER OUTLET		
Test date	7-17-89	7-17-89	7-18-89
Test time period	0445-1223	1441-2221	1434-2134
SAMPLING DATA:			
Sampling duration, min.	370.0	240.0	360.0
Nozzle diameter, in.	0.310	0.310	0.310
Cross sectional nozzle area, sq.ft.	0.000524	0.000524	0.000524
Barometric pressure, in. Hg	26.48	25.94	25.97
Avg. orifice press. diff., in H2O	1.43	1.28	1.39
Avg. dry gas meter temp., deg F	103	120	119
Avg. abs. dry gas meter temp., deg. R	563	580	579
Total liquid collected by train, ml	147.5	109.0	174.0
Std. vol. of H2O vapor coll., cu.ft.	6.9	5.1	8.2
Dry gas meter calibration factor	1.002	1.002	1.002
Sample vol. at meter cond., dcf	240.263	156.630	240.466
Sample vol. at std. cond., dscf (1)	200.363	124.351	191.429
Percent of isokinetic sampling	96.2	99.2	98.0
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	1.4	1.3	1.1
O2, % by volume, dry basis	17.2	17.5	17.6
CO, ppm by volume, dry basis (2)	19.0	100.4	169.0
N2, % by volume, dry basis	81.4	81.2	81.3
Molecular wt. of dry gas, lb/lb mole	28.9	28.9	28.9
H2O vapor in gas stream, prop. by vol.	0.034	0.040	0.041
Mole fraction of dry gas	0.966	0.960	0.959
Molecular wt. of wet gas, lb/lb mole	28.5	28.5	28.4
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	-0.48	-0.50	-0.52
Static pressure, in. Hg	-0.035	-0.037	-0.038
Absolute pressure, in. Hg	26.44	25.90	25.93
Avg. temperature, deg. F	440	509	498
Avg. absolute temperature, deg.R	900	969	958
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	12	12	12
Avg. gas stream velocity, ft./sec.	35.8	36.7	37.7
Stack/duct cross sectional area, sq.ft.	1.77	1.77	1.77
Avg. gas stream volumetric flow, wacf/min.	3800	3900	4000
Avg. gas stream volumetric flow, dscf/min.	1900	1800	1800
Nitrated Esters Emissions:			
Nitrated esters catch, ug	35692.58	8099.875	7703.13
Concentration, gr/dscf	2.75E-03	1.01E-03	6.21E-04
Mass rate, lbs/hr	0.045	0.015	0.010
Total Hydrocarbon Emissions: (2)			
Concentration, ppm/v dry basis as propane	33.9	27.8	27.9
Concentration, lb/dscf	3.88E-06	3.18E-06	3.19E-06
Mass emission rate, lb/hr	0.442	0.336	0.351

(1) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)

(2) As measured by the WESTON CEM trailer

Table 8-7C
(continued)

Summary of Data and Results from Stack Test Conducted during Test Run 3 at

Flash Chamber Outlet - Semivolatiles

TEST DATA:	
Test run number	T3-1
Test location	FLASH CHAMBER OUTLET
Test date	7-17-89
Test time period	0445-1226
LABORATORY REPORT, ug	
Phenol	64
Naphthalene	42
2-Methylnaphthalene	11
Di-n-Butylphthalate	75
bis(2-Ethylhexyl)phthalate	18
Di-n-Octyl phthalate	2
SEMIVOLATILE EMISSIONS:(1)	
Phenol	
Concentration, lbs/dscf	7.28E-10
Concentration, ppm/v	2.98E-03
Mass rate, lbs/hr	8.36E-05
Naphthalene	
Concentration, lbs/dscf	4.78E-10
Concentration, ppm/v	1.44E-03
Mass rate, lbs/hr	5.49E-05
2-Methylnaphthalene	
Concentration, lbs/dscf	1.25E-10
Concentration, ppm/v	3.39E-04
Mass rate, lbs/hr	1.44E-05
Di-n-Butylphthalate	
Concentration, lbs/dscf	8.53E-10
Concentration, ppm/v	1.18E-03
Mass rate, lbs/hr	9.80E-05
bis(2-Ethylhexyl)phthalate	
Concentration, lbs/dscf	2.05E-10
Concentration, ppm/v	2.02E-04
Mass rate, lbs/hr	2.35E-05
Di-n-Octyl phthalate	
Concentration, lbs/dscf	2.27E-11
Concentration, ppm/v	3.15E-05
Mass rate, lbs/hr	2.61E-06

(1) The reported semivolatiles should be considered qualitative only. Benzoic acid was present in the sample at a concentration beyond the calibration range. All other semivolatiles were either below the detection limit or unidentified.

Table 8-7D

Summary of Data and Results from Stack Test Conducted during Test Run 3 at Afterburner Outlet - Explosives

TEST DATA:			
Test run number	T3-1	T3-2	T3-3
Test location	AFTERBURNER OUTLET		
Test date	7-17-89	7-17-89	7-18-89
Test time period	0445-1226	1440-2221	1433-2134
SAMPLING DATA:			
Sampling duration, min.	360.0	240.0	360.0
Nozzle diameter, in.	0.760	0.760	0.760
Cross sectional nozzle area, sq.ft.	0.003150	0.003150	0.003150
Barometric pressure, in. Hg	26.48	25.94	25.97
Avg. orifice press. diff., in H2O	0.60	0.55	0.72
Avg. dry gas meter temp., deg F	98	116	119
Avg. abs. dry gas meter temp., deg. R	558	576	579
Total liquid collected by train, ml	317.0	210.0	353.0
Std. vol. of H2O vapor coll., cu.ft.	14.9	9.9	16.6
Dry gas meter calibration factor	0.995	0.995	0.995
Sample vol. at meter cond., dcf	174.486	112.964	191.591
Sample vol. at std. cond., dscf (1)	145.534	89.424	151.316
Percent of isokinetic sampling	101.8	101.4	100.0
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	6.5	6.7	6.2
O2, % by volume, dry basis	10.3	11.0	11.2
CO, ppm by volume, dry basis	4.9	1.3	6.6
N2, % by volume, dry basis	83.2	82.3	82.6
Molecular wt. of dry gas, lb/lb mole	29.5	29.5	29.4
H2O vapor in gas stream, prop. by vol.	0.093	0.100	0.099
Mole fraction of dry gas	0.907	0.900	0.901
Molecular wt. of wet gas, lb/lb mole	28.4	28.4	28.3
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	-0.10	-0.10	-0.10
Static pressure, in. Hg	-0.007	-0.007	-0.007
Absolute pressure, in. Hg	26.47	25.93	25.96
Avg. temperature, deg. F	1818	1802	1806
Avg. absolute temperature, deg.R	2278	2262	2266
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	24	24	24
Avg. gas stream velocity, ft./sec.	11.3	10.7	12.2
Stack/duct cross sectional area, sq.ft.	17.10	17.10	17.10
Avg. gas stream volumetric flow, wacf/min.	11600	11000	12500
Avg. gas stream volumetric flow, dscf/min.	2200	2000	2300
EXPLOSIVES EMISSIONS:			
HMX			
Concentration, lbs/dscf	< 1.92E-11	< 3.13E-11	< 1.85E-11
Concentration, ppm/v	< 2.50E-05	< 4.07E-05	< 2.41E-05
Mass rate, lbs/hr	< 2.49E-06	< 3.75E-06	< 2.53E-06
RDX			
Concentration, lbs/dscf	5.77E-11	9.42E-11	4.08E-11
Concentration, ppm/v	1.00E-04	1.63E-04	7.08E-05
Mass rate, lbs/hr	7.47E-06	1.13E-05	5.59E-06
Trinitrobenzene (1 3 5 TNB)			
Concentration, lbs/dscf	< 3.17E-11	8.53E-11	4.05E-11
Concentration, ppm/v	< 5.72E-05	1.54E-04	7.32E-05
Mass rate, lbs/hr	< 4.10E-06	1.02E-05	5.55E-06
Dinitrobenzene (1 3 DNB)			
Concentration, lbs/dscf	8.48E-11	2.07E-10	7.53E-11
Concentration, ppm/v	1.94E-04	4.75E-04	1.73E-04
Mass rate, lbs/hr	1.10E-05	2.48E-05	1.03E-05
Nitrobenzene			
Concentration, lbs/dscf	< 6.36E-12	4.98E-10	< 6.12E-12
Concentration, ppm/v	< 1.99E-05	1.56E-03	< 1.92E-05
Mass rate, lbs/hr	< 8.23E-07	5.96E-05	< 8.38E-07
Tetryl			
Concentration, lbs/dscf	< 7.57E-11	< 1.23E-10	< 7.28E-11
Concentration, ppm/v	< 1.02E-04	< 1.66E-04	< 9.78E-05
Mass rate, lbs/hr	< 9.80E-06	< 1.48E-05	< 9.98E-06
2 4 6 Trinitrotoluene (TNT)			
Concentration, lbs/dscf	< 2.91E-11	< 4.73E-11	< 2.80E-11
Concentration, ppm/v	< 4.94E-05	< 8.04E-05	< 4.75E-05
Mass rate, lbs/hr	< 3.76E-06	< 5.67E-06	< 3.83E-06
Destruction removal efficiency, %	> 99.997	> 95.500	> 98.328
2 4 Dinitrotoluene (2 4 DNT)			
Concentration, lbs/dscf	< 6.36E-12	< 1.04E-11	< 6.12E-12
Concentration, ppm/v	< 1.35E-05	< 2.19E-05	< 1.29E-05
Mass rate, lbs/hr	< 8.23E-07	< 1.24E-06	< 8.38E-07
2 6 Dinitrotoluene (2 6 DNT)			
Concentration, lbs/dscf	< 6.06E-12	< 9.86E-12	< 5.83E-12
Concentration, ppm/v	< 1.28E-05	< 2.09E-05	< 1.23E-05
Mass rate, lbs/hr	< 7.84E-07	< 1.18E-06	< 7.98E-07

(1) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)

Table 8-7D
(continued)

Summary of Data and Results from Stack Test Conducted during Test Run 3 at

Afterburner Outlet - Semivolatiles

TEST DATA:	
Test run number	T3-1
Test location	AFTERBURNER OUTLET
Test date	7-17-89
Test time period	0445-1226
LABORATORY REPORT, ug	
Phenol	3
Naphthalene	15
Diethylphthalate	136
Di-n-Butylphthalate	61
Butylbenzylphthalate	3
bis(2-Ethylhexyl)phthalate	29
Di-n-Octyl phthalate	4
SEMIVOLATILE EMISSIONS:	
Phenol	
Concentration, lbs/dscf	4.54E-11
Concentration, ppm/v	1.86E-04
Mass rate, lbs/hr	5.88E-06
Naphthalene	
Concentration, lbs/dscf	2.27E-10
Concentration, ppm/v	6.83E-04
Mass rate, lbs/hr	2.94E-05
Diethylphthalate	
Concentration, lbs/dscf	2.06E-09
Concentration, ppm/v	4.78E-03
Mass rate, lbs/hr	2.67E-04
Di-n-Butylphthalate	
Concentration, lbs/dscf	9.24E-10
Concentration, ppm/v	1.28E-03
Mass rate, lbs/hr	1.20E-04
Butylbenzylphthalate	
Concentration, lbs/dscf	4.54E-11
Concentration, ppm/v	5.61E-05
Mass rate, lbs/hr	5.88E-06
bis(2-Ethylhexyl)phthalate	
Concentration, lbs/dscf	4.39E-10
Concentration, ppm/v	4.33E-04
Mass rate, lbs/hr	5.69E-05
Di-n-Octyl phthalate	
Concentration, lbs/dscf	6.06E-11
Concentration, ppm/v	8.39E-05
Mass rate, lbs/hr	7.84E-06

Table 8-7E

Summary of Data and Results from Stack Test Conducted during and Test Run 3 at

Afterburner Outlet - Nitrated Esters and Particulate

TEST DATA:			
Test run number	T3-1	T3-2	T3-3
Test location		AFTERBURNER OUTLET	
Test date	7-17-89	7-17-89	7-18-89
Test time period	0445-1226	1440-2221	1434-2134
SAMPLING DATA:			
Sampling duration, min.	360.0	240.0	360.0
Nozzle diameter, in.	0.860	0.860	0.860
Cross sectional nozzle area, sq.ft.	0.004034	0.004034	0.004034
Barometric pressure, in. Hg	26.48	25.94	25.97
Avg. orifice press. diff., in H2O	0.84	1.08	0.00
Avg. dry gas meter temp., deg F	98	114	115
Avg. abs. dry gas meter temp., deg. R	558	574	575
Total liquid collected by train, ml	368.0	283.0	422.0
Std. vol. of H2O vapor coll., cu.ft.	17.3	13.3	19.9
Dry gas meter calibration factor	1.003	1.003	1.003
Sample vol. at meter cond., dcf	191.534	142.223	221.775
Sample vol. at std. cond., dscf (1)	161.159	114.142	177.915
Percent of isokinetic sampling	100.7	102.1	101.5
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	6.5	6.7	6.2
O2, % by volume, dry basis	10.3	11.0	11.2
CO, ppm by volume, dry basis	4.9	1.3	6.6
N2, % by volume, dry basis	83.2	82.3	82.6
Molecular wt. of dry gas, lb/lb mole	29.5	29.5	29.4
H2O vapor in gas stream, prop. by vol.	0.097	0.105	0.100
Mole fraction of dry gas	0.903	0.895	0.900
Molecular wt. of wet gas, lb/lb mole	28.3	28.3	28.3
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	-0.09	-0.10	-0.10
Static pressure, in. Hg	-0.007	-0.007	-0.007
Absolute pressure, in. Hg	26.47	25.93	25.96
Avg. temperature, deg. F	1747	1800	1789
Avg. absolute temperature, deg.R	2207	2260	2249
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	24	24	24
Avg. gas stream velocity, ft./sec.	9.6	10.6	11.0
Stack/duct cross sectional area, sq.ft.	17.10	17.10	17.10
Avg. gas stream volumetric flow, wacf/min.	9900	10900	11300
Avg. gas stream volumetric flow, dscf/min.	1900	2000	2100
Particulate Emissions:			
Total particulate catch,g.	0.0025	0.0049	0.0057
Concentration, gr/dscf	2.39E-04	6.62E-04	4.94E-04
Mass rate, lbs/hr	0.004	0.011	0.009
Nitrated Esters:			
Nitrated esters catch, ug	3184.97	2237.525	5774.47
Concentration, gr/dscf	3.05E-04	3.03E-04	5.01E-04
Mass rate, lbs/hr	4.93E-03	5.12E-03	8.87E-03
Total Hydrocarbon Emissions: (2)			
Concentration, ppm/v dry basis as propane	0.1	0.3	0.1
Concentration, lb/dscf	1.14E-08	3.43E-08	1.14E-08
Mass emission rate, lb/hr	0.001	0.004	0.001
NOx Emissions: (2)			
Concentration, ppm/v dry basis as NO2	55.4	48.8	47.4
Concentration, lb/dscf	6.61E-06	5.83E-06	5.66E-06
Mass emission rate, lb/hr	0.75	0.69	0.70
Carbon Monoxide Emissions: (2)			
Concentration, ppm/v dry basis	4.9	1.3	6.6
Concentration, lb/dscf	3.56E-07	9.44E-08	4.79E-07
Mass emission rate, lb/hr	0.040	0.011	0.059

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(1) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)
(2) As measured by the WESTON CEM trailer

Table 8-8A

Summary of Data and Results from Stack Test Conducted during Test Run 5 at

Flash Chamber Inlet - Total Hydrocarbons

TEST DATA:			
Test run number	T5-1	T5-2	T5-3
Test location	FLASHCHAMBER INLET		
Test date	07-29-89	07-29-89	07-30-89
Test time period	1017-1630	1900-2400	1230-1630
SAMPLING DATA:(1)			
Sampling duration, min.	373.0	300.0	240.0
Nozzle diameter, in.	NA	NA	NA
Cross sectional nozzle area, sq.ft.	NA	NA	NA
Barometric pressure, in. Hg	26.41	26.41	26.38
Avg. orifice press. diff., in H2O	1.13	1.35	1.26
Avg. dry gas meter temp., deg F	99	92	102
Avg. abs. dry gas meter temp., deg. R	559	552	562
Total liquid collected by train, ml	92.0	88.0	67.0
Std. vol. of H2O vapor coll., cu.ft.	4.3	4.1	3.2
Dry gas meter calibration factor	0.999	0.999	0.999
Sample vol. at meter cond., dcf	183.074	143.763	130.243
Sample vol. at std. cond., dscf (2)	152.810	121.476	108.067
Percent of isokinetic sampling	NA	NA	NA
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	1.6	2.2	2.0
O2, % by volume, dry basis	17.4	16.5	16.7
CO, ppm by volume, dry basis (3)	136.8	261.3	206.1
N2, % by volume, dry basis	81.0	81.3	81.3
Molecular wt. of dry gas, lb/lb mole	29.0	29.0	29.0
H2O vapor in gas stream, prop. by vol.	0.028	0.033	0.028
Mole fraction of dry gas	0.972	0.967	0.972
Molecular wt. of wet gas, lb/lb mole	28.6	28.6	28.7
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	0.05	0.05	0.05
Static pressure, in. Hg	0.004	0.004	0.004
Absolute pressure, in. Hg	26.41	26.41	26.38
Avg. temperature, deg. F	874	1036	898
Avg. absolute temperature, deg.R	1334	1496	1358
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	16	16	16
Avg. gas stream velocity, ft./sec.	40.4	49.5	41.9
Stack/duct cross sectional area, sq.ft.	1.77	1.77	1.77
Avg. gas stream volumetric flow, wacf/min.	4300	5300	4500
Avg. gas stream volumetric flow, dscf/min.	1500	1600	1500
Total Hydrocarbon Emissions: (3)			
Concentration, ppm/v dry basis as propane	32.2	50.8	45.8
Concentration, lb/dscf	3.68E-06	5.81E-06	5.24E-06
Mass emission rate, lb/hr	0.32	0.55	0.47

(1) Sampling data presented for EPA Method 4 (moisture) sampling train

(2) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)

(3) As measured by the WESTON CEM trailer

Table 8-8B

Summary of Data and Results from Stack Test Conducted during Test Run 5 at

Flash Chamber Outlet - Explosives

TEST DATA:			
Test run number	T5-1	T5-2	T5-3
Test location	FLASH CHAMBER OUTLET		
Test date	7-29-89	7-29-89	7-30-89
Test time period	0955-1720	1823-0129	1221-1719
SAMPLING DATA:			
Sampling duration, min.	390.0	360.0	240.0
Nozzle diameter, in.	0.300	0.300	0.300
Cross sectional nozzle area, sq.ft.	0.000491	0.000491	0.000491
Barometric pressure, in. Hg	26.41	26.41	26.37
Avg. orifice press. diff., in H2O	1.09	1.38	1.20
Avg. dry gas meter temp., deg F	106	99	108
Avg. abs. dry gas meter temp., deg. R	566	559	568
Total liquid collected by train, ml	117.0	139.0	84.0
Std. vol. of H2O vapor coll., cu.ft.	5.5	6.5	4.0
Dry gas meter calibration factor	1.002	1.002	1.002
Sample vol. at meter cond., dcf	254.412	256.323	161.635
Sample vol. at std. cond., dscf (1)	210.339	214.762	133.080
Percent of isokinetic sampling	100.9	99.6	99.5
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	1.2	1.6	1.6
O2, % by volume, dry basis	18.1	17.4	17.5
CO, ppm by volume, dry basis	106.0	171.2	188.5
N2, % by volume, dry basis	80.7	81.0	80.9
Molecular wt. of dry gas, lb/lb mole	28.9	29.0	29.0
H2O vapor in gas stream, prop. by vol.	0.026	0.030	0.029
Mole fraction of dry gas	0.974	0.970	0.971
Molecular wt. of wet gas, lb/lb mole	28.6	28.6	28.6
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	-0.49	-0.58	-0.57
Static pressure, in. Hg	-0.036	-0.043	-0.042
Absolute pressure, in. Hg	26.37	26.37	26.33
Avg. temperature, deg. F	359	480	521
Avg. absolute temperature, deg.R	819	940	981
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	12	12	12
Avg. gas stream velocity, ft./sec.	32.8	42.4	41.2
Stack/duct cross sectional area, sq.ft.	1.77	1.77	1.77
Avg. gas stream volumetric flow, wacf/min.	3500	4500	4400
Avg. gas stream volumetric flow, dscf/min.	1900	2200	2000
EXPLOSIVES EMISSIONS:			
HMX			
Concentration, lbs/dscf	< 2.49E-08	< 1.30E-09	< 2.10E-10
Concentration, ppm/v	< 0.0325	< 0.0017	< 2.74E-04
Mass rate, lbs/hr	< 0.0029	< 1.69E-04	< 2.54E-05
RDX			
Concentration, lbs/dscf	< 1.93E-08	< 1.01E-09	< 1.62E-10
Concentration, ppm/v	< 0.0335	< 0.0017	< 2.82E-04
Mass rate, lbs/hr	< 0.0022	< 1.30E-04	< 1.96E-05
Trinitrobenzene (1 3 5 TNB)			
Concentration, lbs/dscf	< 4.11E-08	< 2.15E-09	< 3.46E-10
Concentration, ppm/v	< 0.0743	< 0.0039	< 6.26E-04
Mass rate, lbs/hr	< 0.0047	< 2.78E-04	< 4.18E-05
Dinitrobenzene (1 3 DNB)			
Concentration, lbs/dscf	< 1.16E-08	< 6.06E-10	< 9.77E-11
Concentration, ppm/v	< 0.0267	< 0.0014	< 2.24E-04
Mass rate, lbs/hr	< 0.0013	< 7.84E-05	< 1.18E-05
Nitrobenzene			
Concentration, lbs/dscf	< 8.26E-09	< 4.31E-10	< 6.96E-11
Concentration, ppm/v	< 0.0259	< 0.0014	< 2.18E-04
Mass rate, lbs/hr	< 0.0010	< 5.58E-05	< 8.39E-06
Tetryl			
Concentration, lbs/dscf	< 9.83E-08	< 5.13E-09	< 8.28E-10
Concentration, ppm/v	< 0.1320	< 0.0069	< 1.11E-03
Mass rate, lbs/hr	< 0.0113	< 6.64E-04	< 9.99E-05
2 4 6 Trinitrotoluene (TNT)			
Concentration, lbs/dscf	8.05E-07	6.95E-09	3.05E-09
Concentration, ppm/v	1.3665	0.0118	0.0052
Mass rate, lbs/hr	0.0929	9.00E-04	3.68E-04
2 4 Dinitrotoluene (2 4 DNT)			
Concentration, lbs/dscf	< 8.18E-09	< 4.31E-10	< 6.96E-11
Concentration, ppm/v	< 0.0173	< 0.0009	< 1.47E-04
Mass rate, lbs/hr	< 9.44E-04	< 5.58E-05	< 8.39E-06
2 6 Dinitrotoluene (2 6 DNT)			
Concentration, lbs/dscf	< 7.86E-09	< 4.11E-10	< 6.63E-11
Concentration, ppm/v	< 0.0166	< 0.0009	< 1.40E-04
Mass rate, lbs/hr	< 9.07E-04	< 5.32E-05	< 7.99E-06

(1) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)

Table 8-8C

Summary of Data and Results from Stack Test Conducted during Test Run 5 at

Flash Chamber Outlet - Nitrated Esters/Total Hydrocarbons

TEST DATA:			
Test run number	T5-1	T5-2	T5-3
Test location	FLASH CHAMBER OUTLET		
Test date	7-29-89	7-29-89	7-30-89
Test time period	0955-1720	1824-0129	1221-1719
SAMPLING DATA:			
Sampling duration, min.	390.0	360.0	240.0
Nozzle diameter, in.	0.310	0.310	0.310
Cross sectional nozzle area, sq.ft.	0.000524	0.000524	0.000524
Barometric pressure, in. Hg	26.41	26.41	26.37
Avg. orifice press. diff., in H2O	1.61	1.51	1.64
Avg. dry gas meter temp., deg F	115	108	117
Avg. abs. dry gas meter temp., deg. R	575	568	577
Total liquid collected by train, ml	125.0	149.0	96.0
Std. vol. of H2O vapor coll., cu.ft.	5.9	7.0	4.5
Dry gas meter calibration factor	1.002	1.002	1.002
Sample vol. at meter cond., dcf	278.842	247.516	172.069
Sample vol. at std. cond., dscf (1)	227.428	204.323	139.751
Percent of isokinetic sampling	99.5	93.0	97.6
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	1.2	1.6	1.6
O2, % by volume, dry basis	18.1	17.4	17.5
CO, ppm by volume, dry basis (2)	106.0	171.2	188.5
N2, % by volume, dry basis	80.7	81.0	80.9
Molecular wt. of dry gas, lb/lb mole	28.9	29.0	29.0
H2O vapor in gas stream, prop. by vol.	0.025	0.033	0.031
Mole fraction of dry gas	0.975	0.967	0.969
Molecular wt. of wet gas, lb/lb mole	28.6	28.6	28.6
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	-0.50	-0.57	-0.58
Static pressure, in. Hg	-0.037	-0.042	-0.043
Absolute pressure, in. Hg	26.37	26.37	26.33
Avg. temperature, deg. F	379	478	520
Avg. absolute temperature, deg.R	839	938	980
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	12	12	12
Avg. gas stream velocity, ft./sec.	34.5	40.5	41.4
Stack/duct cross sectional area, sq.ft.	1.77	1.77	1.77
Avg. gas stream volumetric flow, wacf/min.	3700	4300	4400
Avg. gas stream volumetric flow, dscf/min.	2000	2100	2000
Nitrated Esters Emissions:			
Nitrated esters catch, ug	23326	1041.31	4389.53
Concentration, gr/dscf	1.58E-03	7.86E-05	4.85E-04
Mass rate, lbs/hr	0.027	0.001	0.008
Total Hydrocarbon Emissions: (2)			
Concentration, ppm/v dry basis as propane	25	34.7	30.5
Concentration, lb/dscf	2.86E-06	3.97E-06	3.49E-06
Mass emission rate, lb/hr	0.339	0.490	0.422

(1) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)

(2) As measured by the WESTON CEM trailer

Table 8-8D
Summary of Data and Results from Stack Test Conducted during Test Run 5 at
Afterburner Outlet - Explosives

TEST DATA:			
Test run number	T5-1	T5-2	T5-3
Test location		AFTERBURNER OUTLET	
Test date	7-29-89	7-29-89	7-30-89
Test time period	0955-1720	1824-0129	1221-1718
SAMPLING DATA:			
Sampling duration, min.	390.0	360.0	240.0
Nozzle diameter, in.	0.800	0.800	0.800
Cross sectional nozzle area, sq.ft.	0.003491	0.003491	0.003491
Barometric pressure, in. Hg	26.41	26.41	26.37
Avg. orifice press. diff., in H2O	0.97	1.01	0.93
Avg. dry gas meter temp., deg F	118	105	120
Avg. abs. dry gas meter temp., deg. R	578	565	580
Total liquid collected by train, ml	404.5	364.0	216.0
Std. vol. of H2O vapor coll., cu.ft.	19.0	17.1	10.2
Dry gas meter calibration factor	0.995	0.995	0.995
Sample vol. at meter cond., dcf	239.435	219.621	142.886
Sample vol. at std. cond., dscf (1)	192.617	180.603	114.422
Percent of isokinetic sampling	99.2	99.2	98.7
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	6.6	6.2	6.1
O2, % by volume, dry basis	10.3	11.0	11.2
CO, ppm by volume, dry basis	6.9	5.6	6.9
N2, % by volume, dry basis	83.1	82.8	82.7
Molecular wt. of dry gas, lb/lb mole	29.5	29.4	29.4
H2O vapor in gas stream, prop. by vol.	0.090	0.087	0.082
Mole fraction of dry gas	0.910	0.913	0.918
Molecular wt. of wet gas, lb/lb mole	28.4	28.4	28.5
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	-0.10	-0.10	-0.10
Static pressure, in. Hg	-0.007	-0.007	-0.007
Absolute pressure, in. Hg	26.40	26.40	26.36
Avg. temperature, deg. F	1692	1704	1714
Avg. absolute temperature, deg.R	2152	2164	2174
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	24	24	24
Avg. gas stream velocity, ft./sec.	12.1	12.3	11.7
Stack/duct cross sectional area, sq.ft.	17.10	17.10	17.10
Avg. gas stream volumetric flow, wacf/min.	12400	12600	12100
Avg. gas stream volumetric flow, dscf/min.	2400	2500	2400
EXPLOSIVES EMISSIONS:			
HMX			
Concentration, lbs/dscf	1.45E-10	1.79E-11	< 2.45E-11
Concentration, ppm/v	1.89E-04	2.33E-05	< 3.18E-05
Mass rate, lbs/hr	2.13E-05	2.67E-06	< 3.48E-06
RDX			
Concentration, lbs/dscf	3.16E-11	3.14E-11	5.47E-11
Concentration, ppm/v	5.48E-05	5.44E-05	9.49E-05
Mass rate, lbs/hr	4.62E-06	4.67E-06	7.78E-06
Trinitrobenzene (1 3 5 TNB)			
Concentration, lbs/dscf	< 2.39E-11	2.67E-11	1.47E-10
Concentration, ppm/v	< 4.33E-05	4.83E-05	2.65E-04
Mass rate, lbs/hr	< 3.50E-06	3.98E-06	2.09E-05
Dinitrobenzene (1 3 DNB)			
Concentration, lbs/dscf	3.01E-11	9.28E-11	3.66E-11
Concentration, ppm/v	6.90E-05	2.13E-04	8.39E-05
Mass rate, lbs/hr	4.41E-06	1.38E-05	5.20E-06
Nitrobenzene			
Concentration, lbs/dscf	< 4.81E-12	1.90E-11	3.68E-11
Concentration, ppm/v	< 1.51E-05	5.97E-05	1.15E-04
Mass rate, lbs/hr	< 7.04E-07	2.83E-06	5.23E-06
Tetryl			
Concentration, lbs/dscf	< 5.72E-11	< 6.10E-11	< 9.63E-11
Concentration, ppm/v	< 7.68E-05	< 8.19E-05	< 1.29E-04
Mass rate, lbs/hr	< 8.38E-06	< 9.08E-06	< 1.37E-05
2 4 6 Trinitrotoluene (TNT)			
Concentration, lbs/dscf	< 2.20E-11	< 2.34E-11	< 3.70E-11
Concentration, ppm/v	< 3.73E-05	< 3.98E-05	< 6.28E-05
Mass rate, lbs/hr	< 3.22E-06	< 3.49E-06	< 5.26E-06
Destruction removal efficiency, %	> 99.997	> 99.612	> 98.571
2 4 Dinitrotoluene (2 4 DNT)			
Concentration, lbs/dscf	< 4.81E-12	< 5.13E-12	< 8.09E-12
Concentration, ppm/v	< 1.02E-05	< 1.08E-05	< 1.71E-05
Mass rate, lbs/hr	< 7.04E-07	< 7.63E-07	< 1.15E-06
2 6 Dinitrotoluene (2 6 DNT)			
Concentration, lbs/dscf	< 4.58E-12	< 4.88E-12	< 7.71E-12
Concentration, ppm/v	< 9.69E-06	< 1.03E-05	< 1.63E-05
Mass rate, lbs/hr	< 6.70E-07	< 7.26E-07	< 1.10E-06

(1) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)

Table 8-8E
Summary of Data and Results from Stack Test Conducted during Test Run 5 at Afterburner Outlet - Nitrated Esters and Particulate

TEST DATA:			
Test run number	T5-1	T5-2	T5-3
Test location	AFTERBURNER OUTLET		
Test date	7-29-89	7-29-89	7-30-89
Test time period	0955-1720	1824-0129	1221-1718
SAMPLING DATA:			
Sampling duration, min.	390.0	360.0	240.0
Nozzle diameter, in.	0.810	0.810	0.810
Cross sectional nozzle area, sq.ft.	0.003578	0.003578	0.003578
Barometric pressure, in. Hg	26.41	26.41	26.37
Avg. orifice press. diff., in H2O	1.13	1.35	1.26
Avg. dry gas meter temp., deg F	112	103	112
Avg. abs. dry gas meter temp., deg. R	572	563	572
Total liquid collected by train, ml	369.0	398.0	236.0
Std. vol. of H2O vapor coll., cu.ft.	17.4	18.7	11.1
Dry gas meter calibration factor	1.003	1.003	1.003
Sample vol. at meter cond., dcf	243.418	242.749	156.510
Sample vol. at std. cond., dscf (1)	199.486	202.393	128.111
Percent of isokinetic sampling	100.5	101.5	101.8
GAS STREAM COMPOSITION DATA:			
CO2, % by volume, dry basis	6.6	6.2	6.1
O2, % by volume, dry basis	10.3	11.0	11.2
CO, % by volume, dry basis	6.9	5.6	6.9
N2, % by volume, dry basis	83.1	82.8	82.7
Molecular wt. of dry gas, lb/lb mole	29.5	29.4	29.4
H2O vapor in gas stream, prop. by vol.	0.080	0.085	0.080
Mole fraction of dry gas	0.920	0.915	0.920
Molecular wt. of wet gas, lb/lb mole	28.5	28.5	28.5
GAS STREAM VELOCITY AND VOLUMETRIC FLOW DATA:			
Static pressure, in. H2O	-0.10	-0.10	-0.10
Static pressure, in. Hg	-0.007	-0.007	-0.008
Absolute pressure, in. Hg	26.40	26.40	26.36
Avg. temperature, deg. F	1698	1712	1720
Avg. absolute temperature, deg.R	2158	2172	2180
Pitot tube coefficient	0.84	0.84	0.84
Total number of traverse points	24	24	24
Avg. gas stream velocity, ft./sec.	11.9	13.2	12.4
Stack/duct cross sectional area, sq.ft.	17.10	17.10	17.10
Avg. gas stream volumetric flow, wacf/min.	12300	13500	12800
Avg. gas stream volumetric flow, dscf/min.	2400	2600	2500
Particulate Emissions: (2)			
Total particulate catch,g.	0.0044	0.0017	0.0001
Concentration, gr/dscf	3.40E-04	1.30E-04	1.20E-05
Mass rate, lbs/hr	0.007	0.003	0.0003
Nitrated Esters Emissions:			
Nitrated esters catch, ug	1847.5	< 2575	< 1413
Concentration, gr/dscf	1.43E-04	< 1.96E-04	< 1.70E-04
Mass rate, lbs/hr	2.98E-03	< 4.46E-03	< 3.66E-03
Total Hydrocarbon Emissions: (3)			
Concentration, ppm/v dry basis as propane	0.6	0.3	0.4
Concentration, lb/dscf	6.87E-08	3.43E-08	4.58E-08
Mass emission rate, lb/hr	0.010	0.005	0.007
NOx Emissions: (3)			
Concentration, ppm/v dry basis as NO2	57.3	48.7	51.7
Concentration, lb/dscf	6.84E-06	5.81E-06	6.17E-06
Mass emission rate, lb/hr	1.00	0.92	0.93
Carbon Monoxide Emissions: (3)			
Concentration, ppm/v dry basis	6.9	5.6	6.9
Concentration, lb/dscf	5.01E-07	4.07E-07	5.01E-07
Mass emission rate, lb/hr	0.073	0.065	0.075

(1) Standard conditions = 68 deg. F. (20 deg. C.) and 29.92 inches Hg (760 mm Hg)
(2) Particulate test run three catch is detection limit value
(3) As measured by the WESTON CEM trailer
N.D. = None Detected

- Sheet C - Summarizes the concentration of nitrated esters at the flash chamber outlet. As discussed in Subsection 9.6.2.3, the analysis used to measure smokeless powder (nitrocellulose/nitroglycerin) emissions did not allow nitrocellulose and nitroglycerin to be distinguished from one another. Also, nitrous oxide emissions and other nitrated compounds may have interfered in analysis. Thus, total nitrated esters, which include nitrocellulose and nitroglycerin, have been reported. Sheet C also presents THC values (T1-T3) and semivolatile emissions (for T3 only) measured at the flash chamber outlet.

- Sheet D - Presents the explosive emissions measured at the afterburner outlet. Information on each parameter included in the explosives analytical method is included. Concentrations that are not present at levels above the detection limit are shown as "less than" the method detection limit. Sheet D also presents semivolatile emissions (for T3 only) measured at the afterburner outlet.

- Sheet E - Includes information on particulate, nitrated esters, total hydrocarbons, nitrous oxides and carbon monoxide emissions measured at the afterburner outlet. Data for total hydrocarbons, nitrous oxides and carbon monoxide were not monitored as part of the stack test program; data shown represents average values measured during each stack sampling event by the CEM system.

No sampling problems were noted during the source testing program.

8.2 ANALYTICAL DATA

The raw analytical data corresponding to the test items are provided in Appendix F; raw analytical data for the stack test program are provided in Appendix G.

8.2.1 TEST ITEMS

Summary tables for the test items have been prepared and are contained in Appendix H. The following information is provided:

- Equipment type.

- Sample matrix (rinse, wipe, solid).

- Contaminant mass.

- Contaminant concentration (HMX, RDX, 1,3,5-TNB, 1,3-DNB, NB, Tetryl, 2,4,6-TNT, 2,6-DNT, 2,4-DNT, nitrated esters, and ammonium picrate).

- Total explosives concentration (sum of individual contaminants).

Sample results that exceeded the method detection limit (i.e, "hits") are shown in bold type.

If the analysis indicated that the compound was not present above the method detection limit, the detection limit is shown with the classification U (e.g., 635U ug signifies that the contaminant was not present above the detection level of 635 ug). Detection limits vary by matrix and total sample volume. For example, the detection limits associated with motors are much higher than the detection limits associated with steam-heated risers. In the case of the motors, about 26 gallons of solvent were required for the soak process. The detection limit is elevated, as follows:

- Detection limit from laboratory - 0.635 ug/mL.
- Total sample volume (108,000 mL).
- Reportable detection limit - 68,580 ug (0.635 ug/mL x 108,000 mL = 68,580 ug).

The method for determing the reportable detection limit is based on EPA protocol established in the Contractor Laboratory Program (CLP).

Review of the analytical data in Appendix H indicates the presence of nitrobenzene in many wipe samples. For convenience, the data corresponding to nitrobenzene "hits" are summarized on Table 8-9. In the early stages of the pilot study (T3, T2, and T5), the predominance of nitrobenzene was evaluated to determine if this contaminant was actually present or was the result of field or laboratory contamination. Analytical results for blank wipe samples were reviewed.

To determine the source of nitrobenzene, wipe samples were collected in the laboratory of Building 117-1 and in the loading dock area of Building 117-15. Two wipe samples were collected in the laboratory. The first wipe sample was collected by waving a dry wipe filter in the air and placing the filter in a sample jar for analysis. The second wipe was collected by soaking a wipe filter in acetonitrile and waving the saturated filter in the air. The filter was placed in a sample jar for analysis. The results of both wipe samples collected in the laboratory indicated the mass of nitrobenzene to be below method detection limits. These tests eliminated the filter paper and acetonitrile as sources of the detected nitrobenzene.

Two wipe samples were collected in the loading area of Building 117-15. The first wipe sample was collected (prior to T5) from a section of steel pipe that was delivered to the site from an off-base hardware store (sample identified as T5 Pre-Test, Steel Pipe Blank on Table 8-9). The pipe was lying on the ground outside the flash chamber for a few days prior to sampling. A wipe filter was soaked with acetonitrile. A small section of the pipe was wiped and the filter placed into a sample jar for analysis. The second wipe was collected by soaking a wipe filter with acetonitrile, waving the filter in the air and placing the filter into a sample jar for analysis. The mass of nitrobenzene found on the steel pipe was 4.58 ug. Nitrobenzene was not detected on the second wipe sample.

Table 8-9

Summary of Nitrobenzene Analytical Results

Test Number		Sample Identification^{a,b,c}	Mass of Nitrobenzene (ug)
0	Post-Test	T0 Clay Pipe	35.1
2	Pre-Test	Shell Support Rack 1	6.4
		Shell Support Rack 1 Decon	9.7
		Shell Support Rack 2	4.1
	Post-Test	Flash Chamber Wall	19.9
		Ship Mine W1	12.6
		Steam Heated Riser 1 Nipple	8.31
		Shell Support Rack 1 W1BOT	9.93
		Shell Support Rack 1 W2TOP	13.3
		Shell Support Rack 1 W2BOT	20.1
		Shell Support Rack 1 W2TOP	8.4
		Shell Support Rack 1 W3BOT	17.9
		Shell Support Rack 1 W4BOT	15.9
		Shell Support Rack 1 W4TOP	15.1
		Steel Pipe	34.1
		*Wipe Blank	5.22
3	Pre-Test	Shell Support Rack 1	6.4
		Shell Support Rack 1 Decon	9.7
		Shell Support Rack 2	4.1
		Shell Support Rack 2 Decon	6.6
	Post-Test	Powder Box W1	20.5
		Ship Mine W1	16.3
		Shell Support Rack 1 W1	10.7
		Shell Support Rack 1 W2	9.67
		Shell Support Rack 1 W3	8.59
		Shell Support Rack 1 W4	8.83
		Shell Support Rack 1 W5	12
		Shell Support Rack 1 W6	14.7
		Shell Support Rack 1 W7	13.9
		Shell Support Rack 1 W8	8.23
5	Pre-Test	*Steel Pipe Blank	4.58
	Post-Test	Flash Chamber Wall	17.5
		*Flash Chamber Wall Blank	8.29
		Ship Mine W1	20.1

Table 8-9

Nitrobenzene Analytical Results
(continued)

Test	Number	Sample Identification[a,b,c]	Mass of Nitrobenzene (ug)
		Shell Support Rack 2 W1	24.2
		Shell Support Rack 2 W2	7.24
		Shell Support Rack 2 W3	4.94
		Shell Support Rack 2 W5	25.6
		Shell Support Rack 2 W6	6.71
		Shell Support Rack 2 W7	4.84
8	Pre-test	Ship Mine W1	7.3
		*Ship Mine Field Blank	4.94
		Shell Support Rack 1 W1-W4	18.7
		Shell Support Rack 1 W5-W8	19.7
		Shell Support Rack 2 W1-W4	36.3
		Shell Support Rack 2 W5-W8	36.8
13	Pre-Test	Shell Support Rack 2 W5-W8	8.25
	Post-Test	T13 Clay Pipe	38.3
14	Pre-Test	Shell Support Rack 1 W1-W4	16.9
		Shell Support Rack 1 W5-W8	19.6
		Shell Support Rack 2 W1-W4	25.4
	Post-Test	T14 Clay Pipe	12.2
15	Post-Test	T15 Clay Pipe	13.3
16	Pre-Test	Shell Support Rack 1 W5-W8	19.4
		Shell Support Rack 2 W5-W8	4.3
18	Pre-Test	Shell Support Rack 1 W1-W4	9.7
		Shell Support Rack 2 W1-W4	65.7

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[a] All samples are wipe samples.

[b] Sample identification conventions include:
- ug = Microgram.
- Decon = Sample collected from top of shell support rack during decontamination.
- W = Wipe.
- Bot = Bottom shelf.
- Top = Top shelf.

[c] Asterisk (*) indicates blanks noted for reference.

The source of nitrobenzene was thought to be located in or around Building 117-15. The remainder of blank wipe samples were collected inside Building 117-15. A review of the analytical results corresponding to blank samples indicates that the nitrobenzene concentrations are in the same order of magnitude as those found in the test samples. The average mass of nitrobenzene found in various types of wipe samples is as follows:

• Blank samples	6.56 ug.
• Pre-test samples	17.9 ug.
• Post-test samples	13.6 ug.
• Chamber walls	18.5 ug.

The predominance of nitrobenzene was determined to be a field contaminant. This determination was based on the following:

- The mass of nitrobenzene in blank samples was in the same order of magnitude as test samples.

- Nitrobenzene was present on an uncontaminated pipe delivered to the site.

- In some cases, the mass of nitrobenzene was higher in post-test samples than pre-test samples.

There was only one other occasion where field or laboratory contamination was determined to be present. After Test 3 (500°F/36 hours), contamination was determined to be present in the fourth rinsate sample from a steam-heated riser (729 ug TNT; 2,400 ug TNT in duplicate rinsate sample analyzed). The contaminant levels in the rinsate samples from the first three flushes were below detection levels. The steam heated riser was rinsed an additional four times (eight total rinses). These additional rinsates did not contain detectable levels of TNT. To determine if the TNT was actually present or was due to field or laboratory contamination, the spare steam-heated riser was sampled for analysis. The contaminant levels in all four rinses of the spare riser were below detection levels. Since the spare steam heater riser was handled in the same way as the originally sampled riser (i.e., flushed and spiked), it was determined that the source of contamination was field or laboratory contamination.

As shown in Appendix H, the mass of some contaminants is shown as a "J value" (i.e., 3.36 J). This indicates that the compound was determined to be present but below the detection level. The mass of contaminant reported in the Appendix is an estimated value. Although provided in Appendix H, J values were not used in determinations of whether test objectives were achieved. If a contaminant mass was below the detection level it was not determined to be present.

The gear oil in one motor gear reducer was tested for explosives. Explosives concentrations were below detection limits.

8.2.2 STACK TEST PROGRAM

Summary data were shown on Tables 8-6, 8-7, and 8-8. Analytical results for TNT were used to calculate destruction and removal efficiencies (DREs) for the afterburner.

As shown on Table 8-10, a DRE of at least 99.99 percent for TNT was achieved during at least one sampling event for each stack test. DREs that are below 99.99 percent do not indicate that the afterburner was not operating properly. They indicate that there was not a sufficient quantity of TNT in the flash chamber outlet gases (i.e., afterburner inlet gases) to result in a DRE of 99.99 percent. By nature of the calculation for DRE, if the mass of contaminant in the inlet stream is not sufficiently high, the DRE will be less than 99.99 percent, even if detectable levels of TNT were not present. Since most of the TNT removal occurred during the first sampling event for each stack test, DREs associated with this sampling event are the highest at greater than 99.99 percent.

Although the DREs were determined for TNT, review of the summary data presented on Tables 8-6 through 8-8 indicates that detectable levels of other explosives were present in afterburner outlet gases, as follows:

- T2 - HMX, RDX, 1,3,5-TNB and 1,3-DNB.
- T3 - RDX,1,3,5-TNB, 1,3-DNB,NB.
- T5 - HMX, RDX, 1,3,5-TNB, 1,3-DNB, NB.

Analyses for semivolatiles and C_7-C_{17} hydrocarbons were conducted at the flash chamber outlet and afterburner outlet during T3. Summary data are presented on Table 8-7. The reported semivolatiles should be considered qualitative only. Benzoic acid was present in the samples at a concentration beyond the calibration range of the analytical instrument. As such, it was not possible to quantify the semivolatiles present, and reported values are estimated. Benzoic acid in the samples is not thought to be a heat degradation product of TNT. It may be a biodegradation product (some items such as the vitrified clay pipe had been accumulating TNT over many years; some biodegradation could have occurred). Benzoic acid is also a common contaminant found in soil (based on observations from the laboratory personnel). The debris found in the bottom of the clay pipe sections had the appearance of dirt. It is possible that when the debris in the vitrified clay pipe combusted (as evidenced by temperature spikes in the clay pipe from about 400°F to 1,000°F), soil or debris in the form of particulate was carried out and collected in the sampling train.

The average hydrocarbon concentrations measured by the CEM system during the stack test program are as follows:

- Flash chamber inlet - 40 parts per million by volume (ppm/v).
- Flash chamber outlet - 30 ppm/v.
- Afterburner outlet - 0.3 ppm/v.

Table 8-10

Summary of TNT Destruction and Removal Efficiencies

Test Run Number	TNT DRE* (Percent)
T3-1	>99.997
T3-2	>95.500
T3-3	>98.328
T2-1	>99.996
T2-2	>99.992
T2-3	>97.139
T5-1	>99.997
T5-2	>99.612
T5-3	>98.571

*DREs that are less than 99.99 percent are not indicative of poor afterburner performance. For each stack sampling event, the mass of TNT in the afterburner discharge gases (M2 in equation for DRE) was below detection limits. Low DREs are attributable to the decreased mass of TNT in afterburner inlet calculations (i.e., M1 in equation for DRE).

An average reduction of 99 percent of hydrocarbon was achieved over the afterburner.

Average concentrations measured at the afterburner are as follows:

- Oxides of nitrogen - 53 ppm/v (73 ppm/v at 7 percent oxygen).
- Carbon monoxide - 6 ppm/v (8 ppm/v at 7 percent oxygen).
- Particulate - 0.004 grains per dry standard cubic foot (gr/dscf) (0.005 gr/dscf at 7 percent oxygen).

A summary of the actual oxygen percentages recorded at the time of collection is presented in the raw operational data sheets in Appendix G.

SECTION 9

DISCUSSION OF RESULTS

TNT was the primary explosive evaluated during the pilot study. As such, the bulk of the discussions (found in Subsection 9.1) addresses TNT. Discussions for smokeless powder and ammonium picrate are included in Subsections 9.3 and 9.4, respectively.

9.1 DISCUSSION OF RESULTS FOR TNT

The test program included nine runs to evaluate the removal of TNT from the test items. Six of the tests were successful in removing all detectable levels of TNT. Three tests indicated the presence of detectable quantities of TNT on one or more test items. These test runs were considered failures.

9.1.1 VARIABLES AFFECTING TNT REMOVAL

Based on the results of the pilot study, there are three factors that affect the removal of TNT from test items, as follows:

- Time - The total number of hours that a test item is exposed to elevated temperatures.
- Temperature - The average temperature that a test item is exposed to during treatment.
- Location - The proximity of the test item to the hot gas source (diffusers), as well as the physical location of the explosive on the test item (internal or external surfaces).

Each variable will be discussed separately in the following subsections.

9.1.1.1 Time

Test items were exposed to elevated temperatures from a minimum of 69 hours (T-16) to a maximum of 165 hours (T-17). The treatment time was broken down into three periods or phases. The three time periods are defined as follows:

- Heatup - Commenced when the air preheater was ignited and continued until the target temperature was achieved and maintained.
- Steady state operation - Commenced when the target temperature was achieved and maintained and continued for the designated amount of time as set out in the test matrix.
- Cooldown - Commenced at the end of steady state operation and continued until the temperature in the flash chamber was safe for entry (usually about 120°F).

Sampling of test items was conducted following completion of each test. The total time of treatment is considered to have an affect on the removal of explosives. To illustrate the effect, Figure 9-1 provides a bar graph showing total detectable levels of TNT for the three failed tests at 400°F. The longer treatment times produced lower levels of detected explosives.

To evaluate when actual removal of TNT is occurring, the flash chamber emissions were reviewed. Based on the analyses from the stack sampling program, TNT was primarily removed from test items during the heatup period; however, removal continued throughout steady state operation and possibly into the cooldown period. For illustration, analyses results from the stack sampling conducted at the flash chamber outlet during successful Test Run 5 (500°F/24 hours) indicate the following concentrations of TNT:

- Stack Test 1 (6 hours beginning when the air preheater was fired) - 0.0929 lb/hr TNT.
- Stack Test 2 (6 hours immediately following probe changeout from Stack Test 1) - 0.0009 lb/hr TNT.
- Stack Test 3 (last 4 hours of steady state conditions; began 26 hours after ignition of the air preheater) - 0.000368 lb/hr TNT.

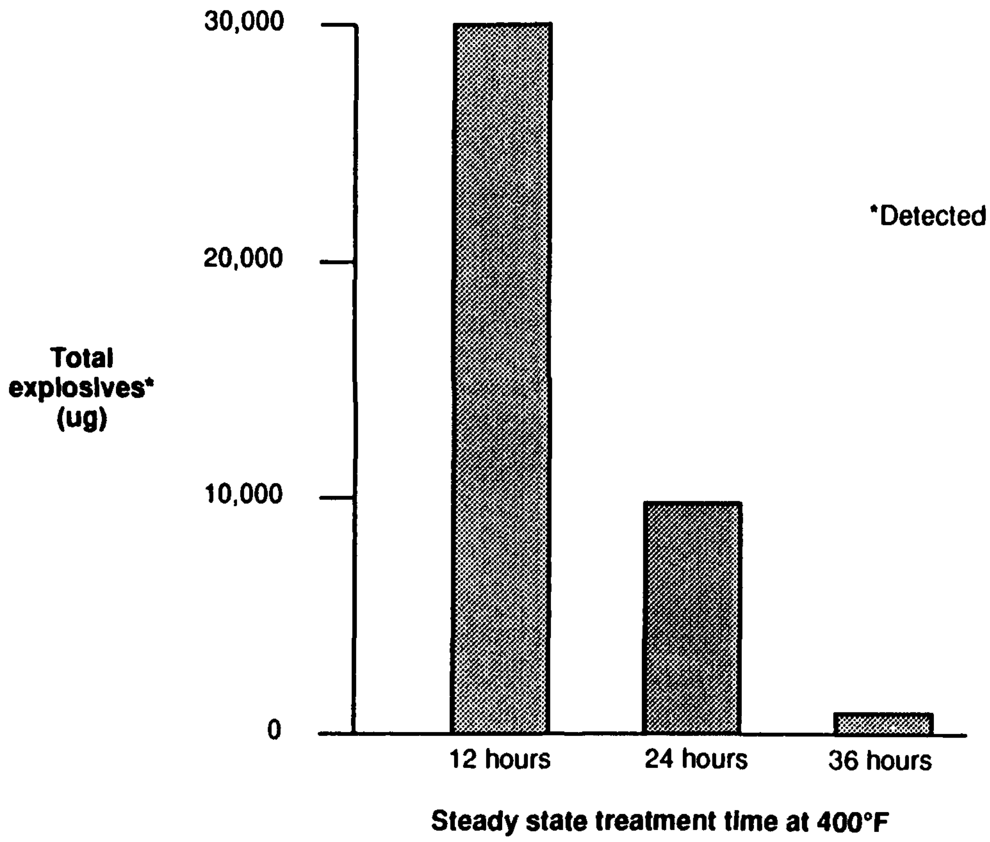
A diagram that illustrates the removal trend is shown on Figure 9-2. The natural logarithm of TNT removal rate (pounds/hour) is plotted versus treatment time. Natural logarithms were required due to the order of magnitude differences between the removal rates. As shown, TNT continued to be removed during the entire time the air preheater was operating, including the last 4 hours of steady state. The removal trend decreased with time. Based on these observations, it is expected that measureable quantities of TNT continued to be removed during the cooldown period since the flash chamber temperatures remained elevated.

The TNT emission rates corresponding to Test T5 were integrated over the test time to determine the amount of TNT emissions associated with each time period. The following two cases were evaluated over the time period beginning with ignition of the air preheater (t=0) and ending upon completion of the cooldown period (t=109 hours for Test T5):

- Case 1 - Minimum rate of TNT emissions.
- Case 2 - Maximum rate of TNT emissions.

The minimum rate of emissions was calculated based on the following time periods and removal rates:

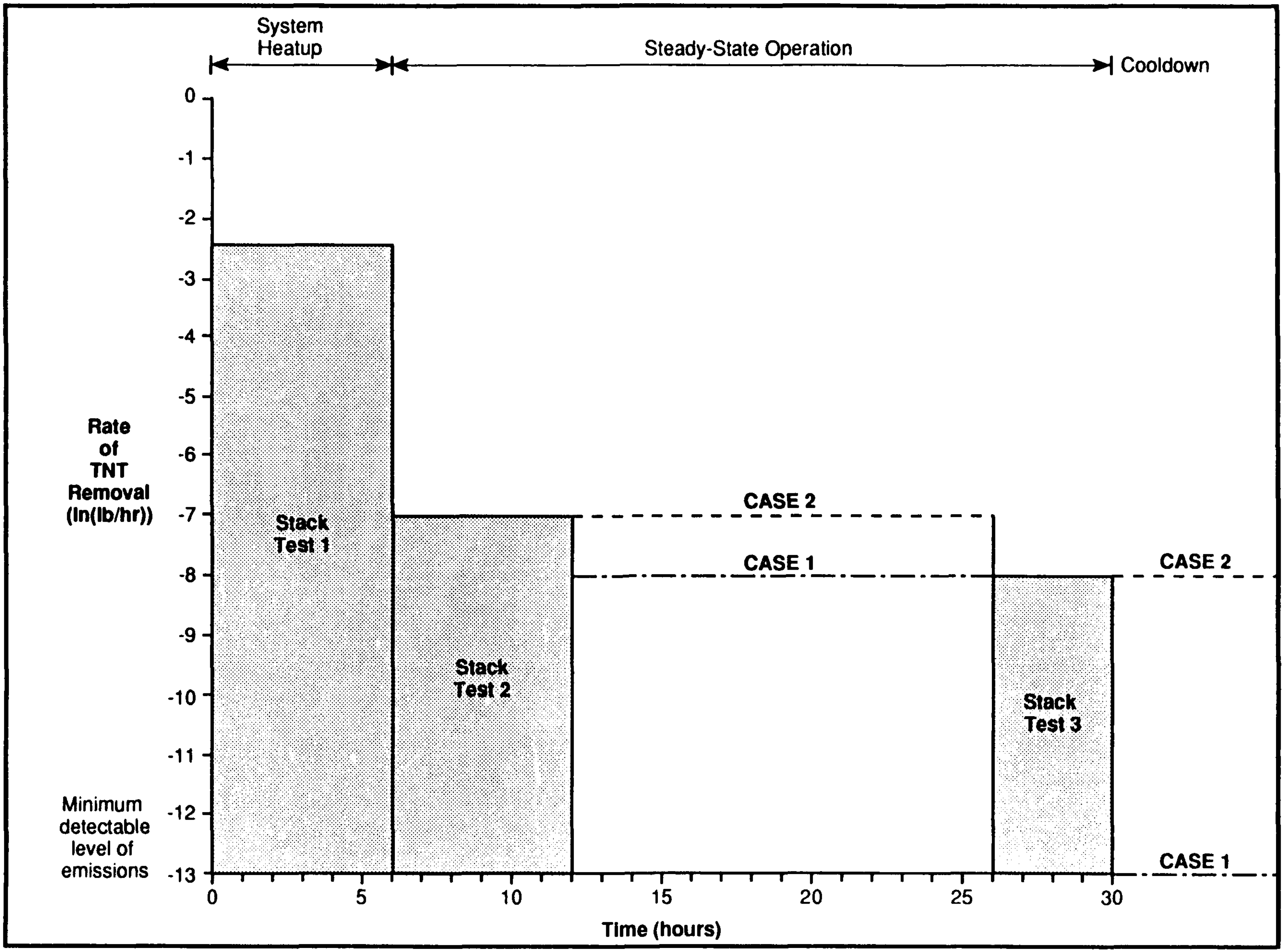
Time (hours)	Removal Rate (lb/hr)	TNT Removal (lb)	Percent Removed (%)
0-6	0.0929	0.557	97.89
6-12	0.00090	0.0054	0.95
12-30	0.000368	0.00662	1.16
30-109	No emissions	--	
		0.569	



*Detected explosives include:
TNT, HMX, RDX

G43-225n

Figure 9-1. Residual explosives mass vs. steady state treatment time.



G42-225I

Figure 9-2. TNT removal trend as measured in the flash chamber discharge gases during Test Run 5.

The maximum rate of emissions was calculated based on the following time periods and removal rates:

Time (hours)	Removal Rate (lb/hr)	TNT Removal (lb)	Percent Removed (%)
0-6	0.0929	0.557	91.9
6-26	0.00090	0.018	2.97
26-106	0.000368	0.0305	5.03
		0.606	

Both cases are illustrated on Figure 9-2.

The results of the integration indicate that the first 6 hours of testing produced 92 percent to 98 percent of the measured TNT emissions. The 6 to 30-hour time period produced 0.95 percent to 3.0 percent of the measured emissions. The extended cooldown period could potentially emit up to 5.0 percent of the measured TNT emissions, assuming that the emissions measured at the end of Test 5 continued constantly for the remaining 83 hours of cooldown.

Calculations were completed to determine the approximate length of time required for test items to achieve the target temperature of 500°F. For calculations, a rectangular steel slab was evaluated. The length and width of the slab were both assumed to be 1 foot; the depth of the slab varied, depending on assumed masses. Three masses were evaluated: 500 pounds (depth of 1 foot), 1000 pounds (depth of 2 feet) and 1500 pounds (depth of 3 feet). Calculations are shown in Appendix I. Assuming a surrounding air temperature of 550°F (during heatup), the times required to bring the items to a target temperature of 500°F are as follows:

- 500 pound slab - 4 minutes.
- 1000 pound slab - 12 minutes.
- 1500 pound slab - 26 minutes.

Calculations were further developed to evaluate worst case conditions (entire chamber filled to capacity with test items). To evaluate this scenario, a steel rectangular slab was assumed to encompass all available space on the rail cart. The dimensions of the slab were assumed to be 6 feet high (restricted by chamber entry), 20 feet long, and 6 feet wide. The slab would weigh about 175 tons. Assuming a constant surrounding temperature of 550°F, about 50 minutes would be required for the slab to achieve a target temperature of 500°F.

Calculations demonstrate that the mass of the test items only has a moderate effect on the total time required for treatment. Assuming the system is adequately insulated and that the available heat is absorbed by the test items and not the flash chamber walls and floor, during routine system operation, if a minimum of 1 hour is utilized for system heatup, each test item should be at the appropriate temperature (500°F) by the time steady state conditions commence.

9.1.1.2 Temperature

Analytical results indicate that temperature is a key factor in explosives removal. Temperature monitoring conducted during the test program included monitoring for:

- The hot gas temperatures (inlet and exit).
- The test item temperatures.
- The flash chamber temperatures (i.e., walls, etc.).

The hot gas temperature as measured at the discharge duct was the primary control item for execution of the test program. The hot gas entered the system at temperatures ranging from 650°F to 1,130°F and cooled to temperatures ranging from 400°F to 600°F. As discussed in Subsection 9.2.2, the loss of gas temperature is primarily caused by heat absorbed by the flash chamber walls. Using the hot gas discharge temperature as the indication of overall chamber conditions, for the treatment times evaluated, a minimum of 500°F is required to remove explosives (TNT) below measurable levels on the treated test items. Partial removal was observed at 400°F. However, in general for items with gross contamination (such as clay pipe) and items with internal contamination, a temperature of 400°F was not sufficient for complete removal. Since relatively large temperature gradations were evaluated (±100°F), the minimum effective operating temperature may lie somewhere between 400°F and 500°F.

Test item temperatures were monitored by a series of thermocouples attached to the surface and internals of the test items. Under ideal conditions, the temperature of various types of test items would be equivalent during steady state operation. The pilot test apparatus, however, was not "ideal". The temperatures of test items varied from 360°F to 560°F during a 500°F test run (T18). Items nearest the heat source were observed to be at a higher temperature than items located farthest away from the diffusers. The test item temperatures reflect the hot gas temperature gradient that exists from the inlet to the exit of the flash chamber. Also, some test items never achieved the target temperature suggesting poor circulation of the hot gas within the flash chamber. Table 9-1 summarizes information on those test items that contained residual levels of TNT following treatment.

As shown, although three of the items that contained residual contamination did not reach the steady state temperature of 400°F, the average temperatures were very close to the target temperature (i.e., 383°F, 384°F, and 398°F). The temperature difference of a maximum of 17°F was probably not the reason for residual TNT levels. Residual TNT would probably have been present even if 400°F was achieved and maintained.

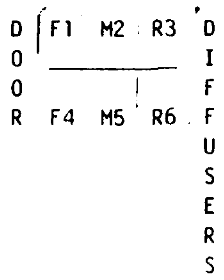
The flash chamber walls and ceiling were monitored by thermocouples. The data from these thermocouples confirmed the poor circulation of hot gas in the chamber. As expected, temperatures at the ceiling were consistently higher than the wall.

Table 9-1

Summary of Average Steady State Temperatures for Test Items with Residual TNT Contamination

Test Item	Test Conditions	Average Steady State Temperature	Mass of TNT Spiked (g)	Residual TNT	Location on Rail Cart[a]
Steam-heated riser	400° F/12 hrs.	398° F	10	46.36 mg	M1
Shell support rack	400° F/12 hrs.	383° F	1	0.0655 mg	M1
Steam-heated discharge valve	400° F/24 hrs.	384° F	10	9.6 mg	M1
Powder box	400° F/36 hrs.	439° F	10	2.41 mg	F1
Clay Pipe (soil/debris)[b]	400° F/36 hrs.	436° F	NS[c]	5.03 ug/g	R1

[a] See diagram.
[b] Other contaminants detected in porous media for T14 include 1,3,5 TNB and 2,6 DNT.
[c] NS = Not spiked; initial TNT contamination was 59,600 ug/g



9.1.1.3 Location

Location, in this context, refers to the proximity of the test item to the hot gas source (diffusers), as well as to the physical location of the TNT on the test items (internal and external surface areas).

9.1.1.3.1 Location of Test Items on the Rail Cart

Temperatures of the various types of test items were not uniform throughout each test run. As expected, test items positioned closest to the diffusers heated up more rapidly than those items located at the front of the cart (by the chamber door). Even after the target temperature was achieved and maintained, the test items located nearest the diffusers generally had temperatures that were higher than those items located farther away.

Due to the layout of the hot gas process components (diffusers on rear wall and discharge duct on side wall near front), hot gas exiting the diffusers tended to "short circuit" to the discharge duct. The temperatures of items located on the rail cart on the opposite side from the air discharge duct were not as high, therefore, as items located in the direct path of the hot gas. For illustration, a schematic of the average temperatures associated with test items evaluated in Test Run T3 (500°F/36 hours) is presented on Figure 9-3. For reference, the target temperature of 500°F is shown as a straight horizontal line. The average steady state temperature of 527°F, as measured in the exit gas duct, is shown as a dashed line.

The test items are categorized by location, as follows:

- Rear of the cart (by diffusers) - Ship mine and clay pipe.
- Middle of the cart - Steam-heated valve, shell support rack, and steam-heated riser.
- Front of the cart - Powder box.

Temperatures associated with the rear diffuser and rear diffuser support are also shown for illustration. Average temperatures for the rear, middle and front of the cart are 560°F, 486°F, and 487°F, respectively.

Potential problems with nonuniform temperatures can best be overcome by locating more difficult items to treat, such as items with internal surface or bulk contamination, at the rear of the cart near the diffusers. Items that are less difficult to treat, such as items with external surface area only, will likely be effectively treated when placed at the front of the cart, near the chamber door.

9.1.1.3.2 Location of Explosives on Test Items

The physical location of the explosives on the test items affects contaminant removal. Basically, contaminants are located on the following areas:

- External surfaces.

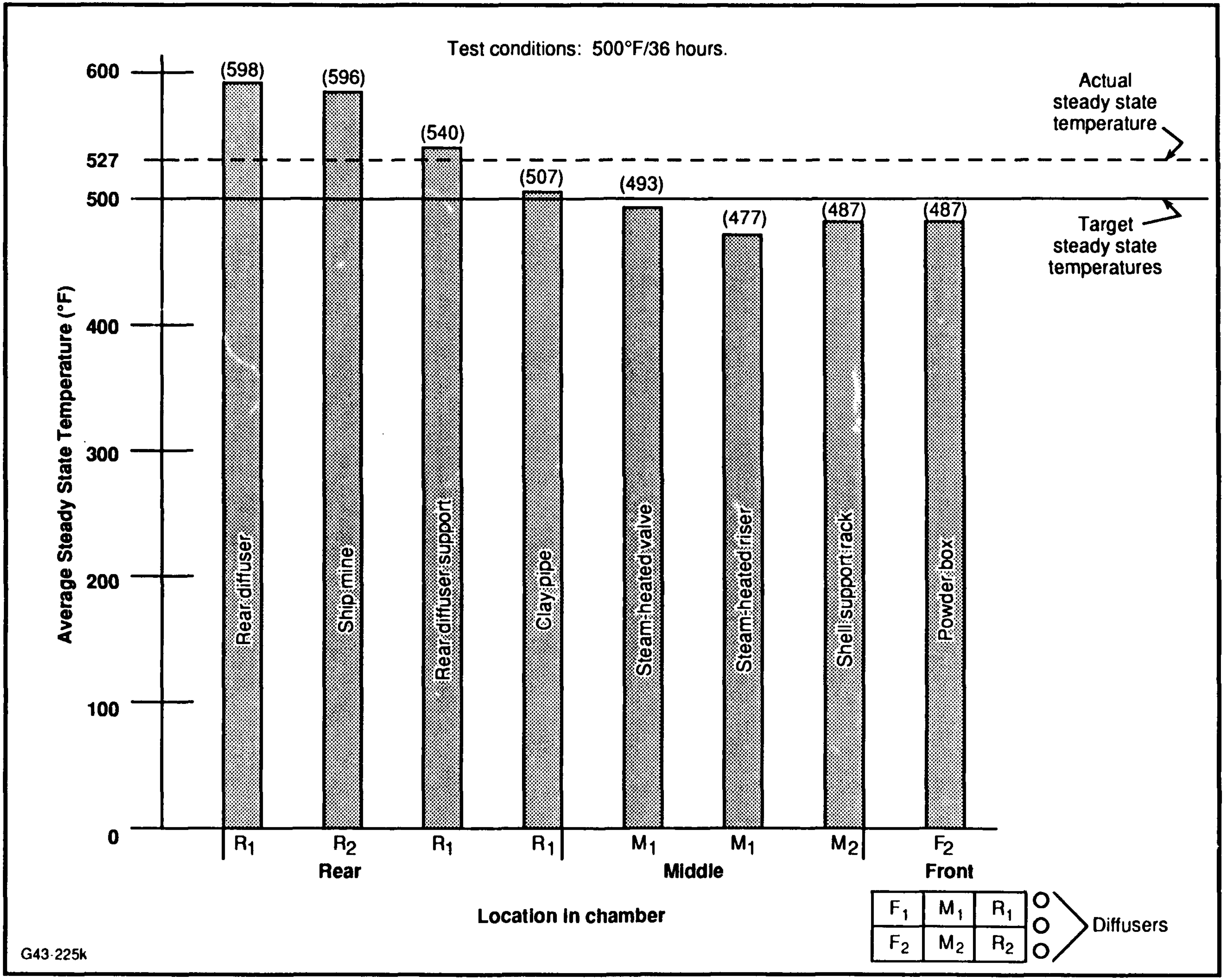


Figure 9-3. Typical temperature distribution in flash chamber.

- Internal surfaces (such as within the jacket of steam-heated vessels or inside the housing on mechanical components).
- Porous media (such as within the clay matrix of sewer pipe).

Items with contamination on external surfaces only were generally the least difficult to treat; three failures were observed (one failure was associated with soil/debris in the clay pipe). Test items with contamination on internal surfaces or within the porous media proved to be more difficult to treat, although three test items were observed to fail. Residual concentrations were generally higher. The internal surface contamination was expected to be more difficult to remove because the mode of escape for the contaminant is restricted. The steam-heated risers are provided with 0.25-inch steam connections; steam-heated discharge valves are provided with 1-inch steam connections. TNT located within the porous media of the clay pipe had to diffuse through the clay matrix for escape.

9.1.2 INTERPRETATION OF 600° F TEST RUNS

Tests T-16 and T-15 were conducted to evaluate TNT removal associated with a steady state temperature of 600°F with steady state treatment times of 6 and 12 hours, respectively. The flash chamber heatup rates were considerably longer than anticipated during planning stages. For illustration, the average heatup times associated with the steady state temperatures evaluated during the pilot study are as follows:

• Steady State Temperature	Average Heatup Time
400°F	6 hours
500°F	10 hours
600°F	17 hours

For comparison, the following actual heatup times were required for designated steady state temperatures:

• Steady State Temperature	Actual Heatup Time
400°F	
- T2	7 hours
- T8	7 hours
- T14	5 hours
500°F	
- T3	10 hours
- T5	10 hours
- T13	10 hours
- T18	9 hours
600°F	
- T15	16 hours
- T16	11 hours
- T17	22 hours

This suggests that during the 600°F test runs, before the steady state temperature was achieved, the system had operated at conditions that were very similar to the 500°F/6 hour test run. The results of the 500°F/6 hour test run indicate decontamination of TNT. Therefore, during the 600°F test run, the test items were adequately treated before the steady state temperature was even achieved. Due to this overlap of test conditions, it is difficult to evaluate the effects of the 600°F results.

9.1.3 AUTOIGNITION

During each of the tests a phenomena consistent with autoignition was observed for the bulk explosives contained in clay pipe. The autoignition point is defined as the minimum temperature required to initiate or cause self-sustained combustion in any substance in the absence of a spark or flame[1]. Autoignition of TNT is reported to occur after about 38 hours at 392°F[2]. The material in the clay pipe was highly concentrated with TNT (average of 415,000 ppm). During each test run, when the temperatures in the clay pipe ranged from 396°F to 542°F, the material in the pipe reacted. The temperature of the pipe instantaneously spiked as high as 1,000°F. During temperature excursions, the nitrous oxide readings in the stack spiked to values as high as 185 ppm/v after the initial reaction. During the stack testing program, heavy particulate (coke, soil, debris) was evidenced on the sampling filters, consistent with a violent reaction or combustion. The clay pipe was also observed after the test to be discolored as if a fire or burn had taken place. During pilot study activities, the clay pipe was placed within the chamber and each end left uncovered. It is expected that if a critical mass of bulk explosives were contained or not adequately vented, the autoignition phenomenon could produce destructive results.

9.1.4 MECHANISMS FOR TNT REDUCTION

There are four mechanisms by which explosives on the test items can be removed. These methods are:

- Combustion.
- Particulate carryover.
- Evaporation.
- Degradation.

The subsections below provide discussion of observations made which illustrate removal mechanisms.

9.1.4.1 Combustion

Combustion, or burning, is a rapid combination of oxygen with a fuel; in this case, the fuel is TNT. Oxygen can be supplied externally (i.e., atmospheric air)

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[1] Condensed Chemical Dictionary, N. Irving Sax and Richard J. Lewis, 11th Edition, Van Nostrand Reinhold Company.

[2] Military Explosives, Department of the Army Technical Manual TM-9-1300-214, September 1984.

air) or internally (i.e., within the chemical composition of the explosive). A release of heat accompanies a combustion. The products of combustion are dependent on many factors such as local pressure conditions, source, and availability of oxygen, degree of confinement, etc. Major products of combustion are expected to be carbon dioxide, water vapor, nitrous oxides and carbon monoxide. Small amount of nitrogen, hydrogen and ammonia may also be present (Military Explosives, op cit.). The observation of a nitrous oxide spike that occured during the autoignition of the clay pipe (discussed in Section 9.1.3) provides a clear indication that combustion was taking place.

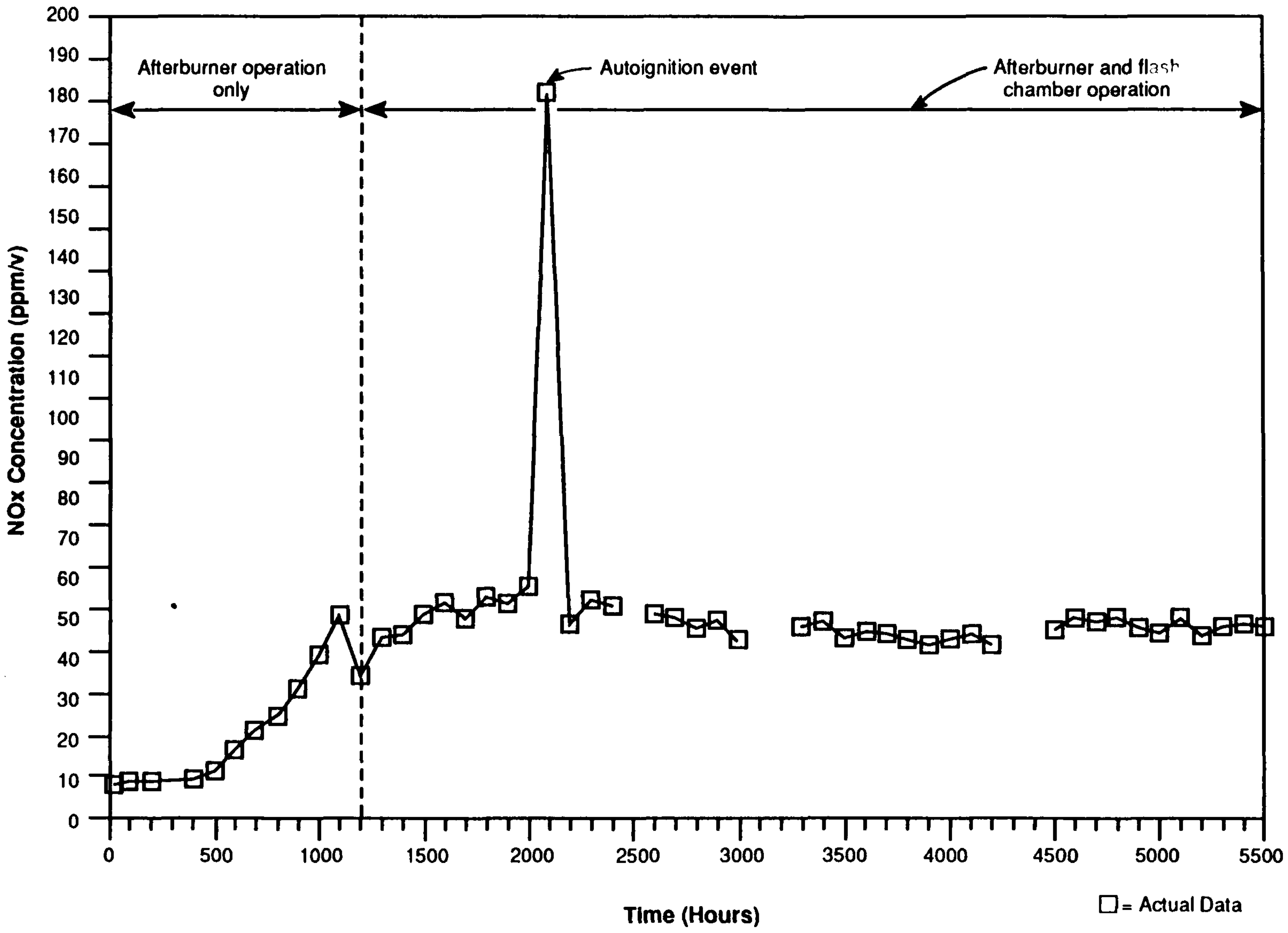
An illustration of the nitrous oxide peak observed during Test Run 3 is shown in Figure 9-4.

9.1.4.2 Particulate Carryover

Particulate carryover of TNT could occur if solid explosive was swept from the chamber by the hot gas stream. This phenomena would be expected to be the greatest from items with external surface contamination, such as powder boxes or shell support racks. Also, it was observed that during the combustion of explosives in the clay pipe, particulate was inadvertently carried out of the chamber with the sweep stream. This particulate may have contained solid TNT. If present, solid TNT or particulate would have been captured on the filter of the EPA Modified Method 5 (MM5) sampling train located at the flash chamber outlet. Visual observations of the filter after combustion of the material in the clay pipe indicated the presence of a black material (consistent with coke). Since standard procedures associated with MM5 require composite analysis of the filter and XAD-2 tubes, however, there is no way to distinguish the presence of TNT in particulate form on the filter. Simultaneous visual observations of the filter located at the afterburner outlet indicated a gray discoloration. This color differential (i.e., from black to gray) suggests combustion of the unexploded TNT or coke in the afterburner.

9.1.4.3 Evaporation

Evaporation is the change of a substance from the solid or liquid phase to the gaseous or vapor phase. In some cases, the compound does not go through a liquid phase; the vapor is formed from the solid phase. This phenomenon is known as sublimation. At ordinary temperatures, TNT is essentially nonvolatile (Military Explosives, op cit.). However, when exposed to elevated temperatures, there is some degree of evaporation. The boiling point of TNT is 653°F. Evaporation of TNT is confirmed by the presence of quantities of TNT (and other explosives) determined to be present in the internal surfaces of items used in the manufacture and handling processes, e.g., small quantities of TNT in the jacket of steam-heated vessels and in the inner components of motors. During manufacture or handling, TNT was generally in the molten state when exposed to these types of test items. Apparently, small amounts of explosives evaporated and infiltrated the housings or jackets of equipment. During the pilot study, evaporated TNT would have discharged the flash chamber in vapor form and been adsorbed in the XAD-2 sorbent modules (part of the EPA Modified Method 5 (MM5) sampling train).



G5C 225s

Figure 9-4. Illustration of nitrous oxide emissions measured during Test Run 3.

Only TNT in the vapor form would be expected to be present on the sorbent modules; solid TNT would have been captured on the filter located prior to the adsorbent tubes. The standard MM5 procedures, however, require that the filter catch and XAD-2 sorbent tubes be analyzed as a composite. As such, there is no way to determine the mass of TNT that was present on the sorbent tubes.

A comparison of the particulate emission rate from the afterburner to the mass emission rate of TNT from the flash chamber does not provide a clear correlation. Figure 9-5 presents a plot of the data. If a correlation existed, those cases where TNT emissions were high would be accompanied by high particulate emissions. Lack of correlation suggests that TNT removal is occurring by evaporation in addition to particulate release caused during the autoignition events.

9.1.4.4 Degradation

Degradation is a type of decomposition that can result from pyrolysis, oxidation, heat, sunlight, solvents, or bacterial action. Literature sources indicate that TNT shows no deterioration after 20 years storage in a magazine or after 2 years storage as a liquid at 185°F. Only a small amount of decomposition occurs after storage at 302°F for 40 hours. Above that temperature, slow decomposition occurs (Military Explosives, op cit.). Literature sources indicate that major degradation products obtained by heating a sample of TNT for 26 hours at 392°F are unreacted TNT, explosive coke, 4,6-dinotro-anthranil, 2,4,6-trinitrobenzaldehyde, azo/azoxy compounds, and 2,4,6-trinitrobenzyl alcohol.

Assuming decomposition occurred, the associated degradation products would be present in the flash chamber discharge gases. It is possible, however, that some degradation products have short lives and are an intermediate step prior to complete oxidation. Some degradation products, therefore, may combust in the flash chamber and will not be present in the discharge gases. The stack tests from T-3 were analyzed for semivolatile compounds (on the Hazardous Substance List) and C_7-C_{14} compounds. Although 22 compounds were tentatively identified in the semivolatile scan, none were identified as TNT degradation compounds. Degradation of TNT is not considered the major removal method.

9.2 DISCUSSION OF PROCESS EQUIPMENT RESULTS

Process and operational data from the flash chamber and afterburner were evaluated. Mass balances, heat balances and heat transfer calculations were performed for the system, as discussed in the following subsections.

9.2.1 Mass Balance

Combined mass and heat balances were performed for Test Runs T2, T3, and T5 (Appendix I). The mass balances were checked for closure (the comparison of measured values at the inlet to measured values at the outlet) and were found to be within 10.5 percent for all three tests. This is within the process

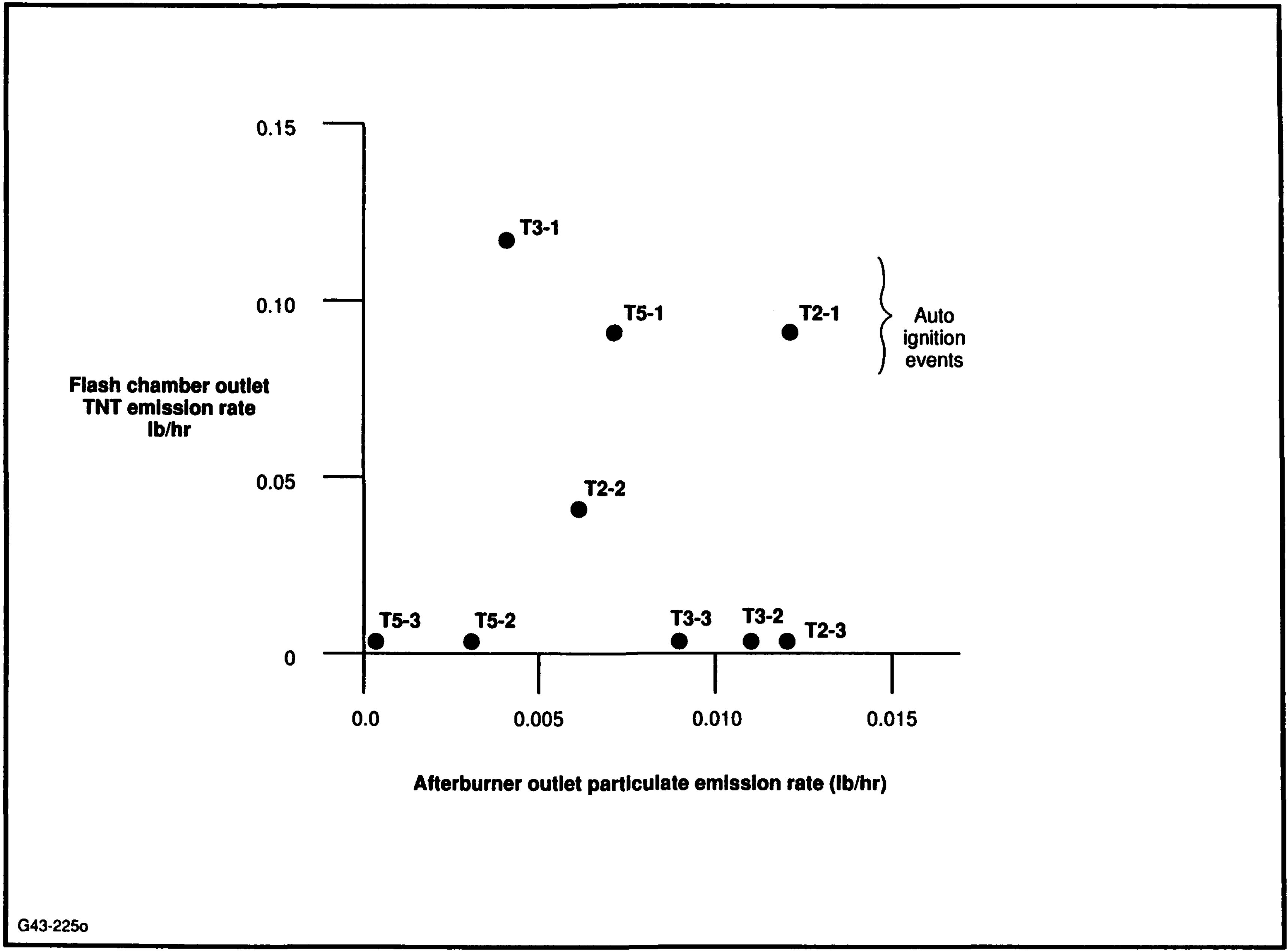


Figure 9-5. Particulate emission rate vs. TNT emission rate.

measurement errors. The mass balances provided a calculated flash chamber infiltration or leak air flow rate. The leakage volumes for the three tests were as follows:

Test Run	Flow Rate of Infiltration Air (scfm)	Percentage of Exit Gas Flow Rate
T-2	467	22.9%
T-3	207	11.1%
T-5	499	24.2%

9.2.2 Heat Balances

Heat balances were completed around the flash chamber for all three tests. Under steady state conditions, the hot gas entering the chamber was used to heat the infiltration air and to heat the walls of the chamber. As shown on the table below, over 75 percent of the heat from the process gas is being lost through the chamber walls.

	Total Heat Loss Btus/hr	Heat Lost to Infiltration Air Btus/hr	Heat Lost to Walls Btus/hr	Heat Lost to Walls (%)
T-2	755,900	161,700	594,200	79
T-3	1,024,970	92,270	932,700	91
T-5	850,900	207,900	643,000	76

9.2.3 Heat Transfer Rates

Using the process data from the thermocouples located within the flash chamber and hot gas system, the average gas phase heat transfer coefficients were determined for each of the three stack tests.

The gas phase heat transfer coefficient was calculated to range from 1.17 Btu/hr Ft^2 (°F/Ft) to 1.82 Btu/hr Ft^2 (°F/Ft). Figure 9-6 is a plot of the heat transfer coefficient versus the natural logarithm of the gas velocity in the flash chamber. The heat transfer coefficient shows some correlation with the logarithm of the gas velocity, as predicted by classical thermodynamic principles.

The thermal conductivity constant for the composite flash chamber wall was also determined for each of the tests. The K factor was determined to average 5.10 Btu/hr Ft^2 (°F/Ft) (± 20%), which is within the error of the process measurements. The average thermal conductivity is between the conductives associated with the major components of the flash chamber (K steel = 27 Btu/hr Ft^2 (°F/Ft), K concrete = 0.30 Btu/hr Ft^2 (°F/Ft)).

9.3 DISCUSSION OF RESULTS FOR SMOKELESS POWDER

The test program included nine test runs to evaluate the removal of smokeless powder. Only one type of test item (ship mine) was contaminated with

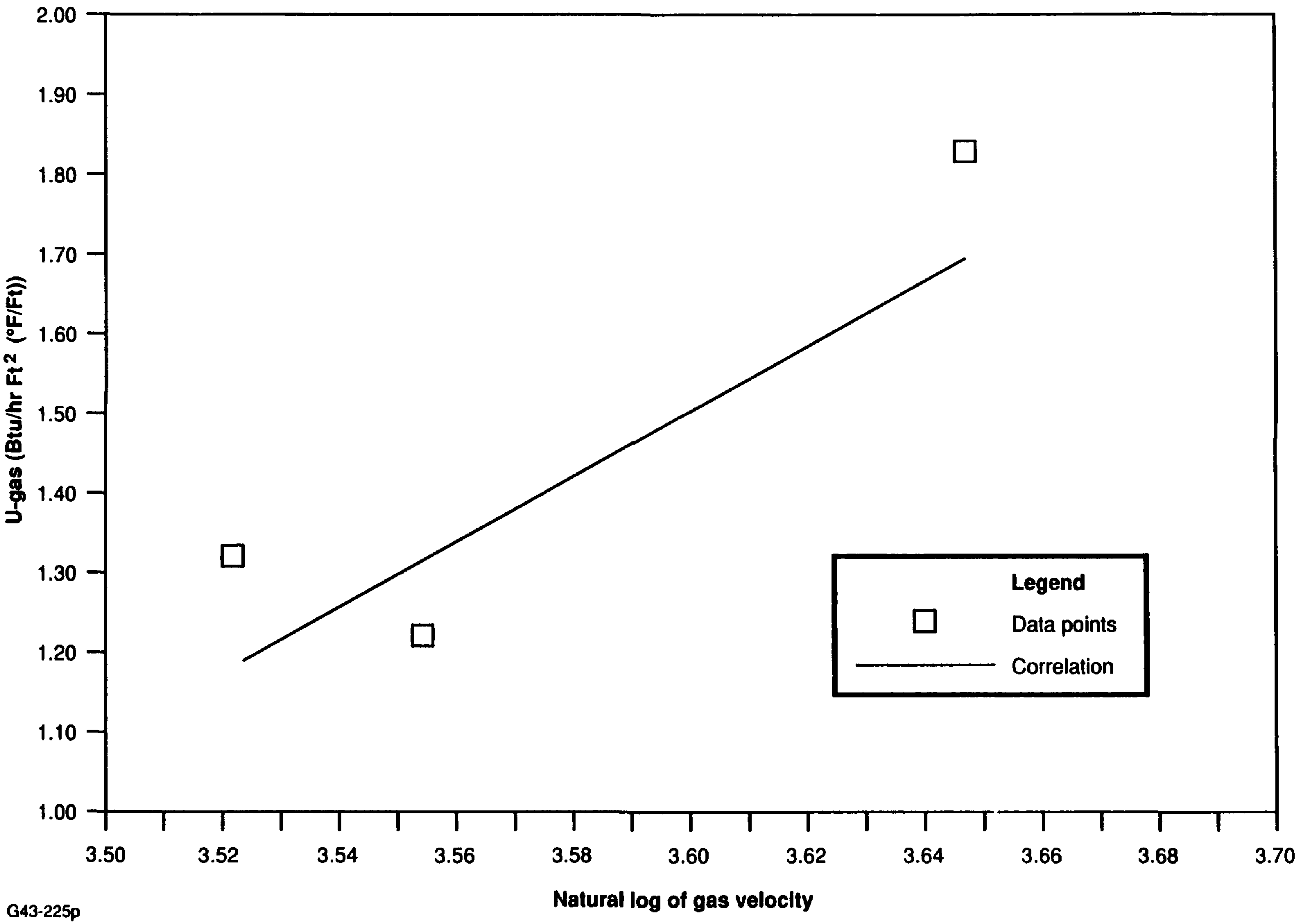


Figure 9-6. Gas phase heat transfer coefficient vs. flash chamber gas velocity.

smokeless powder. Ship mines were spiked previously by base personnel; they were not spiked as part of pilot study activities.

The analytical method utilized by the laboratory for determination of smokeless powder (nitrocellulose and nitroglycerin) is a nonspecific method. The analytical method used was developed for analysis of a water matrix. During the planning stages, it was our intent to modify the water-based method to include wipe samples and air samples. During the analytical stage, however, it was determined that nitrocellulose and nitroglycerin cannot be distinguished from one another or from other nitrated esters. As such, reported results represent quantities of total nitrated esters (presumed to contain nitrocellulose and nitroglycerin).

Analytical results indicate that only four ship mines contained detectable levels of contamination prior to being placed into the flash chamber. One of these ship mines contained detectable levels of nitrated esters after treatment. The test is considered meaningless. In addition, during test T-5, the inlet concentration of nitrated esters was less than the detection limit (5.0 ug), however, post-test sampling indicated a positive result of 5.6 ug. This test is also considered to be meaningless. The test results for nitrated esters are provided in matrix format on Figure 9-7. Given the small number of sampling data, the extreme variability in test item contamination and suspected analytical method uncertainties for smokeless powder, it is not possible to analyze trends in the smokeless powder data.

In addition to the ship mines, the flash chamber walls were also contaminated with nitrated esters. Sampling of the walls following eight tests indicated the presence of nitrated esters following three test runs (Tests T8, T14, and T15 conducted midway through the pilot study). Presence on the flash chamber walls is not presented on Figure 9-7 since wall temperature could be up to 150°F below the hot gas treatment temperature and are not representative of process capabilities.

9.4 DISCUSSION OF RESULTS FOR AMMONIUM PICRATE

One test run was conducted to evaluate the decontamination of test items contaminated with ammonium picrate. It was not an objective of the pilot study to optimize conditions for ammonium picrate decontamination. It was desired to evaluate conditions that were expected to be effective for reducing ammonium picrate levels below detection limits. Conditions suspected to be below optimum conditions that would leave residual contamination on the test items were not evaluated (due to potential degradation to picric acid). Operating conditions of 600°F, coupled with a steady state time of 48 hours, were found to be effective for reducing levels of ammonium picrate below detection limits. Optimum conditions, however, may include lower temperatures and/or decreased residence times.

9.5 DISCUSSION OF PILOT STUDY IN REGARD TO PROJECT OBJECTIVES

Pilot study objectives are presented in Subsection 2.2. Each objective is discussed separately in the following subsections.

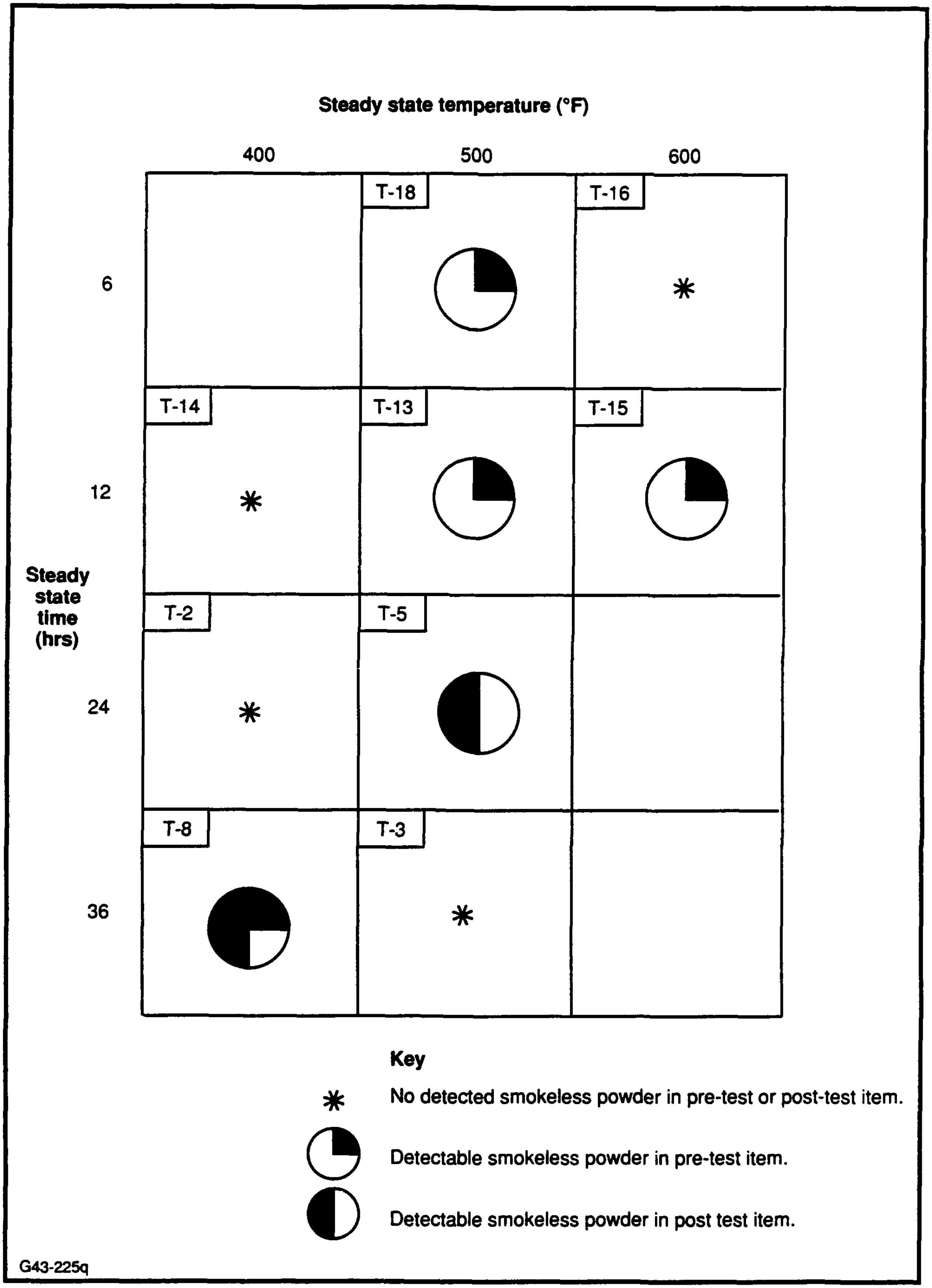


Figure 9-7. Smokeless powder removal results.

9.5.1 OPTIMUM OPERATING CONDITIONS FOR TNT

Nine test runs were conducted to evaluate the effectiveness of the hot gas system for treating test items contaminated with TNT. Results of these tests indicate that a temperature of 500°F coupled with a steady state residence time of 6 hours are the optimum conditions for TNT decontamination.

Results are based on operations at the HWAAP facility; operations included a heat-up period of 9 hours and a system cooldown period of 54 hours. Also, since relatively large temperature gradations were evaluated during the pilot study (± 100°F), the minimum effective operating temperature may lie somewhere between 400°F and 500°F.

9.5.2 EFFECTIVENESS OF THE TREATMENT ON VARIOUS TEST ITEMS

To evaluate the effectiveness of the hot gas treatment on a range of test items, various configurations and materials of construction were selected. Configurations consisted of items with external surface contamination, internal surface contamination (such as within the jacket of steam-heated vessels) and contamination within porous media (clay pipe). The hot gas process was found to be effective for treating all configurations of test items. Contamination present on internal surfaces and within porous media proved to be most challenging.

Materials of construction consisted of steel, aluminum, and clay. All test items were visually inspected before and after each test run. Some items were in poor condition before treatment (holes in powder boxes, etc.). Generally, items constructed of steel or aluminum showed no signs of damage due to treatment. Discoloration and scorch marks were present on some items and paint was found to crack and peel on ship mines, but no flaw in the structural aspects of the items was evident. As expected, weight loss for metallic items was negligible (if at all).

For clay, however, exposure to the hot gas resulted in cracks throughout the entire pipe sections. The clay became very brittle and was easily broken. Prior to treatment, the soil/debris on the inside of the pipes resembled a yellow, plastic clay with some sandy material. After treatment, the material was reduced to an ash-like material. A comparison of pre- and post-test weights for clay pipe (presented in Table 8-2) indicates a substantial weight loss (average of 6 percent). Weight loss is due to loss of water from the clay and combustion of organic debris and explosives contained in the pipe.

It should be noted that the clay pipe was not intended to be reused after testing; effects on its structure, therefore, are inconsequential.

9.5.3 EFFECTS TREATMENT HAS ON EQUIPMENT REUSE

The test items can be handled following treatment as:

- Scrap for disposal.
- Reuse in explosives manufacturing and handling operations.

Each item will be discussed separately in the following subsections.

9.5.3.1 Disposal as Scrap

Based on the results of the pilot study, test items that are treated for 6 hours at a minimum temperature of 500°F are safe for public release as scrap. Items treated in the prescribed manner are not considered characteristically hazardous and are appropriate for disposal or potentially for resale as scrap.

9.5.3.2 Reuse in Manufacturing or Handling Operations

Treated test items that are constructed of steel or aluminum and have no intricate or mechanical components (such as powder boxes, shell support racks, steam-heated vessels, etc.) may be appropriate for reuse in manufacture or handling operations. Their structural stability, however, should be verified. Non-destructive testing can be used for verification. The following tests are applicable:

- Visual Inspection (VI) - Easy and quick, visual inspection can be performed on any type of test item or material of construction. Only surface defects visible to the naked eye or magnification will be detected. Visual inspection should be conducted prior to any other testing.
- Magnetic Particle Test (MT) - This test procedure is effective for evaluating surface defects on magnetic base metals and welds. Although some near-surface cracks may be detected, this test is not reliable for detection of subsurface defects. Wet or dry magnetic particle testing can be performed, depending on the configuration of the item to be tested. Eddy current is suggested for aluminum items.
- Dry Pentrant Test (PT) - This test is used to detect surface defects on base metals and welds. PT is not effective for detection of subsurface defects.
- Ultrasonic Test (UT) - UT is effective for evaluation of subsurface base material and weld defects in all types of material. UT does not detect surface defects. Some surface preparation may be required to provide acceptable testing surfaces. Part configuration will play a role in the ability to detect all defects, if present. UT is often used in conjunction with other nondestructive tests.
- Radiographic Test (RT) - RT is recommended for use on all base and weld metals. RT is effective for detection of subsurface defects. Defect orientation, however, can affect RT's ability to detect some defects. For this reason, UT is often used to supplement RT.

All of the tests outlined above are non-destructive and portable. They are widely used in government and private industry. Various professional organizations, such as the American Society for Testing Materials (ASTM) and the American National Standards Institute (ANSI), have established acceptance criteria for tests. All tests can be done onsite by qualified personnel. Onsite radiographic testing, however, may require some special set ups and precautions.

Treated metallic test items that have intricate or mechanical components (such as motors, pumps, etc.) would not be appropriate for reuse. The mechanical integrity of these items is questionable. Internal components constructed of copper, plastic or rubber would not withstand the sustained elevated temperatures and would be too severely damaged to function properly. These items should be disposed of as scrap.

Treated test items that are constructed of clay are too severely altered and are not appropriate for reuse of any kind.

9.6 STACK EMISSIONS

A stack sampling program was conducted to monitor the emissions of semivolatiles, CO, THC, NOx, particulates, explosives, and smokeless powder (nitrated esters). The results for each parameter are discussed in the subsections below.

9.6.1 SEMIVOLATILE RESULTS

Semivolatile emissions were measured at the flash chamber outlet and afterburner outlet during Test Run T3. The semivolatile emissions measured at each location were either below the detection limit or classified as a tentatively identified compound (TIC).

9.6.2 COMBUSTION EFFICIENCY, CO, AND THC RESULTS

During the operation of the hot gas process, carbon monoxide and total hydrocarbon (THC) emissions can be generated by three sources:

- Incomplete combustion of fuel in the air preheater.
- Incomplete combustion and volatilization of explosives and other organic matter (i.e., paint, oil) in the flash chamber.
- Incomplete combustion of fuel and volatile organics in the afterburner.

Air testing during test runs T2, T3, and T5 was conducted to evaluate the rate and source of CO and THC emissions. The testing confirmed that the air preheater is not operating efficiently and is generating CO and THC emissions. The CO levels in flash chamber discharge gases ranged from 9 ppm/v to 260 ppm/v with an average of 143 ppm/v. The THC emissions were not as variable as the CO emissions but ranged from 30 ppm/v to 50 ppm/v. These values are one order of magnitude larger than typical gas-fired heater emissions.

The levels of CO and THC in the flash chamber inlet gases were compared to levels in the flash chamber outlet gases to determine if CO and THC are being generated in the flash chamber. The comparison is shown on Table 9-2. The inlet concentrations were appropriately corrected for dilution (leak) air entering the flash chamber using the following equation:

$$CO_{out} = CO_i \left(\frac{Vi}{Vo} \right)$$

where

CO_{out} = Amount of carbon monoxide measured at the outlet of the flash chamber.

CO_i = Amount of carbon monoxide measured at the inlet of the flash chamber.

Vi = Volume of air entering the flash chamber.

Vo = Volume of air exiting the flash chamber.

The calculated generation (and in the case of test T-2, destruction) of CO/THC was not consistent. The generation values calculated were within the statistical variations of the inlet and outlet measurements, therefore no generalization regarding CO or THC creation can be made. To make the determination of THC and CO generation during future operations, it will be necessary to eliminate high levels of emissions from the air preheater.

Alternately, the afterburner was found to be operating very efficiently as evidenced by destruction of CO and THC contained in the inlet gases. The CO and THC levels in the afterburner discharge gases were typically below 7 ppm and 0.5 ppm, respectively. A comparison of the poorly operating air preheater and the properly operating afterburner can be seen in Table 9-2.

Combustion efficiency, which is an indication of completeness of combustion, was determined for the afterburner and air preheater. Table 9-3 lists the combustion efficiencies associated with test runs T-2, T-3, and T-5. The air preheater clearly operated poorly. The afterburner exceeded combustion efficiency criteria established by regulatory requirements.

9.6.3 NITROUS OXIDES (NOx) RESULTS

Nitrous oxide emissions from the hot gas process can be generated by operation of a combustion flame and degradation or combustion of explosives. The emissions of NOx were measured at the afterburner discharge during each test. The air preheater was not operational during heatup of the afterburner. NOx data corresponding to operation of the afterburner only, therefore, could be compared to data corresponding to operation of the afterburner and airpreheater.

Table 9-2

Comparison of Carbon Monoxide and Total Hydrocarbon Emissions
From Air Preheater, Flash Chamber Outlet, and Afterburner Outlet

	Carbon Monoxide Concentration (ppm)				
	Air Preheater Outlet		Flash Chamber Outlet	Calculated Flash Chamber Generation Rate	After Burner Outlet
Test Run	As Measured	Corrected to FCO Volume*			
T-2	169 ± 35	128 ± 27	101 ± 19	-27	6.8 ± .8
T-3	59 ± 52	53 ± 46	96 ± 75	43	4.3 ± 2.7
T-5	201 ± 62	152 ± 47	155 ± 44	3	6.5 ± .8

	Total Hydrocarbon Concentration (ppm)				
	Air Preheater Outlet		Flash Chamber Outlet	Calculated Flash Chamber Generation Rate	After Burner Outlet
Test Run	As Measured	Corrected to FCO Volume			
T-2	38.3 ± 8.1	29.0 ± 6.1	29.0 ± 5.2	0.0	0.18 ± 0.15
T-3	40.1 ± 8.1	35.7 ± 7.2	29.9 ± 3.5	5.8	0.17 ± 0.11
T-5	42.9 ± 9.6	32.3 ± 7.2	30.0 ± 4.9	2.3	0.43 ± 0.15

*Corrected to exclude infiltration air. FCO = Flash Chamber Outlet.

Table 9-3

Combustion Efficiencies
of the Air Preheater and Afterburner

Test Run	Combustion Efficiency (%)	
	Air Preheater	Afterburner
T-2	99.06	99.9895
T-3	99.72	99.9933
T-5	98.95	99.9897

Note:

$$\text{Combustion Efficiency} = \frac{CO_2}{CO_2 + CO} \times 100\%$$

Where: CO_2 = Concentration of CO_2 in discharge gases
CO = Concentration of CO in discharge gases

The NOx emissions from the afterburner measured during heat-up (i.e., air preheater deactivated) were plotted versus the afterburner operating temperature, as shown on Figure 9-8. As shown, NOx formation undergoes a substantial increase at elevated flame temperatures (>1,600°F). The graphical representative follows data reported from expected "prompt" NOx formations in a hydrocarbon flame. Two equations were prepared using linear regression techniques for the generation of NOx by the hot gas afterburner, as follows:

$$\text{NOx} = 0.0252\,(\text{Temp}) - 4.36 \text{ if Temp } <1{,}600^{\circ}\text{F} \longrightarrow \text{equation 9-1}$$
$$\text{NOx} = 0.1319\,(\text{Temp}) - 173.2 \text{ if Temp } >1{,}600^{\circ}\text{F} \longrightarrow \text{equation 9-2}$$

Where: Temp = Temperature

To compare emissions of the hot gas process (air preheater and afterburner operational) to emissions of the afterburner only, a plot of measured NOx emissions versus calculated NOx emissions (using equations 9-1 and 9-2) has been prepared as Figure 9-9 (results from test run T3 shown for illustration). As shown, the actual NO_x emissions were close to predicted values. The emissions of NOx during the operation of the air preheater and afterburner, however, were consistently below predicted levels for all operations except for the autoignition event. The reduction of NOx is suspected to be caused by the changes in combustion air (gas) entering the afterburner during test operations. The afterburner combustion air is heated; as such it contains increased moisture and decreased oxygen over ambient air used during startup. These are factors that can affect NOx formation.

9.6.4 PARTICULATE RESULTS

The emissions of particulate were measured during nine separate sampling periods during test runs T-2, T-3, and T-5. The particulate emissions ranged from a minimum of 0.0003 lb/hr to 0.012 lb/hr and averaged 0.0071 lb/hr. The emission data, corrected to 7 percent oxygen, ranged from 0.000017 gr/dscf to 0.00093 gr/dscf, two orders of magnitude less than applicable regulations (0.08 gr/dscf corrected to 7 percent oxygen).

9.6.5 EXPLOSIVES RESULTS

Explosive concentrations were measured at the inlet and exit of the afterburner for test runs T-2, T-3, and T-5. For all cases, the emissions of TNT from the afterburner were below detectable levels. In cases where TNT inlet concentrations were sufficiently large, the destruction and removal efficiency exceeded 99.99 percent. (By nature of the calculation, if the mass of contaminant in the inlet stream is not sufficiently high, the DRE will be less than 99.99 percent, even if contaminant levels in the discharge stream are below detection limits).

Other explosives were detected in the afterburner exit gas including HMX, RDX, 1,3,5 TNB, and 1,3 DNB. The emissions of these compounds was not consistently observed and ranged from 475 parts per trillion (ppt) to 6 ppt. Corresponding inlet concentrations were observed only during stack tests T2-3 (1,3 DNB) and T3-3 (1,3,5 TNB). In these cases, the DREs were 72.92

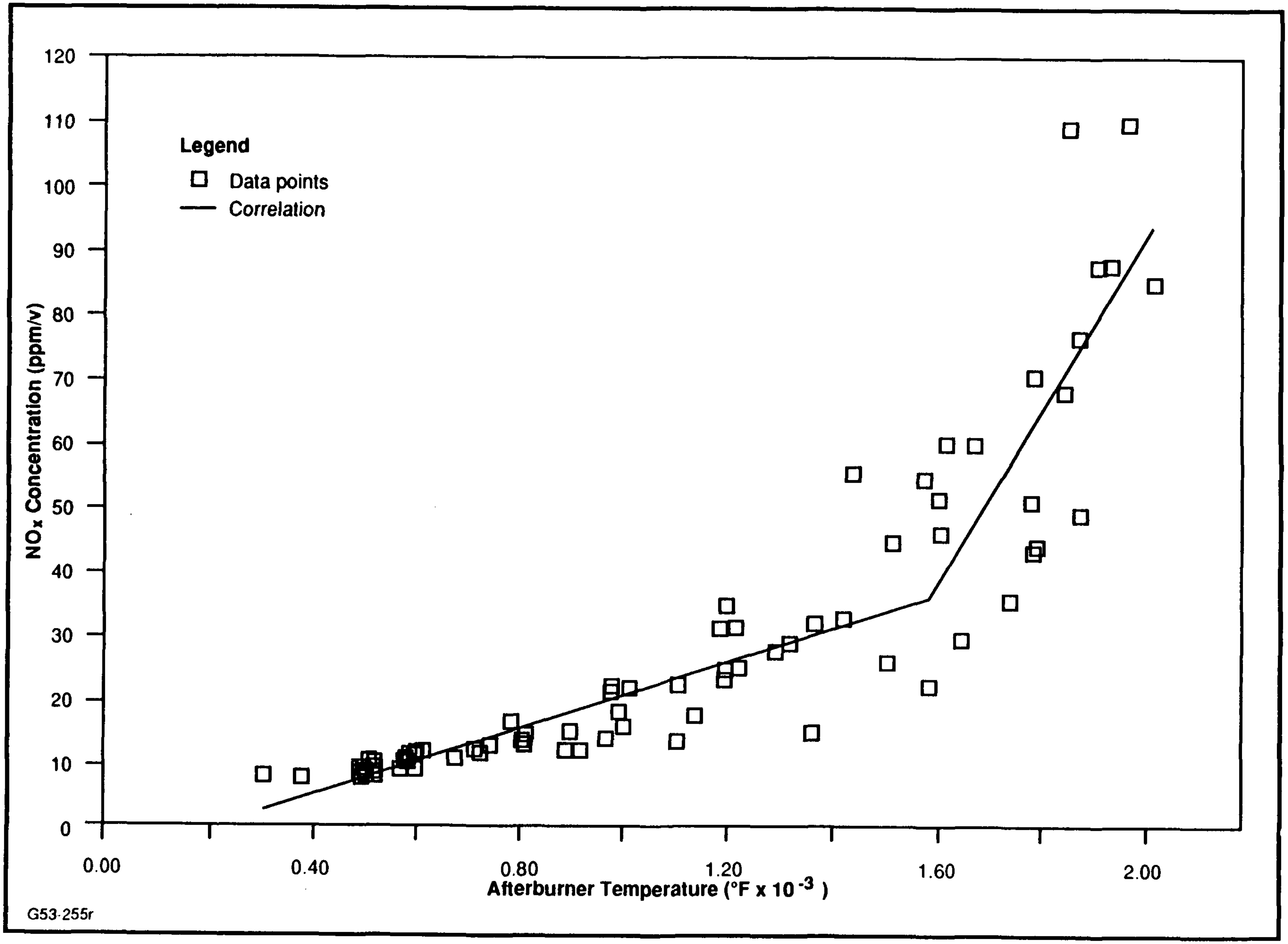


Figure 9-8. NO_x emissions measured during afterburner heatup.

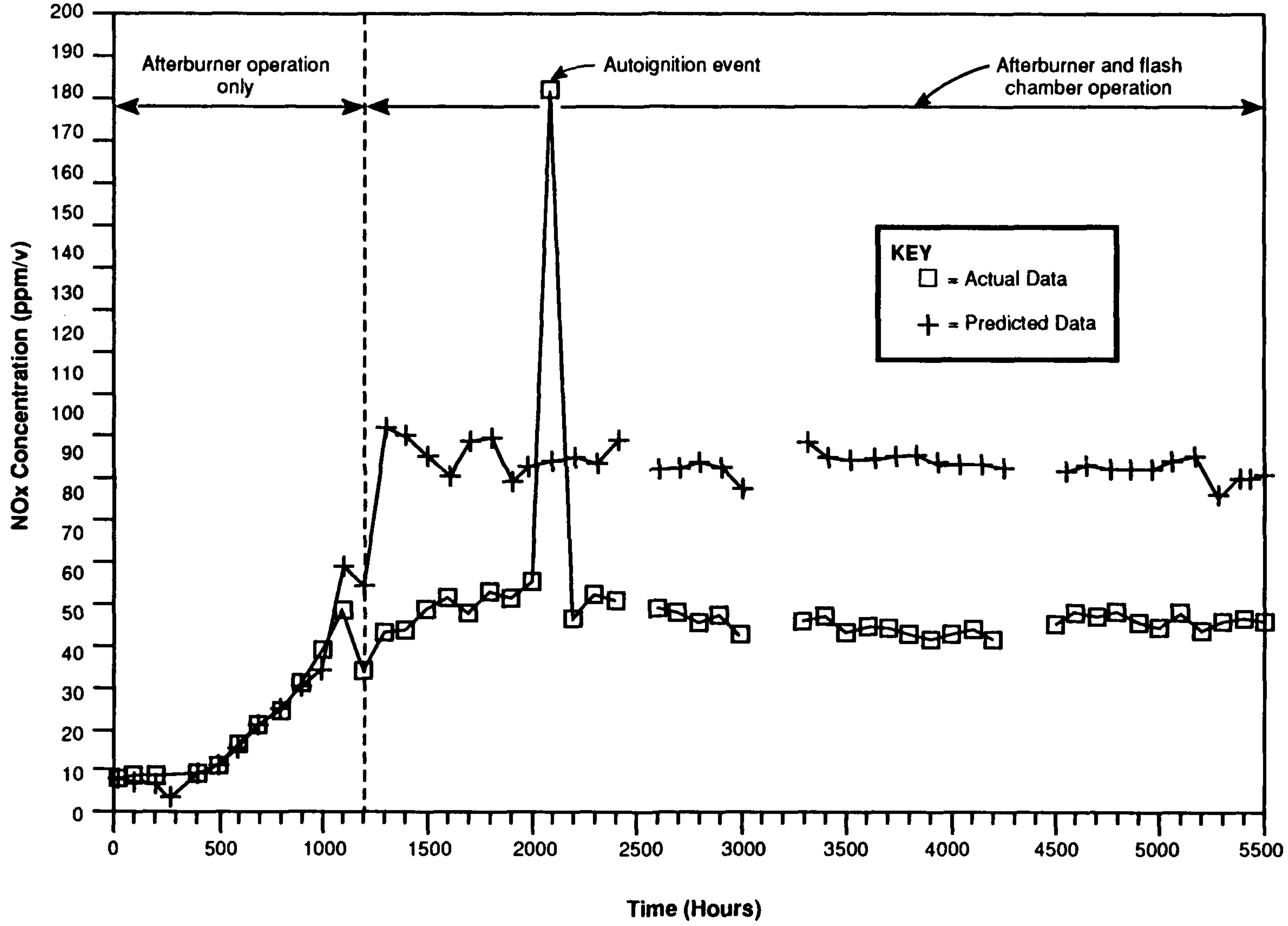


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Figure 9-9. Illustration of predicted NO_x emissions v.s. actual NO_x emissions measured during Test Run 3.

and 80.92, respectively. These DRE are not considered indicative of the afterburner performance since DRE calculations are typically prepared with a large inlet concentration. For the two cases discussed above, the afterburner inlet concentrations were 159 ppt and 442 ppt, respectively.

9.6.6 SMOKELESS POWDER RESULTS

The test plan indicated that the afterburner inlet gas and exit gas would be sampled for determination of smokeless powder emissions. No analytical method exists, however, for determination of smokeless powder in stack gases. The analytical method utilized by the laboratory for the pilot study is a method that has been used in the recent past for the analysis of water samples for nitrocellulose (NC), nitroglycerine (NG), and PETN. The method is a nonspecific method for the determination of organonitrates that decompose under the test conditions of the method. NC, NG, and PETN cannot be distinguished one from the other when using this method. Secondly, indigenous nitrate/nitrite in solution will produce a positive bias (i.e., "hit") in the final result since the method ultimately depends upon the quantification of nitrite ion cleaved from the organonitrate compound. With these factors in mind, upon review of analytical results, the method as applied to this stack test program was found to be inappropriate, and therefore the results are not meaningful.

The hot gas process was conducted to destroy nitrated compounds. CEM data indicates a fairly constant NOx emission from the afterburner. Nitrous oxides are normally generated during combustion of natural gas caused by the reaction of atmospheric nitrogen with excess oxygen. The NOx emissions, if captured by the impinger solutions used to capture the NC/NG, would introduce a positive bias in the analytical data. It is uncertain, at this point, what impact the NOx emissions had on these samples.

It is also uncertain if the sampling protocol was effective at capturing NC/NG emitted from the afterburner. The sampling protocol utilized particulate filter followed by four impingers containing water. NC is completely soluble in acetone and virtually insoluble in water.

The final results as reported currently, may not reflect only NC/NG, but may be biased high from ambient NOx emissions produced during the actual organonitrate destruction in the afterburner.

The data generated in this study, while not available for DRE calculations, do present indications of afterburner performance. Several areas of future study have been indicated. First is that in a gross sense, the nitrated esters reported by this method appear to be degraded in the afterburner and possibly completely destroyed since all of the afterburner outlet samples were significantly lower than the flash chamber outlet samples. Secondly, the sampling protocol needs to be redesigned to afford a more useful final sample for analysis. The sampling media of choice may be acetone since both compounds appear to be collectable in the solvent.

Finally, the analytical method needs to be further developed in an effort to provide for a separation between nitrocellulose, nitroglycerine, and ambient NOx. Potential methodologies would be an initial cleanup of the sample to remove the inorganic NOx emission. Following this cleanup step, the NG and NC could potentially be partioned into different solvents by taking advantage of their different physical properties. Another alternative may be to develop a method utilizing an ion exchange column or liquid chromatograph.

9.7 REGULATORY CONSIDERATIONS

9.7.1 HAZARDOUS WASTE CLASSIFICATION

Most of the test items in the inventory pile at HWAAP are expected to contain trace amounts of explosives. As such, test items are not classified as hazardous. Should items contain bulk amounts of explosives, however, they may be classified as characteristically hazardous for reactivity (EPA Hazardous Waste Number D003). According to Chapter 40 of the Code of Federal Regulations, part 261.23 (40 CFR 261.23), a solid waste exhibits the characteristic of reactivity if a representative sample of the waste has any of the following properties:

- It is normally unstable and readily undergoes violent change with detonating.
- It reacts violently with water.
- It forms potentially explosive mixtures with water.
- When mixed with water, it generates toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment.
- It is a cyanide or sulfide bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment.
- It is capable of detonation or explosive decomposition or reaction if it is subjected to a strong initiating source or if heated under confinement.
- It is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.
- It is a forbidden explosive as defined in 49 CFR 173.51 or a Class A explosive as defined in 49 CFR 173.53 or a Class B explosive as defined in 49 CFR 173.88.

If the quantity of bulk explosives for disposal is sufficient to warrant characterization as reactive, it would be inappropriate to treat these materials in the hot gas process without the process meeting appropriate regulatory requirements.

9.7.2 PARTICULATE

Although not classified as a hazardous waste incinerator (since items containing bulk amounts of explosives are not expected to be treated), regulatory criteria for particulate as identified in 40 CFR 264.343 (performance standards for hazardous waste incinerators) is included herein. The limitations are not considered required but are presented because the hot gas by nature is similar to a waste incinerator. Regulations indicate that an incinerator burning hazardous waste must not emit particulate matter in excess of 180 milligrams per dry standard cubic meter (0.08 grains per dry standard cubic foot) when corrected for the amount of oxygen in the stack gas according to the formula:

$$Pc = Pm \times 14/(21-Y)$$

Where: Pc = corrected concentration of particulate matter
Pm = measured concentration of particulate matter
Y = measured concentration of oxygen in the stack gas

The particulate results presented in Subsection 9.6.3 demonstrated an emission of 0.00093 gr/dscf; emissions are 2 orders of magnitude lower than the regulatory requirement (0.08 gr/dscf corrected to 7 percent oxygen).

9.7.3 HYDROCHLORIC ACID (HCl) EMISSIONS

Although not classified as a hazardous waste incinerator, regulatory criteria for HCl emissions as identified in 40 CFR 264.343 (performance standards for hazardous waste incinerators) is included herein. According to the regulations, an incinerator burning hazardous waste and producing stack emissions of more than 1.8 kilograms per hour (4 pounds per hour) of hydrogen chloride must control HCl emissions such that the rate of emissions is no greater that the larger of either 1.8 kilograms per hour or 1 percent of the HCl in the stack gas prior to entering any pollution control equipment.

The hot gas process at HWAAP provided no controls for emissions of HCl. The process, however, did not process any known quantity of chlorinated compounds or plastic materials. Future operations should limit plastic and chlorinated compounds to avoid exceeding this requirement.

9.7.4 DESTRUCTION AND REMOVAL EFFICIENCY (DRE)

Regulations pertaining to hazardous waste incinerators are provided for reference as a gauge to evaluate the efficiency of the destruction system. Regulations are not applicable since the hot gas process is not considered a hazardous waste operation, however, the regulatory criteria provide guidelines. According to 40 CFR 264.343 (performance standards for hazardous waste incinerators), an incinerator burning hazardous waste (except dioxin/furan waste which has more strict criteria) must achieve a DRE of 99.99 percent for each principal organic hazardous constituent (POHC) designated in its permit for each waste feed.

The results from TNT indicate that, when sufficient levels of TNT were emitted from the flash chamber, DRE exceeded the 99.99 percent requirement. Before demonstration of DRE on smokeless powder can be completed, method development of a suitable sampling system and analytical protocol are necessary.

9.8 STATISTICAL ANALYSIS OF DECONTAMINATION TESTS

The objective of the statistical analysis of the data from the pilot study is to develop a mathematical relationship that could be used to set the operational parameters (i.e., temperature, time (heatup plus steady state), and air flow rate) as low as possible and still have all the treated test items sufficiently decontaminated of TNT (i.e., no residual levels of TNT above detection limits). Although nine test runs were conducted to evaluate TNT, data from only eight of the nine tests are used because the temperature sensors malfunctioned during one test run (Test 18).

9.8.1 STATISTICAL MODEL

The statistical model used for the analysis is a multiple linear regression model having the general form:

$$\text{PASS/FAIL} = a_0 + a_1\,(\text{TEMPERATURE}) + a_2\,(\text{TIME}) + a_3\,(\text{FLOW-RATE}) + e$$

Where:

a_0 = y-intercept of the regression line.
a_1, a_2, and a_3 = regression coefficients for the three predictor variables.
e = error term in the equation.
Temperature = Average temperature during heatup and steady state.
Time = Total number of hours required for heatup and steady state.
Flow rate = The average flow rate measured during the heatup and steady state time.

The prediction of the outcome of the decontamination process is based on simple pass/fail (i.e., 1 or 0) results. Residual TNT concentrations were not used for three reasons. First, a majority of the analyses of residual TNT were below detection limits. Recording the values as 0 (for concentrations below the threshhold concentration, i.e., nondetects) or 1 (for unacceptably high concentrations, i.e., above detection limits) allowed the statistical analysis to be conducted without concern for the statistical distribution of the TNT concentrations. Second, using a model in which the dependent variable is coded as 0 or 1 allows predicted values to be thought of as probabilities so that the model could produce more intuitive results than would a model based on concentrations. Finally, when the decontamination unit becomes operational, it will not be necessary to know the residual concentration of TNT on a piece of apparatus, but instead, only that the apparatus has less than a preestablished threshhold concentration. Therefore, a model employing a pass/fail strategy would be more efficient and easier to implement.

The first step in the statistical analysis is to determine if all the predictor variables (i.e., temperature, time, and air flow-rate) effectively contribute to the prediction of the outcome of a decontamination run. This evaluation was conducted using a process known as stepwise regression. In stepwise regression, predictor variables are added to a model one at a time until there is no improvement in the model from the addition of any of the remaining variables. Based on the stepwise regression analysis of the model described above, it was determined that the variables time and flow-rate were not effective predictors and could be dropped from the model. This simplified the prediction model to:

$$\text{PASS/FAIL} = a_0 + a_1\,(\text{TEMPERATURE}) + e.$$

There are several possible reasons why time and flow-rate were not effective predictors. First, because of the extended heat-up and cooldown periods, the significance of time was diminished. As a consequence, it was impossible to measure the "effective" time of decontamination. Second, the measured air flow rate is an averaged value that may not represent the true air movement around individual pieces of apparatus. Finally, flow rate and time may not be important in the decontamination process so long as certain threshhold values are attained.

The second step in the analysis is to determine if "interaction" variables would be useful in the model. (Interaction variables are combinations of the originally measured variables.) Three interaction variables were evaluated using stepwise regression analysis:

- Interaction 1 = Time*Temperature.
- Interaction 2 = Time*Temperature*Flow Rate.
- Interaction 3 = (Time*Temperature)/Flow Rate.

None of the three interaction terms proved to be superior to temperature for predicting the success of decontamination nor did they provide additional predictive capability when used in conjuction with temperature.

The final step in the analysis is to calculate the model regression coefficients and the diagnostic statistics. These results are summarized in the next subsection. Attempts were made to develop models for each type of test item; however, there were not enough data points available to make this effort worthwhile. Developed models, therefore, are applicable to all types of test items evaluated.

9.8.2 MODEL RESULTS

Table 9-4 summarizes the results of the modeling effort. The model calculated from the eight decontamination tests is:

- $\text{PASS/FAIL} = 0.00909\,(\text{TEMPERATURE}) - 3.48.$

This model is statistically significant at the 0.01 level and accounts for up to 74 percent of the variability observed in the results of the decontamination tests. Figure 9-10 illustrates the model and the original data, as well as the 95 percent confidence limits for mean and individual predictions.

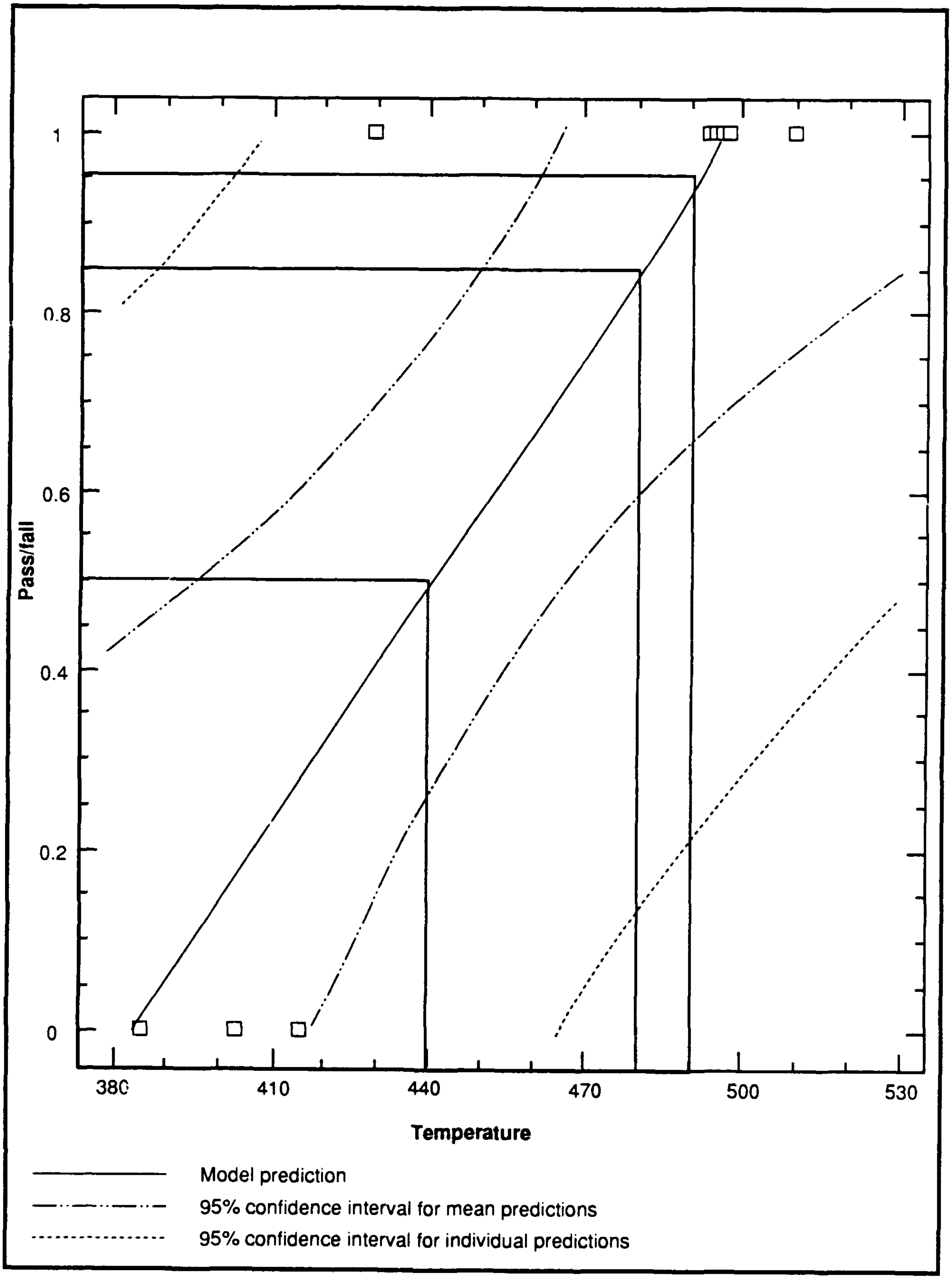
Table 9-4

Results of Statistical Model for
Predicting the Success of Decontamination

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	1.393523	1	1.393523	17.36561	.00590
Error	.4814768	6	.0802461		
Total (Corr.)	1.8750000	7			

Correlation Coefficient = 0.862098 R-squared = 74.32 percent
Stnd. Error of Est. = 0.283277

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	-3.48288	0.990839	-3.51509	.01259
Slope	.009086	.002180	4.16721	.00590



G-224m

Figure 9-10. Regression of decontamination pass/fail based on heatup plus steady state temperature.

Based on this model, the heat up plus steady state temperature should be at least 440°F to have better than a 50 percent chance of successful decontamination. Predicted temperatures for 85 percent and 95 percent chance of successful decontamination are 480°F and 490°F, respectively. The 95 percent confidence intervals around these predictors are quite wide, which is attributable to the small number of tests analyzed.

9.8.3 RECOMMENDATIONS FOR OPTIMIZATION OF STATISTICAL MODEL

The prediction model described above is calibrated for the test apparatus at HWAAP and may not apply to another operational system. To develop a model for a general operational system, a similar testing program should be conducted. The precision of the prediction model could be improved by implementing the following actions:

- Improve the construction of the decontamination chamber to allow for better control of temperature and flow rate.
- Improve the ability to measure temperature and flow rate precisely.
- Run several tests between 410°F and 460°F to determine if there is a threshhold temperature for effective decontamination.
- Develop models for specific types of test items to determine how much more difficult some items are to decontaminate than others.
- Increase the total number of tests to at least 25.

SECTION 10

ECONOMIC EVALUATION

An economic evaluation was conducted to determine the costs associated with operation of the hot gas process at HWAAP at the optimum condition (500°F/6 hours). Costs correspond to a total operational time of 95 hours (based on actual test time associated with completion of a test conducted at the desired conditions during the pilot study). Costs are based on operation of the current configuration of the pilot system; modifications to the system will change costs. (Section 11 of this report discusses full-scale design considerations applicable to the hot gas system used at HWAAP. The costs associated with implementing these modifications are provided.) Table 10-1 provides a summary of costs for the current configuration. A brief discussion of each cost element is discussed in the following subsections.

10.1 LABOR

The requirements for dedicated labor were determined to be as follows:

- Two operators ($15/hr).
- One CEM operator ($17/hr).

A 40-hour work week was assumed for cost determinations. As shown on Table 10-1, a cost of $1800 was developed. The labor cost could be reduced significantly if onsite personnel operate the facility.

10.2 FUEL

Propane costs are based on a purchase cost of $0.471/gallon. The price will vary depending on the vendor. Operational times of 16 hours for the air preheater (2.15 million Btus/hour) and 95 hours for the afterburner (4.8 million Btus/hr) were assumed based on field operations during the pilot study. Total fuel cost is estimated to be $2,600, as shown on Table 10-1.

10.3 ELECTRICITY

Electrical costs were developed assuming a purchase cost of $0.07 per kilowatt hour. The electrical requirements for the system are as follows:

- Air preheater - 1.5 hp.
- Afterburner - 4.5 hp.
- CEM - 120 V/single phase, 100 amps.

Costs are based on operating times of 16 hours for the air preheater and 95 hours for the afterburner. As shown on Table 10-1, electrical costs are estimated to be $200.

Table 10-1

Economic Evaluation for Optimum Conditions
500°F for 6 Hours

	Cost ($)
Labor Two operators at $15/hour for 40 hours One CEM operator at $17/hour for 40 hours	1,800
Propane Air preheater 2.15 million Btus/hour Afterburner 4.8 million Btus/hour Propane cost $0.471 per gallon	2,600
Electricity Air preheater 1.5 hp motor Afterburner 4.5 hp motor CEM 120V/single phase, 100 amps Electricity cost $0.07 per kilowatt hour	200
CEM	1,000
TOTAL	$5,600

10.4 CEM SYSTEM

There are three alternatives available for the CEM system:

- Rental of a CEM system.
- Purchase of a CEM system.
- Temporary rental of a CEM system and purchase of a carbon monoxide unit.

The rental cost is shown on Table 10-1. The monthly rental cost for a CEM system equivalent to the system used during the pilot study is $4,000. A daily cost was developed for Table 10-1; costs for calibration gases and spare parts are included.

The purchase cost of a CEM system, equivalent to the system used during the pilot study, is about $150,000. Acquisition of a system allowing continuous monitoring of nitrous oxides, total hydrocarbons, oxygen and carbon dioxide would probably not be required. Continuous monitoring of carbon monoxide concentrations would likely be sufficient since this compound serves as an indicator of proper operation of an incineration system.

A cost effective alternative is to temporarily rent a CEM system for about 6 months. Rental of a system would allow for the development of baseline data. Once a baseline is established, continous monitoring of nitrous oxides, total hydrocarbons, oxygen and carbon dioxide would be discontinued. A carbon monoxide unit would be used to monitor proper operation of the facility. The cost of a carbon monoxide unit is about $32,000, as shown on Table 10-2.

Table 10-2

Cost of Purchasing a Carbon Monoxide (CO) Continuous Emission Monitor

	Cost ($)
CO Analyzer (Precision ± 1 ppm)	$10,000
Conditioning System (eliminates dust and moisture from system)	5,000
Sampling Lines	2,000
Regulators	1,000
Calibration gases (based on 1 year full time use)	2,000
Data System (computer and chart recorder)	10,000
Shelter for unit	2,000
Total	32,000

SECTION 11

FULL-SCALE DESIGN CONSIDERATIONS

Equipment utilized during the pilot test program at HWAAP was previously used onsite for flash powder decontamination and at the Cornhusker Army Ammunition Plant for a similar hot gas pilot test. This equipment performed acceptably during the test program and is being considered for use as a full scale system by HWAAP. If the equipment is to remain installed at HWAAP, it is suggested that a series of improvements and modifications be made to the system. These improvements will increase the thermal efficiency, safety aspects, and ease of operation for HWAAP personnel. The improvements recommended in the remainder of this section apply to the system at Hawthorne but, should a full scale system be installed elsewhere, the comments would apply to a generic hot gas process design.

11.1 FLASH CHAMBER INSULATION

The flash chamber in Building 117-15 was designed for flash powder decontamination of equipment. The building is a hardened structure constructed of a 1-inch-thick steel shell surrounded by 2 inches of fiber insulation and encased in 4 to 6 feet of reinforced concrete. The system was not intended to be utilized for long term exposure to hot air; consequently, the structure is not very thermally efficient. The excellent conductivity of the steel and large mass of concrete resulted in the chamber acting as a large heat sink, absorbing 42 percent of the heat generated by the air preheater.

The recommended modification for the flash chamber is the installation of 4 inches of a lightweight, preformed insulating blanket on the interior steel shell. A low conductivity insulation, such as A.P. Green INSBLOK-19 or its equal, would be recommended. This type of material is recommended over loose fiberous insulation since it is easier to install and less likely to flake. The lightweight nature does not require structural modifications or need significant anchors. The fiber type insulation is also preferred over cast or brick since it is not as suspectible to spalling caused by frequent temperature cycles.

The cost for this modification consists of the materials and labor to install the blanket, as provided on Table 11-1. The insulating blanket will reduce the composite thermal conductivity of the flash chamber from the present 5.43 Btu/hr ft°F to 0.30 Btu/hr ft°F. For illustration, if the recommended insulation was installed, Test Run 3 (500/36 hours) could be conducted with similar gas flow rates and temperatures and would result in a fuel savings of 850,000 Btu/hr. (The payback period is projected to be 1.01 years, as shown on Table 11-1).

11.2 AFTERBURNER STACK LOSSES

The afterburner is utilized to heat the flash chamber exit gases to approximately 1,800°F, thereby destroying volatilized organics and explosive

Table 11-1

Cost for Flash Chamber Insulation

	Cost ($)
Design	6,000
Material	
Insulation (4,500 board feet)	5,200
Anchors (3,750 pieces)	1,300
Coating	1,200
Labor	
Mobilization	2,500
Anchor Installation	8,500
Material Insulation	4,200
Coating	4,200
Contingency	5,000
Total*	38,100

*The payback period projected for this modification is estimated to be 1.01 years. The payback period was determined as follows:

- Savings = $850{,}000 \text{ Btu/hr} \times \frac{\text{gallon fuel}}{93{,}600 \text{ Btu}} \times \$0.471 = \$4.28\text{/hour}$

- Payback period = $\frac{\$38{,}100}{\$4.28\text{/hour}} = 8{,}908 \text{ hours} = 1.01 \text{ years}$

compounds in the exit gases. To achieve the required temperatures, the afterburner is fired with 4.8 million Btu/hr of propane. The exhaust gases containing 4.3 million Btu/hr of sensible heat (relative to 70°F) are released to the atmosphere. It is recommended that this heat be recuperated and utilized as a source of heat for the hot gas process. Although gases discharge to the afterburner at a temperature of 1,800°F, it is only practical to recuperate gases at a temperature of 1,000°F.

Two methods of recovering afterburner heat are considered potentially acceptable. The first recommended method is direct recirculation of the exhaust gases. In this method the exhaust gases from the afterburner are quenched to 700°F and recycled to the inlet of the air preheater. A schematic of the direct recirculation system is shown in Figure 11-1. The second method of exhaust heat recovery is indirect recirculation where combustion air for the air preheater is heated by the afterburner exhaust in a heat exchanger. The indirect system is shown in Figure 11-2. Each method is further discussed in the following subsections.

11.2.1 DIRECT RECIRCULATION

The direct recirculation method of heat recovery involves the drafting of the afterburner exhaust gases by recycle fan. The hot gases (1,800°F) are drawn from a new exhaust manifold mounted on top of the existing afterburner structure and enter a tempering tee. The tempering tee will admit cool ambient air to control the temperature into the recycle fan. A thermocouple and temperature controller are utilized to monitor and maintain a constant recycle air temperature. A system designed to maintain a 700°F recycle air temperature is recommended to avoid a recycle fan constructed of special materials. The flow of the recycle system is measured by a venturi flow meter and controlled with a discharge damper on the recycle fan. The recycled gases are directed to the air preheater. The air preheater is utilized to provide final control of temperature into the flash chamber.

If the direct recirculation heat recovery system is used, the air preheater burner assembly must be replaced with a smaller unit. The air preheater will be fired at a minimum level sufficient to supplement the recycle system and supply all the heat needed to maintain the flash chamber discharge temperature. The fuel consumed by the air preheater will be reduced to 17,000 Btu/hr (pilot only). The sizing and fuel estimates for the direct recycle system have assumed the flash chamber is insulated as recommended in Subsection 11.1. The costs for installing the direct recycle system are provided on Table 11-2. (The payback period projected for this modification is projected to be 1.46 years, as shown on Table 11-2). The costs include materials needed for the system, including an exit manifold for the afterburner ducting, a recycle fan, a tempering damper and miscellaneous controls.

11.2.2 INDIRECT RECIRCULATION

The second possible method of heat recovery is the indirect recirculation method as shown in Figure 11-2. This method uses a heat exchanger to preheat combustion air for the air preheater. The combustion air is provided under pressure by a new combustion air fan. The air enters the tube side of a

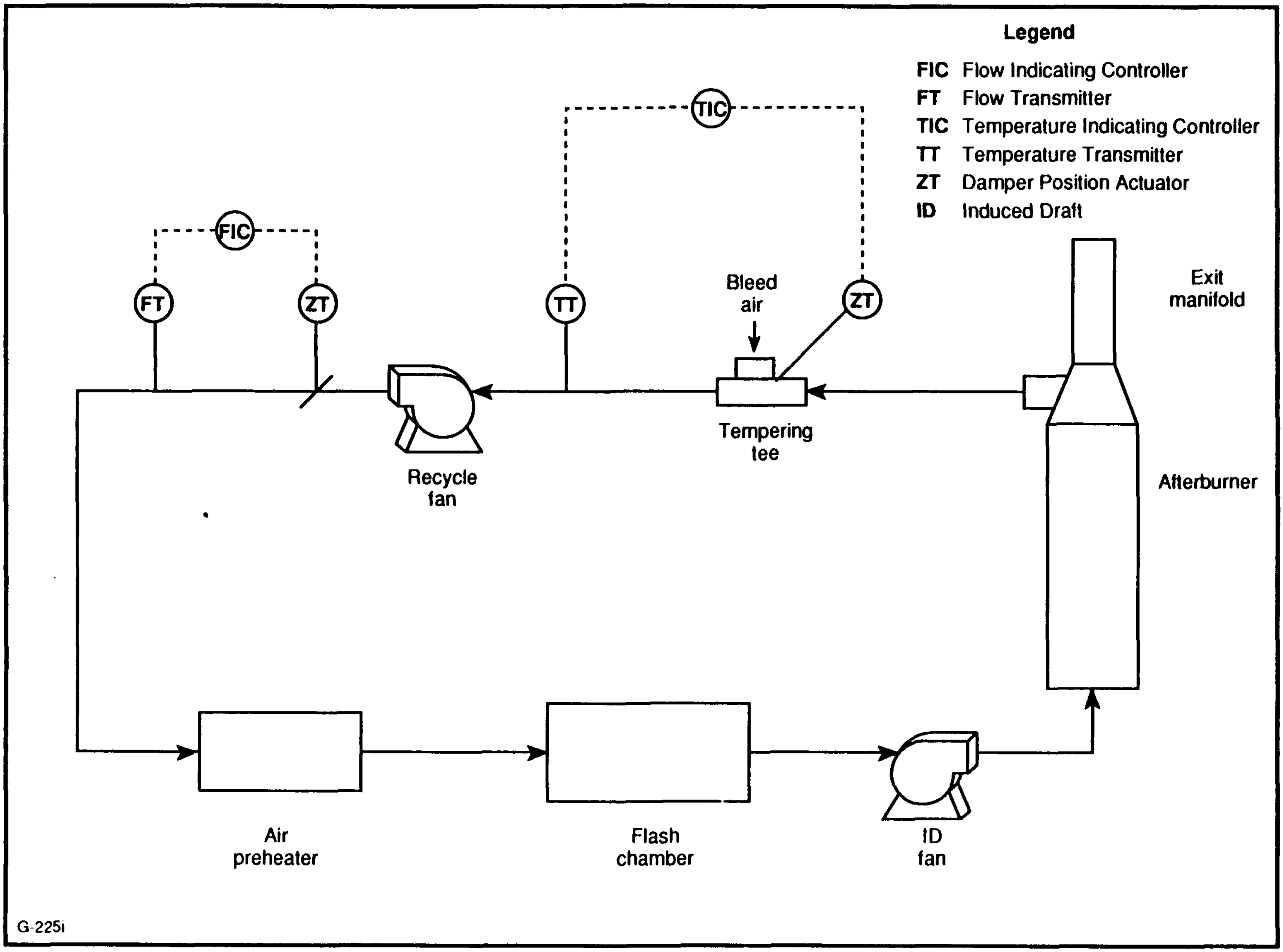


Figure 11-1. Afterburner exhaust heat recovery - direct recycle system.

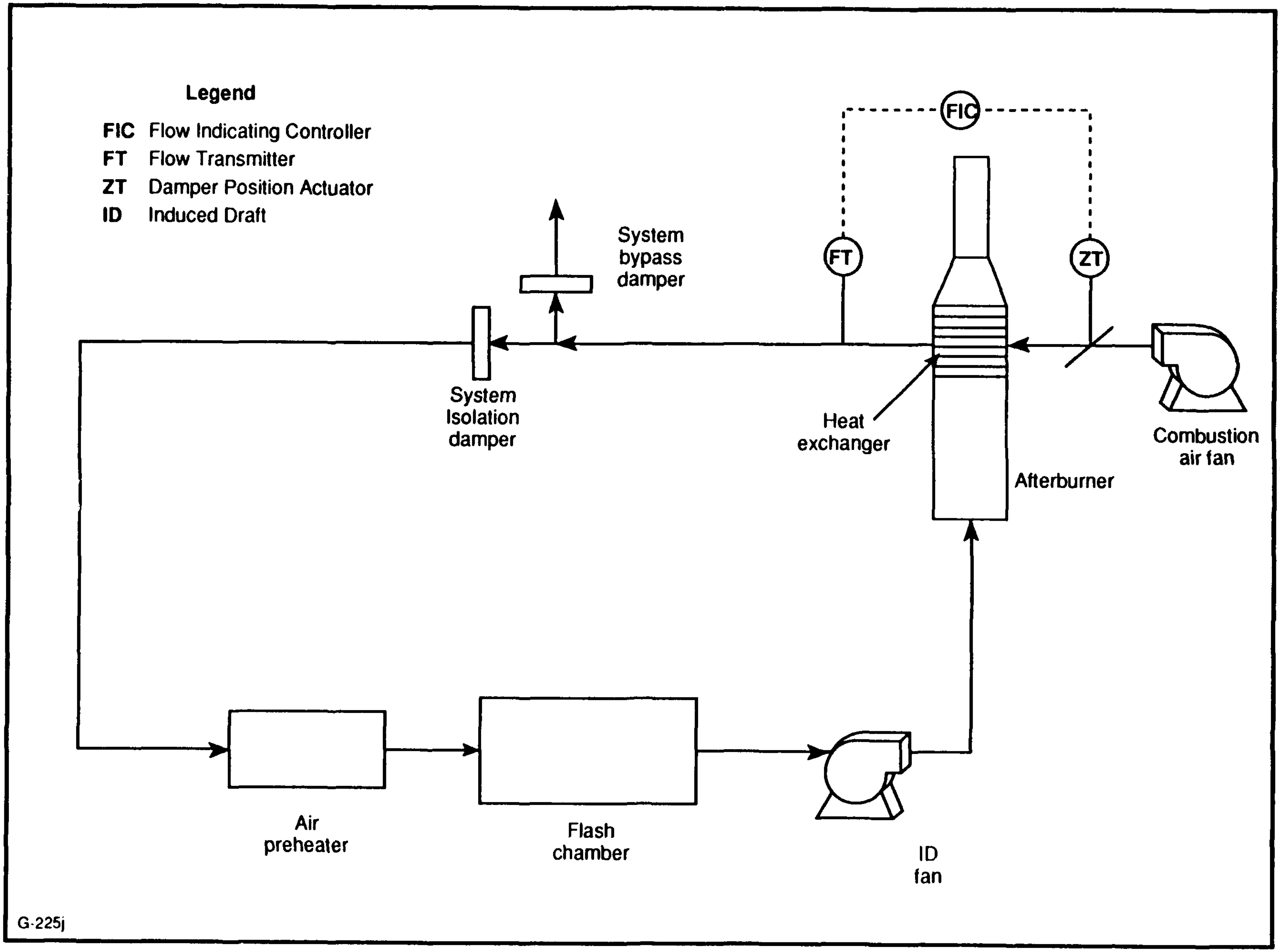


Figure 11-2. Afterburner exhaust heat recovery - indirect recycle system.

Table 11-2

Afterburner Exhaust Heat Recovery Direct Recirculation Costs

	Cost ($)
Design	30,000
Equipment	
Afterburner Exit Duct Manifold; 5-foot diameter to 3-foot diameter lined with 6-inches of fiber insulation.	3,500
Manifold Supports	17,000
Hot Gas Ducting; 1.5-foot diameter with 3-inches refractory lining	13,100
Tempering Damper with Explosion-Proof Actuator	2,500
Hot Air Ducting; 1.5-foot diameter with 3-inches insulation	2,300
Recycle Fan; 6,600 ACFM air at 590°F; 5 inwg pressure; Stainless Steel Sparkless Construction; 700°F maximum Design Temperature; V belt driven; Explosion-proof motor (110 V or 208 3 phase)	12,000
Fan Damper with Explosion-Proof Actuator	2,500
Instruments	
- Type J thermocouple with explosion-proof transmitter	300
- Annubar flow meter with explosion-proof transmitter	900
- Two PID digital controllers	3,000
- Motor starter and controls	1,500
Replacement Burner - 1.7 MM Btu/hr rating	1,100
Labor	
Mechanical Assembly 400 manhours	22,000
Electrical Assembly 60 manhours	3,300
Startup Costs 80 manhours	5,000
Contingency	18,000
Total*	138,000

Table 11-2

Afterburner Exhaust Heat Recovery
Direct Recirculation Costs
(continued)

Notes: ACFM = Actual cubic feet per minute; inwg = Inches of water gauge; V = Volt; MM = Million.

*The payback period projected for this modification is estimated to be 1.46 years. The payback period was determined as follows:

Savings 2,150,000 Btu/hr - 17,000 Btu/hr = 2,133,000 Btu/hour

$$2{,}133{,}000 \text{ Btu/hr} \times \frac{\text{gallon fuel}}{93{,}600 \text{ Btu}} \times \$0.471\text{/gallon} = \$10.71\text{/hour}$$

$$\text{Payback period} = \frac{\$138{,}000}{\$10.71\text{/hour}} = 12{,}866 \text{ hours} = 1.46 \text{ years}$$

heat exchanger. The heat exchanger, which is constructed of 304 stainless steel, is located on top of the existing afterburner. The combustion air exits the heat exchanger and is ducted to the air preheater.

Because the majority of heat for the process is now recycled, the current air preheater burner assembly must be replaced with a smaller unit. The fuel consumed by the air preheater is reduced to 17,000 Btu/hr. The process is also equipped with two dampers which vent the preheated recycle air when personnel are entering the flash chamber. These dampers are actuated to the full open or full close positions only.

The costs for installing the direct recycle system are provided on Table 11-3. The costs include materials needed for the system, including the heat exchanger and supports, ducting, a new combustion air fan, isolation dampers and controls. The labor includes design, installation, and startup costs. (The payback period for this modification is projected to be 1.34 years, as shown on Table 11-1).

11.3 AIR PREHEATER

During operation of the system, the air preheater was the most troublesome piece of equipment to control. A burner with a 10:1 turndown ratio is necessary to control the heatup rate of the flash chamber. The air preheater at HWAAP could only achieve about a 2:1 turndown and only with difficulty could the temperature be controlled. The flame often shut down due to control problems.

Upon reviewing the burner design, it is recommended that the air preheater chamber be enlarged to reduce the gas velocity in the combustion zone. The recommended method of reducing the combustion gas velocity is to separate the introduction of combustion air (air needed to burn fuel slightly above stoichiometric levels) and dilution air (air used to control final temperature of hot gas). This could be accomplished by adding a mixing chamber downstream of the air preheater, as shown on Figure 11-3. The mixing chamber recommended could be utilized with the system as presently constructed or with the recycling alternatives proposed in Subsections 11.1 and 11.2 above.

With the proposed modification, air from the combustion fan is split. A portion of the discharge air is directed to the mixing chamber as dilution air. The remainder of the discharge air is directed to the combustion chamber. The current burner assembly should be replaced with a burner designed to introduce limited combustion air and fuel to the nozzle tip. The air directed to the combustion chamber is regulated by a control valve (damper). The damper controlling the combustion air into the air preheater is driven by the fuel gas (temperature) controller. This method of combustion control permits consistent air to fuel ratio which maintains consistent combustion characteristics. The fuel gas valves used on the current burner could be reused with a new air ratio burner.

The cost for this modification consists of the material to construct a mixing chamber, ducting changes to the combustion air fan, new burner assembly

Table 11-3

Afterburner Exhaust Heat Recovery Indirect Recirculation Costs

Equipment	Cost ($)
Design	30,000
Afterburner Heat Exchanger 304 SS Construction	3,000
Heat Exchanger Supports Supports	17,000
Cold Air Ducting 1.0-foot diameter	2,100
Two 1.5-foot diameter isolation damper with explosion-proof actuator	4,000
Hot Air Ducting 1.5-foot diameter with 3-inches insulation	7,500
Combustion air fan 2,000 ACFM air at 120°F, 10 inwg Pressure Aluminum sparkless construction V belt driven Explosion-proof motor (110 V or 208 3 phase)	3,000
Fan damper with explosion-proof actuator	2,500
Instruments	
- Type J thermocouple with explosion-proof transmitter	300
- Annubar flow meter with explosion-proof transmitter	900
- One PID digital controllers	1,500
- Motor starter and controls	1,500
Replacement Burner - 1.7 MM Btu/hr rating	1,100
Labor	
Mechanical Assembly	27,100
Electrical Assembly	3,300
Startup Costs	4,400
Contingency	17,000
Total*	126,200

Table 11-3

Afterburner Exhaust Heat Recovery
Indirect Recirculation Costs
(continued)

Notes: SS = Stainless steel; ACFM = Actual cubic feet per minute; inwg = Inches of water gauge; V = Volt; MM = Million.

*The payback period projected for this modification is estimated to be 1.34 years. The payback period was determined as follows:

Savings 2,150,000 Btu/hr - 17,000 Btu/hr = 2,133,000 Btu/hour

$$2{,}133{,}000 \text{ Btu/hr} \times \frac{\text{gallon fuel}}{93{,}600 \text{ Btu}} \times \$0.471/\text{gallon} = \$10.71/\text{hour}$$

$$\text{Payback period} = \frac{\$126{,}200}{\$10.73/\text{hour}} = 11{,}761 \text{ hours} = 1.34 \text{ years}$$

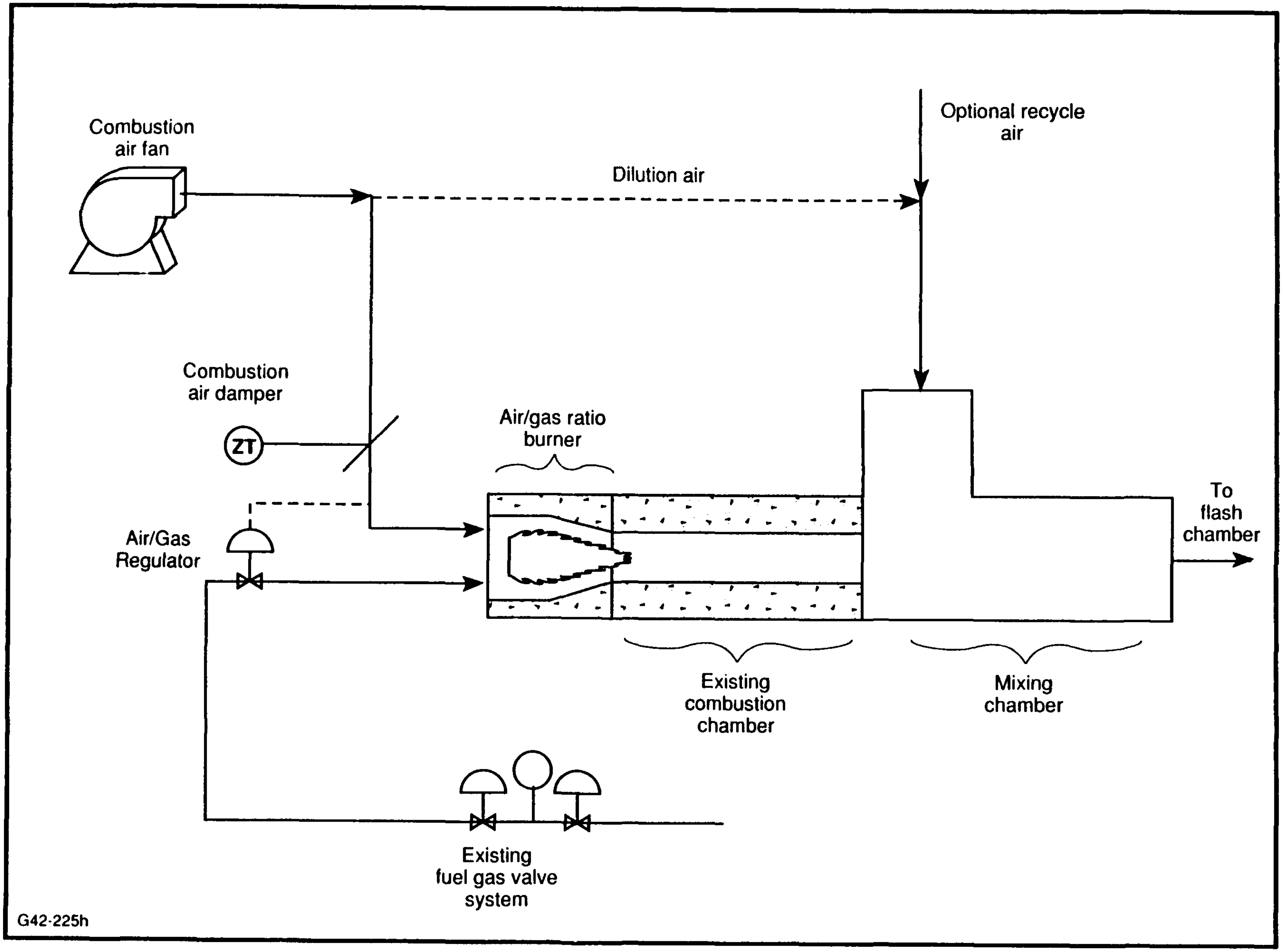


Figure 11-3. Air preheater modifications.

and control valve for the air and fuel lines. The labor to design, install, and start up the system is also included on the total cost provided on Table 11-4.

11.4 CONTROL SYSTEM

The control system for the hot gas system worked well. During the pilot testing WESTON provided thermocouples for monitoring the flash chamber temperatures and a multipen recorder for storing the data. It is recommended that a series of thermocouples be permanently installed along the periphery of the chamber and in the exit gas duct from the flash chamber. These thermocouples, along with the air preheater temperature and afterburner temperature, should be recorded on a strip chart recorder to document operating conditions.

The exit gas temperature from the flash chamber was monitored but not controlled during the pilot test. During the unmanned operation the site was evacuated and the temperature was assumed to have remained constant. The temperature exiting the flash chamber fluctuated, however, during unmanned operation. During manned operation control was not possible because of the difficulty in operating the air preheater. If preheater modifications are made as proposed in Subsection 11.3, it is recommended that a controller be installed to maintain the flash chamber exit gas temperature. A Power Process Controls 512 Process Controller or equal is recommended since it is capable of programmed heatup and cooldown activities which will permit unmanned operation following loading of the flash chamber.

The cost for control system modifications will involve the purchase and installation of instruments and recorders as itemized on Table 11-5.

11.5 REMOTE CAR REMOVAL

The processing of test items during the pilot test typically took 3 to 5 days to complete each batch. The greatest portion of the testing time was due to excessive delays associated with cooling down the flash chamber. Steady state testing time only accounted for 6 to 36 hours. If the system at HWAAP is to be used for decontamination, it is recommended that a system be installed that allows removal of the railcar from a heated chamber. The remote removal system will eliminate any delays associated with a system cooldown.

The modifications suggested to allow for remote car removal include installing isolation dampers in the hot air inlet duct and flash chamber exit duct. These dampers will close prior to opening the access door to the flash chamber. No hot air from the preheater or backflow of afterburner gases can occur with these dampers in the closed position.

Secondly, the railcar holding the treated test items and engine or driven rail car used to push the load into the flash chamber, should be modified. A large eyelet should be installed on the treated equipment railcar. The engine or

Table 11-4

Cost for Air Preheater Modifications

	Cost ($)
Design	20,000
Equipment	
Mixing Chamber	6,000
Burner Assembly	2,500
Combustion Air Piping 6-inch Carbon Steel	1,500
Combustion Air Damper 6-inch	2,000
Air/Fuel Ratio Regulator	2,000
Labor	
Installation	6,500
Startup	2,200
Contingency	6,400
Total	49,100

Table 11-5

Costs for Control System Modifications

	Cost ($)
Design	2,500
Equipment	
Five Thermocouples (Type J)	1,250
Five Temperature Transmitters	3,400
12 Channel Multipen Recorder	2,600
Process Controller	2,400
Labor	
Installation	4,400
Startup	1,100
Contingency	2,600
Total	20,250

driven railcar should be equipped with an extended hook allowing the operating personnel to attach the railcar holding treated equipment without entering or approaching the flash chamber entrance. The eyelet and hook assemblies are shown in Figure 11-4.

It is assumed HWAAP personnel could procure and install the eyelet and hooks from industrial supply catalogs. The costs for this modification is expected to be less than $5,000.

11.6 POWER SUPPLY

The operation of the hot gas system was interupted numerous times during the summer months due to electrical blackouts. Because of the large mass of the flash chamber, the hot gas process maintains temperature without operation of the burners. As long as temperature is maintained in the flash chamber, organics and explosives will volatilize and be vented by natural draft through the afterburner. To assure complete destruction of the organics in the off gas, the afterburner should be continuously fired. An uninteruptable power supply (or backup generator system) is recommended to maintain continuous operations. A small propane fired generator system rated at 10 kilowatts (kw) is needed to supply electrical power to the control system and motors. The cost for purchasing and installing a propane fired generator with automatic transfer switch is estimated to cost $4,500.

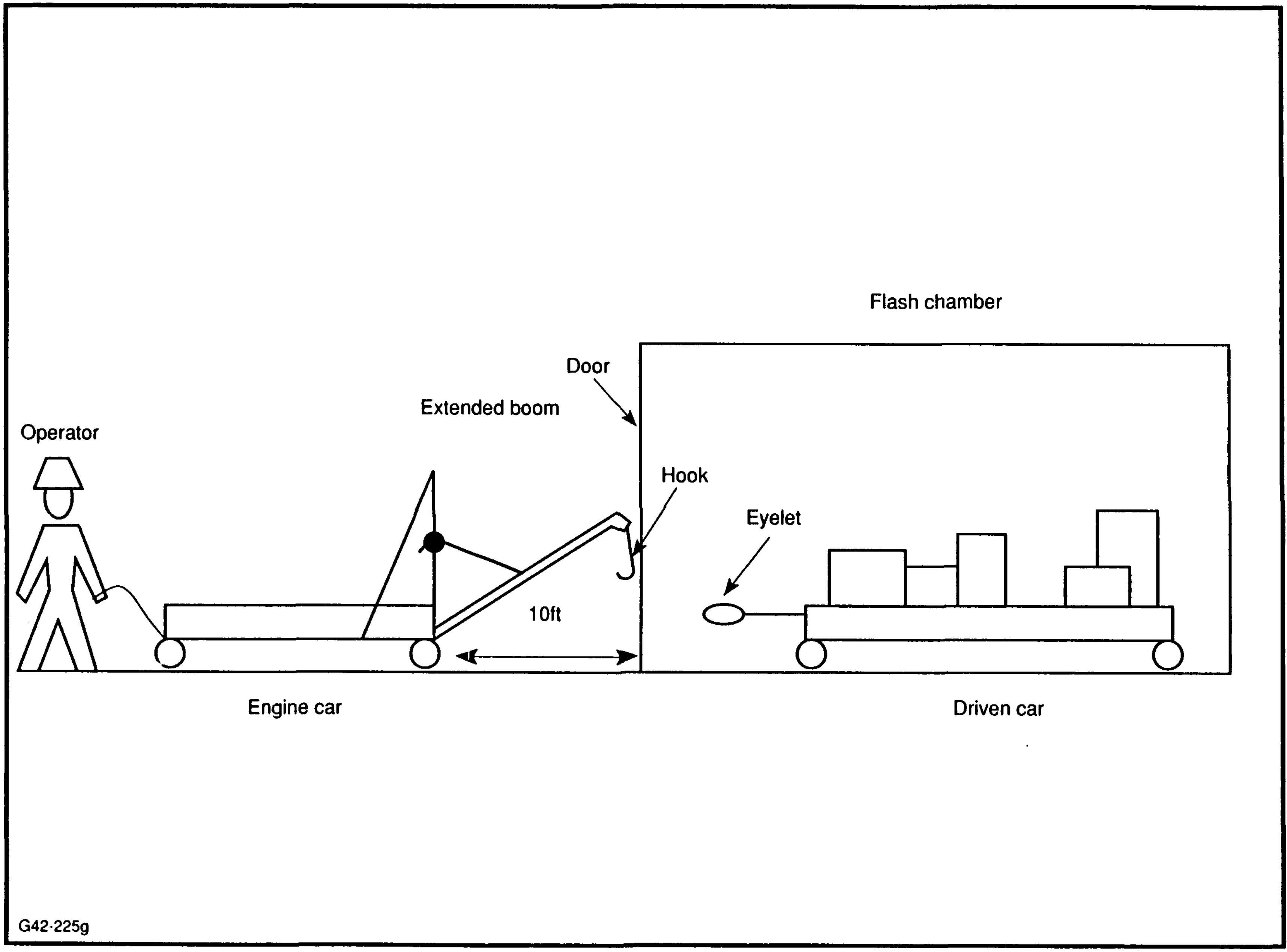


Figure 11-4. Remote car removal system.

SECTION 12

CONCLUSIONS AND RECOMMENDATIONS

12.1 CONCLUSIONS

The following conclusions are drawn from the pilot study:

- The hot gas process is effective for treating items contaminated with TNT, smokeless powder, and ammonium picrate.
- Analytical results indicate that temperature is a key factor in explosives removal. It was determined that a minimum temperature of 500°F is required to remove TNT below measurable levels on the treated test items. Partial removal was observed at 400°F; however, in general, for items with gross contamination (such as clay pipe) and items with internal contamination, a temperature of 400°F was not sufficient for complete removal. Since relatively large temperature gradations were evaluated (±100°F), the minimum effective operating temperature may lie somewhere between 400°F and 500°F.
- Test items that are treated for 6 hours at a minimum temperature of 500°F are safe for public release as scrap. Items treated in the prescribed manner are not considered characteristically hazardous and are appropriate for disposal or potentially for resale as scrap.
- Items with contamination on external surfaces only were generally the least difficult to treat; three failures were observed (one failure associated with soil/debris in clay pipe). Test items with contamination on internal surfaces or within the porous media proved to be more difficult to treat; although three test items were observed to fail, residual concentrations were generally higher.
- Calculations completed to determine the length of time required for test items (steel) to achieve a steady state temperature of 500°F indicate that the mass of test items only has a moderate effect on the total time required for treatment. Assuming the system is adequately insulated and that the available heat is absorbed by the test items and not the flash chamber walls and floor, during routine system operation, if a minimum of 1 hour is utilized for system heatup (at a heat-up temperature of 550° F), each test item should be at the appropriate temperature by the time steady conditions commence.
- Based on the analyses from the stack sampling, TNT was primarily removed from test items during the heatup period; however, removal continued throughout steady state operation and possibly into the cooldown period.

- Generally, items constructed of steel or aluminum showed no signs of damage due to treatment. For clay, however, exposure to the hot gas resulted in cracks throughout the entire pipe sections. The clay became very brittle and was easily broken.

- Treated test items that are constructed of steel or aluminum and have no intricate or mechanical components should be appropriate for reuse in manufacturing or handling operations.

- Treated test items that are constructed of steel or aluminum and contain intricate or mechanical components would not be appropriate for reuse. These items should be disposed as scrap.

- Based on a limited statistical model developed for the hot gas system at HWAAP, the heatup/steady state average temperature should be at least 440°F to have better than a 50 percent chance of successful decontamination. Predicted temperatures for 85 percent and 95 percent chance of successful decontamination are 480°F and 490°F, respectively.

- Operating conditions of 600°F, coupled with a steady state time of 48 hours, were found to be effective for reducing levels of ammonium picrate below detection limits. Optimum conditions may include lower temperatures and/or decreased residence times; optimization of conditions for ammonium picrate was not an objective of the pilot test.

- Due to the limited testing on smokeless powder and the variability in pre-test item contamination, it is not possible to analyze trends in the data.

- The sampling and analytical methods employed for determination of smokeless powder emissions in the stack gases (and presence of smokeless powder on test items) were determined to be inappropriate. The method did not allow NC and NG to be distinguished from one another or from other nitrated esters. The stack sampling protocol was also questionable; the sampling media may not have captured NC and NG.

- During each of the tests, a phenomenon consistent with autoignition was observed for the bulk explosives contained in the clay pipe.

- The gas phase heat transfer coefficient for the hot gas system was calculated to range from 1.17 Btu/hr ft^2 °F to 1.82 Btu/hr ft^2 °F.

- The thermal conductivity constant (K) for the composite flash chamber wall was determined to average 5.10 Btu/hr ft^2 °F (°F/ft) (±20 percent). The average thermal conductivity constant is between the conductivity constants associated with the major structural components of the flash chamber (K is 27 and 0.30 Btu/hr ft^2 °F (°F/ft) for steel and concrete, respectively).

- TNT emissions from the afterburner, as measured during the stack testing program, were consistently below detectable levels. In cases where TNT inlet concentration was sufficiently high, the DRE exceeded 99.99 percent.

- Emissions of explosives (other than TNT) were observed in the afterburner discharge gases (including HMX, RDX, 1,3,5-TNB, and 1,3-DNB). The emission of these compounds was not consistently observed and ranged from 475 ppt to 6 ppt. Corresponding inlet concentrations were observed only during stack tests T2-3 (1,3-DNB) and T3-3 (1,3,5-TNB). In these cases, the calculated DREs were 72.9 percent and 80.9 percent, respectively. Low DREs are not indicative of poor performance of the afterburner, but reflect insufficient concentrations of explosives in the inlet program.

- The emissions of particulate from the afterburner, as measured during the stack testing program, ranged from 0.00017 gr/dscf to 0.00093 gr/dscf (corrected to 7 percent oxygen). Emissions are ten orders of magnitude lower than applicable regulations.

- Combustion efficiency of the afterburner ranged from 99.9895 to 99.9933 percent during the stack testing program; efficiencies reflect the excellent performance of the afterburner.

- Emissions of carbon monoxide and total hydrocarbons at the flash chamber inlet indicate that the existing air preheater at HWAAP is operating poorly. Emissions were one order of magnitude higher than emissions associated with typical gas-fired heaters. Combustion efficiencies for the air preheater ranged from 98.95 percent to 99.72 percent during the stack testing program.

- Due to extended heatup and cooldown periods, it is difficult to evaluate the effects of the 600°F test runs. During the 600°F test runs, before the steady state temperature was achieved, the system had operated at conditions that were very similar to the 500°F/6 hour test run. The results of the 500°F/6 hour test run indicate decontamination of TNT. Therefore, during the 600°F test run, the test items were adequately treated before the steady state temperature was even achieved.

12.2 RECOMMENDATIONS

The following recommendations are provided:

- The modifications presented in Section 11 should be implemented to improve the overall efficiency of the test system at HWAAP (i.e., flash chamber insulation, reduction of afterburner stack heat losses, air preheater chamber enlargement, upgrades in the monitoring system, and remote car removal).

- For operation at HWAAP, the modified system should be operated at a temperature of 550°F during heatup. The heatup period should be a minimum of 1 hour to assure all test items have reached a temperature of 500°F prior to steady state conditions.

- For the system at HWAAP, to overcome potential problems with nonuniform temperatures in the flash chamber, items that are more difficult to treat (such as steam-heated vessels and items with internal contamination) should be located at the rear of the rail cart near the diffusers. Items that are less difficult to treat, such as items with external surface area only, will likely be effectively treated when placed at the front of the cart, near the chamber door.

- If explosive or propellent compounds (other than TNT) are to be treated in the hot gas system, stack testing should be conducted to determine the associated DREs.

- If test items to be treated during future operations are radically different from those items evaluated during the pilot study, further testing (sampling and analysis) should be conducted to verify optimum conditions.

- The structural stability of treated test items that are appropriate for reuse in manufacturing or handling should be verified through nondestructive testing using one or a combination of the following tests:

  - Visual Inspection.
  - Magnetic Particle Test.
  - Dry Penetrant Test.
  - Ultrasonic Test.
  - Radiographic Test.

  Testing should be conducted by qualified personnel.

- To develop a statistical model for a general operational system, a testing program similar to the pilot study should be conducted. The precision of the model could be improved by implementing the actions outlined in Subsection 9.8.3.

- The sampling protocol for smokeless powder should be redesigned to afford a more useful final sample for analysis. The sampling media should be selected to assure complete capture of NC and NG. The analytical method needs to be researched and further developed in an effort to provide a separation between NC, NG and ambient nitrous oxides. Potential developments are summarized in Subsection 9.6.5.

- To determine the means of removal for explosives (i.e., evaporation, combustion, particulate carryover, etc.), future testing should include separate analysis of all components of the air sampling equipment.