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US Army Corps of Engineers

Toxic and Hazardous
Materials Agency

Report No. CETHA-TS-CR-91033
FINAL REPORT

Engineering Test Report Paint Waste Reduction Fluidized Bed Process Demonstration at Letterkenny Army Depot Chambersburg, Pennsylvania

July 1991
Contract No. DAAA15-88-D-0001
Task Order No. 0007

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DISTRIBUTION STATEMENT A
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Prepared for:

U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland 21010-5423

THAMA Form 45, 1 Jul 90

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Reference 3769-7	5. MONITORING ORGANIZATION REPORT NUMBER(S) CETHA-TS-CR-91033
6a. NAME OF PERFORMING ORGANIZATION IT Environmental Programs,Inc	6b. OFFICE SYMBOL *(If applicable)*
7a. NAME OF MONITORING ORGANIZATION U.S. Army Corps of Engineers Toxic and Hazardous Materials Agency	
6c. ADDRESS *(City, State, and ZIP Code)* 1133-21st Street, NW Washington, D.C. 20036	7b. ADDRESS *(City, State, and ZIP Code)* ATTN: CETHA-TS-D Aberdeen Proving Ground, MD 21010-5401
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U.S. Army Corps of Engineers THAMA	8b. OFFICE SYMBOL *(If applicable)*
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Contract DAAA 15-88-D-001 Task Order No. 0007	
8c. ADDRESS *(City, State, and ZIP Code)* ATTN: CETHA-TS-D Aberdeen Proving Ground, MD 21010-5401	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE *(Include Security Classification)*
Paint Waste Reduction-Process Demonstration at Letterkenny Army Depot

12. PERSONAL AUTHOR(S)
J.P. Murphy and D. Parker

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT *(Year, Month, Day)*	15. PAGE COUNT
Final	FROM 5/90 TO 7/91	1991, July	52 + Appendices

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
* Chemical Cleaning
* Paint Stripping
* Hazardous

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

Objectives

Degreasing and removal of paint from metal parts are processes performed at several Army depots across the country as part of vehicle and equipment rebuilding operations. These processes generate many tons of hazardous waste and release some hazardous materials into the workplace because most of them incorporate toxic chlorinated solvents or caustic soda. These substances also produce sludges that are classified as hazardous waste.

U.S. Army Depot Support Command (DESCOM), as part of its hazardous waste minimization program, has established as a goal the elimination of hazardous waste generation from paint stripping operations. Through specific research and development projects, the U.S. Army's Toxic and Hazardous Materials Agency (USATHAMA) assists Army Depots in developing and evaluating methods for minimizing the quantities of hazardous wastes that they generate. (CONTINUED)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL R. Jackson	22b TELEPHONE *(Include Area Code)* 301-671-2054
	22c. OFFICE SYMBOL CETHA-TS-D

DD Form 1473, JUN 86 *Previous editions are obsolete.*

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

In Task No. 0007 of Contract No. DAAA15-88-D-0001, USATHAMA requested that IT Environmental Programs, Inc., conduct an engineering, operability, and economic feasibility study of one such method, the Fluidized Bed Paint Removal Process, at Letterkenny Army Depot.

The objective of this study is to evaluate the viability of the Fluidized Bed Paint Removal Process as a method of removing paint from metal parts at Army depots, to compare the operability, economic performance and environmental impact of the Fluidized Bed Paint Removal Process with existing paint removal systems and to derive conclusions regarding the appropriateness of replacing existing paint removal systems with the Fluidized Bed Paint Removal Process.

Findings and Conclusions

Conclusion 1:
The Fluidized Bed Paint Removal Process is not a suitable replacement for chlorinated solvent stripping systems currently used to remove paint from aluminum and aluminum alloy parts at Army Depots.

Basis: This study, in conjunction with a similar study conducted at Red River Army Depot, found that aluminum and aluminum alloy parts when exposed to the 700 - 800°F temperatures of the Fluidized Paint Removal Process for the 1-2 hours residence time required to pyrolize paint lost essentially all of their hardness or temper. It is possible to restore this property through the addition of a heat treatment step in the repainting process at the depot but this has been deemed impractical by U.S. Army Depot Support Command personnel.

A preliminary evaluation of the Molten Salt Bath as a paint removal alternative confirmed this conclusion regarding effect of temperature on aluminum hardness and gave some indication as to how temperature sensitive aluminum parts are. Exposure of aluminum to a temperature of 600°F for only 2.5 minutes caused a 65 percent hardness reduction. Exposure to 800°F for only 1 minute caused an 87 percent reduction.

Conclusion 2:
The Fluidized Bed Paint Removal Process can be used to remove paint from non-aluminum and non-heat sensitive parts but the cost is an order of magnitude greater to operate that its alternative for this purpose, the Caustic Soda Process.

Basis: The Fluidized Bed Paint Removal Process cost $4.06 per part cleaned as compare to $.31 per part for the Caustic Soda Process. This disparity is due to the fact that the Fluidized Bed Paint Removal Process is more labor intensive and energy consumptive than the Caustic Soda Process. Even the optimized scenario for the Fluidized Bed Paint Removal Process would result in a cost of $2.80 per part processed.

The Fluidized Bed Paint Removal Process requires 72% more labor due to greater handling requirements and the need for more operator attention. The Fluidized Bed Paint Removal Process also consumes more energy in the form of electricity and propane gas due to the greater number of motors incorporated into the system and high thermal requirements both for heating and pyrolysis of paints and combustion of unburned gases.

Conclusion 3:
In the course of removing paints, coatings, or platings containing toxic metals (e.g., lead, chromium, cadmium), the Fluidized Bed Paint Removal Process will cause the Fluidizer Bed Media to become a "hazardous" substance.

Basis: Although the Fluidized Bed Paint Removal Process does not incorporate toxic solvents or materials in its paint removal operation, it does remove heavy metals formulated in paints and contained in coatings and platings from the surface of parts and deposit them, to some extent, into the Fluidizer Bed Media. The exact mechanism for each metal is not defined but significant increases in toxic metals concentration in the Fluidizer Bed Media have been observed after only three Fluidized Bed Paint Removal Process runs. There is no question that the pyrolysis of paints, coatings, or platings containing toxic metals in the Fluidized Bed Paint Removal Process will result in fluid bed material which exceeds the regulatory limits of 40 CFR 261.24 for these metals. This will cause the Fluidizer Bed Media to be classified as a hazardous waste. Of course, this will become less of a problem as the presence of paints containing lead and chrome diminish but must be taken into consideration until such time.

A mass balance conducted around the Fluidized Bed Paint Removal Process during its operation determined that the Fluidizer Bed Media containing toxic metals as well as the toxic metals themselves are not found in any significant concentrations in either the stack gases or effluent water to the industrial water treatment plant.

Conclusion 4:
In the course of removing paints, coatings, and platings containing toxic metals, the Fluidized Bed Paint Removal Process will generate more solid hazardous waste requiring disposal than the Caustic Soda Process.

Basis: As stated in the basis for Conclusion 3 above, the Fluidized Bed Paint Removal Process will generate toxic metal-contaminated Fluidizer Bed Media in the course of treating paints, coatings and platings containing toxic metals. It is estimated that the resulting solid hazardous waste requiring disposal will amount to about 20,000 pounds per year as compared to the 3,000 pounds per year of caustic sludge from the Caustic Soda Stripping Process requiring disposal.

Conclusion 5:
Fluidized Bed Paint Removal Process workers and any workers in the building containing the Fluidized Bed Paint Stripper System will be subject to Occupational Safety and Health Act requirements for employees exposed to lead under 29 CFR 1910.1025.

Basis: As stated in the bases for Conclusions 3 and 4, when the Fluidized Bed Paint Removal process removes paints, coatings or platings containing lead, the Fluidizer Bed Media rapidly increases in lead concentration and exceeds the threshold defining it to be a hazardous waste within the first few runs.

This means that the dust emitted from the Fluidized Bed Paint Removal Process cabinet is not only a hazardous waste by definition but contains high concentrations of lead. Although ambient air monitoring was not conducted during this study, the concentration of lead in the dust and the quantity of dust emitted from the Fluidized Bed Paint Removal Process would lead to an expectation of potential operator exposure in excess of the action level of 30 micrograms per cubic meter of air averaged over an 8-hour period and possibly as high as the permissible exposure limit of 50 micrograms per cubic meter.

In any case, the dust must be considered as a hazardous material containing lead and handling, monitoring and personal protection procedures as required by 29 CFR 1910.1025 should be implemented for all workers employed in any building housing the Fluidized Bed Paint Removal System.

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1.0 Introduction

Through specific research and development projects, the U.S. Army's Toxic and Hazardous Materials Agency (USATHAMA) assists Army Depots in developing and evaluating methods for minimizing the quantities of hazardous wastes that they generate. In Task No. 0007 of Contract No. DAAA15-88-D-0001, USATHAMA requested that IT Environmental Programs, Inc., conduct an engineering, operability, and economic feasibility study of one such method, the fluid bed paint removal process (FBPS), at Letterkenny Army Depot (LEAD).

Degreasing and removal of paint from metal parts are processes performed at several Army depots across the country as part of vehicle and equipment rebuilding operations. These processes generate many tons of hazardous waste and release some hazardous materials into the workplace because most of them incorporate toxic chlorinated solvents or caustic soda. These substances also produce sludges that are classified as hazardous waste.

U.S. Army Depot Support command (DESCOM), as part of its hazardous waste minimization program, has established as a goal the elimination of hazardous waste generation from paint stripping operations. A process that uses a heated, fluidized bed of alumina to remove paint, grease and other organics was considered as being potentially useful in achieving this objective. Two units were installed at Army Depots: A 24-inch diameter unit at LEAD and a larger 48-inch diameter unit at the Red River Army Depot (RRAD).

Since this paint stripping process is a pyrolysis procedure that uses no toxic agents, it was perceived as having good potential for reducing hazardous waste. Both of the test programs required that LEAD and RRAD personnel determine the type and quantities of parts that could be depainted in the units by pyrolizing the coatings in the hot fluidized bed, and also determine the extent and nature of toxic materials emitted from the processes (PEI Associates, 1990).

In the RRAD study, it was found that aluminum parts could not be stripped above the 650°F required by the FBPS, as this condition caused the metal to lose its desired temper (Spessard, 1990). Combined preliminary data from both studies concluded that for LEAD purposes, the fluidized bed paint stripper could only replace the caustic stripping of paints from non-aluminum alloys but not the solvent stripping of aluminum parts. This conclusion was reached because it was deemed impractical to incorporate a heat treatment step in the LEAD paint removal operations to restore the temper to aluminum parts. Therefore, the test program at LEAD was modified to conduct operability, cost and environmental impact comparison of the operation of the FBPS in comparison only to other stripping methods for steel parts (Mraz, 1990). (See May 1991 Test Plan, Appendix A).

Two alternative depainting processes are considered in depth in this report:

- Fluidized Bed Paint Stripping; and
- Caustic Soda Stripping Process.

The Caustic Soda (CS) Stripping Process has been in use at LEAD for several years, while the FBPS was installed in January, 1991 as a demonstration unit. The molten salt bath (MSB), which is given a very preliminary evaluation in this report, is a commercial process used in industry, but it is not presently used in the Army's Depots.

2.0 Process Studies

2.1 Fluidized Bed Paint Stripper

2.1.1 Process Description

The FBPS removes paint or other organic coatings by heating the part at an elevated temperature above 650°F to cause pyrolysis and decomposition of the organic portion of the paint. A granular material, alumina in most cases, is fluidized by blowing air or another gas through the granules. The media, which are converted to a fluid by the action of the gas, efficiently transfer heat to objects with irregular shapes that are held below the surface of the turbulent fluid. The thermal decomposition of the paint produces gases and leaves some carbon-inorganic char on the part. Much of this char may be removed in the fluidized bed, but most parts require further cleaning before they can be repainted. A shot-blast cabinet has been installed at Letterkenny, as part of the FBPS, to complete the cleaning step.

The FBPS uses a three-step process that is designed to remove paints and other coatings, including their organic and inorganic constituents, from heat resistant parts. The FBPS at Letterkenny has been designed and installed by Procedyne Corporation, New Brunswick, New Jersey. Procedyne's specification (Duffy, 1989) and manuals (Procedyne 1979, 1990a, 1990b, and 1990c) were used as source material for this description. The FBPS consists of the following four major components: 1) Fluidized-Bed Furnace or Retort, 2) Fluidized-Bed Cooling System, 3) Off-Gas Afterburner, and 4) Low-Energy Shot-Blast Unit. As shown in Figure 1, a vented cabinet forms a single enclosure above both fluidized bed units. The cabinet is also equipped with motor-controlled double doors (each, approximately 2 by 6 feet) at one end and a small, transparent sliding port at each fluidized bed. The cabinet serves to contain any exhaust gases, smoke, or expelled media, and an exhaust blower expels such materials through a collection and treatment system (Figures 2 and 3). A single track and hoist system is used to transfer the stainless-steel work baskets into the unit, between the two fluidized units, and out to the low-energy shot-blast unit. The chain that hooks to the basket traverses a slot in the cabinet top. The slot is closed with rubber vanes to seal the vent cabinet.

Before depainting, the furnace electric heaters must be used, with fluidizing air, to bring the bed to an operating temperature of 700-850°F. This heat-up step requires approximately four hours. To begin the process, parts are loaded in the stainless-steel work basket, and the basket, attached below the furnace cover, is hooked to the hoist and transferred into the cabinet. After closing the cabinet doors the basket is lowered into the hot fluidized bed. The coatings begin to decompose as the fluidized media transfer the furnace's heat to the parts. The furnace cover prevents the release of decomposition gases into the cabinet, and causes them to be expelled through the furnace duct that is located on the side at the top of the retort (Figure 4). Both the retort duct and the cabinet vent duct are connected to a cyclone that separates media and other larger particles from the gases (Figure 1). The blower attached to the afterburner pulls the pyrolysis gases through the cyclone, into the afterburner and out the exhaust stack. During the pyrolysis a small flow of water is introduced into the retort. This water vaporizes in the furnace to prevent the formation of an explosive mixture. The stainless steel work basket remains in the fluidizer furnace from 1.0 to 2.0 hours depending on the number of parts and the type of coatings applied.

In a normal load of parts there will be an inadequate concentration of oxygen in the fluidizing air to allow complete combustion of the paint constituents, plastic coatings, or

Figure 1 Fluidized Bed Paint Stripper

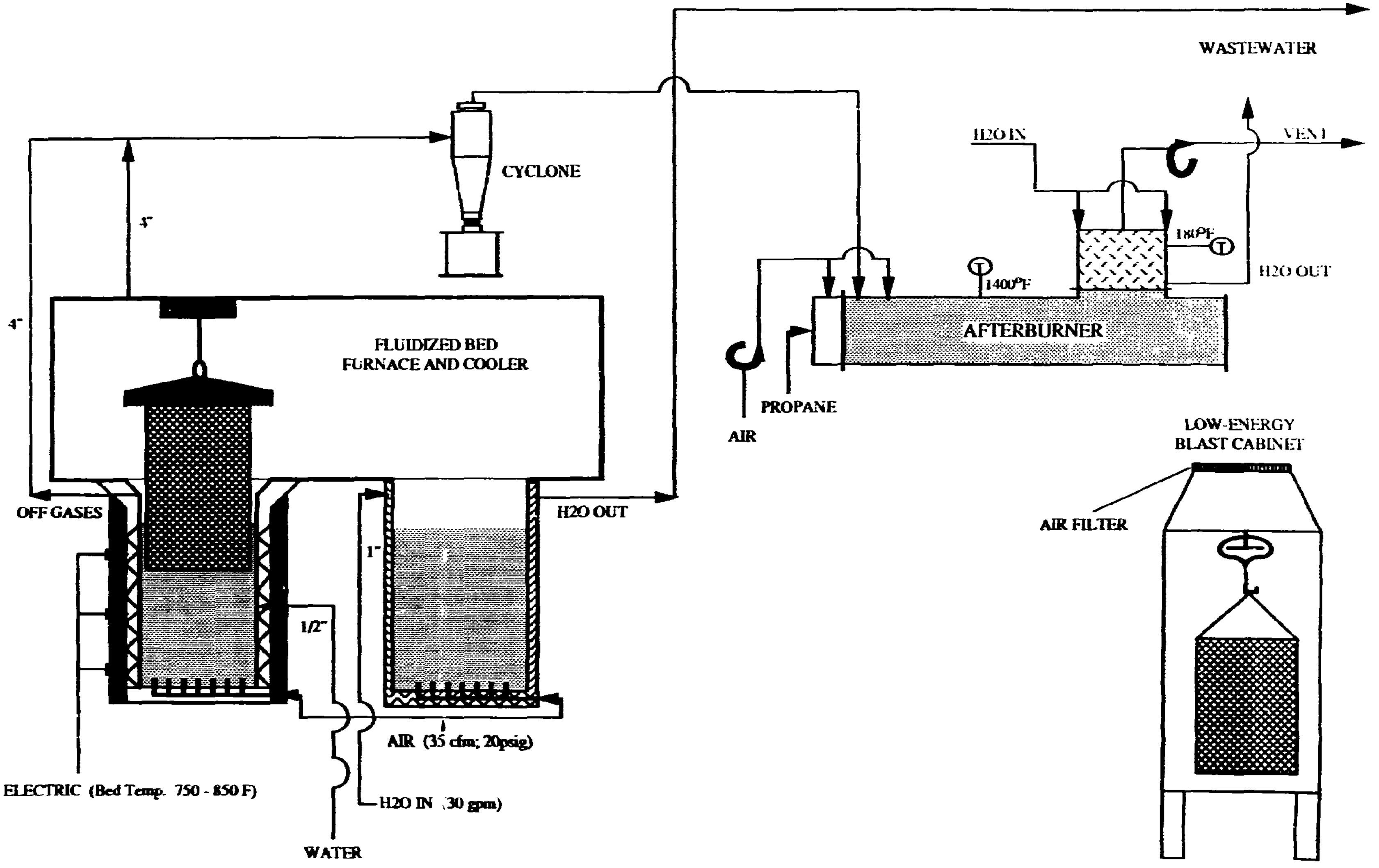
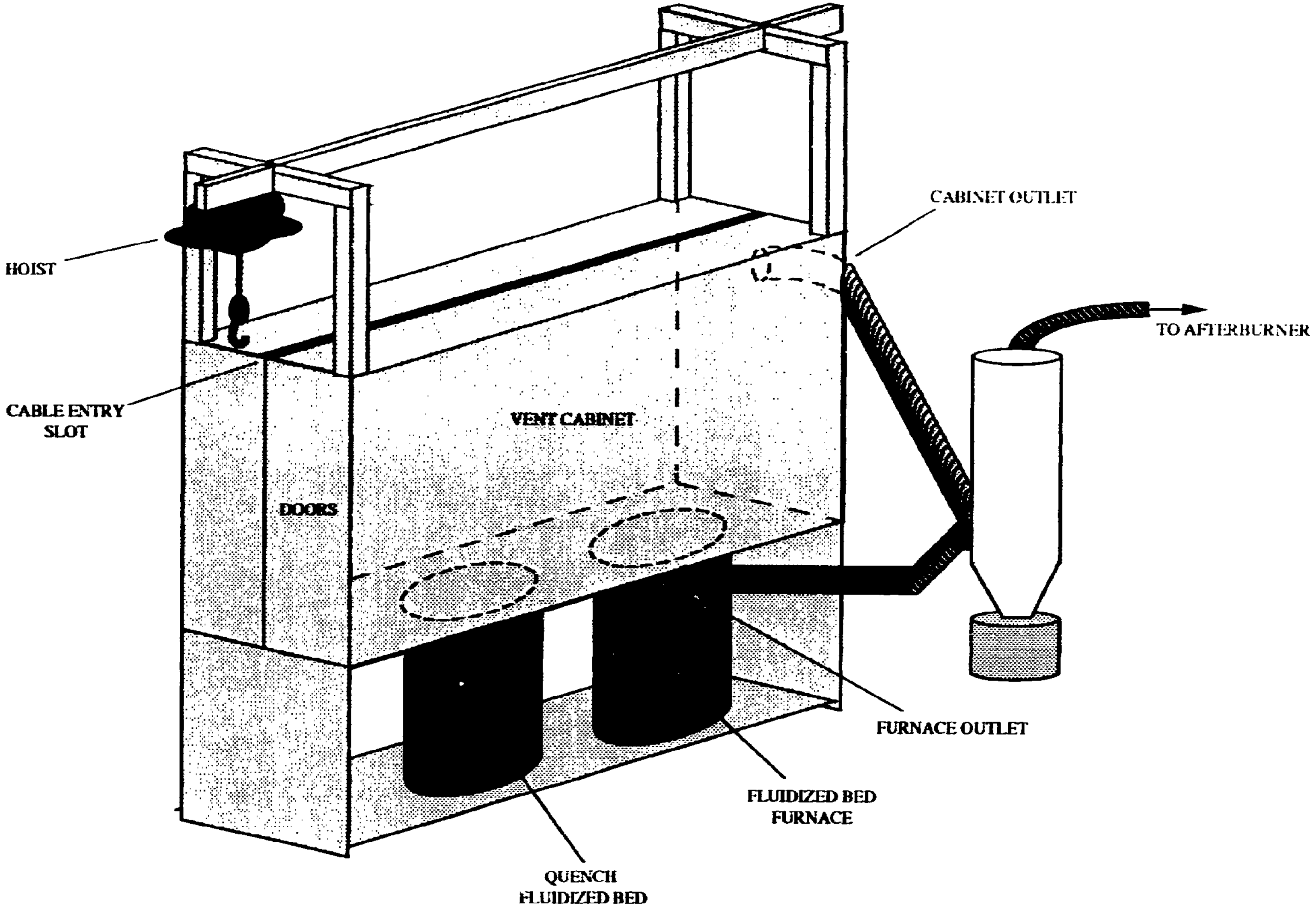
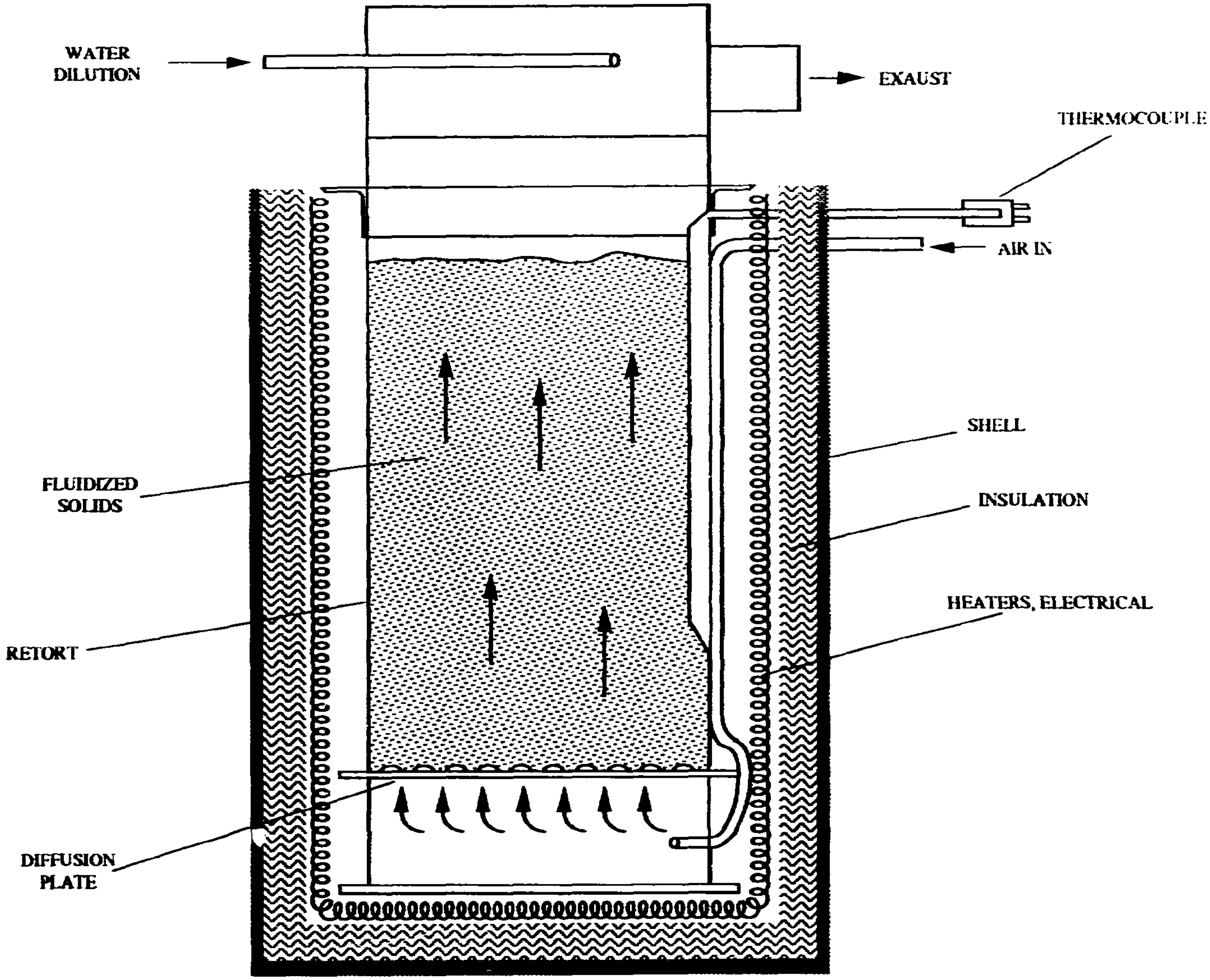


Figure 2 Fluidized Beds and Cabinet (Rear View)



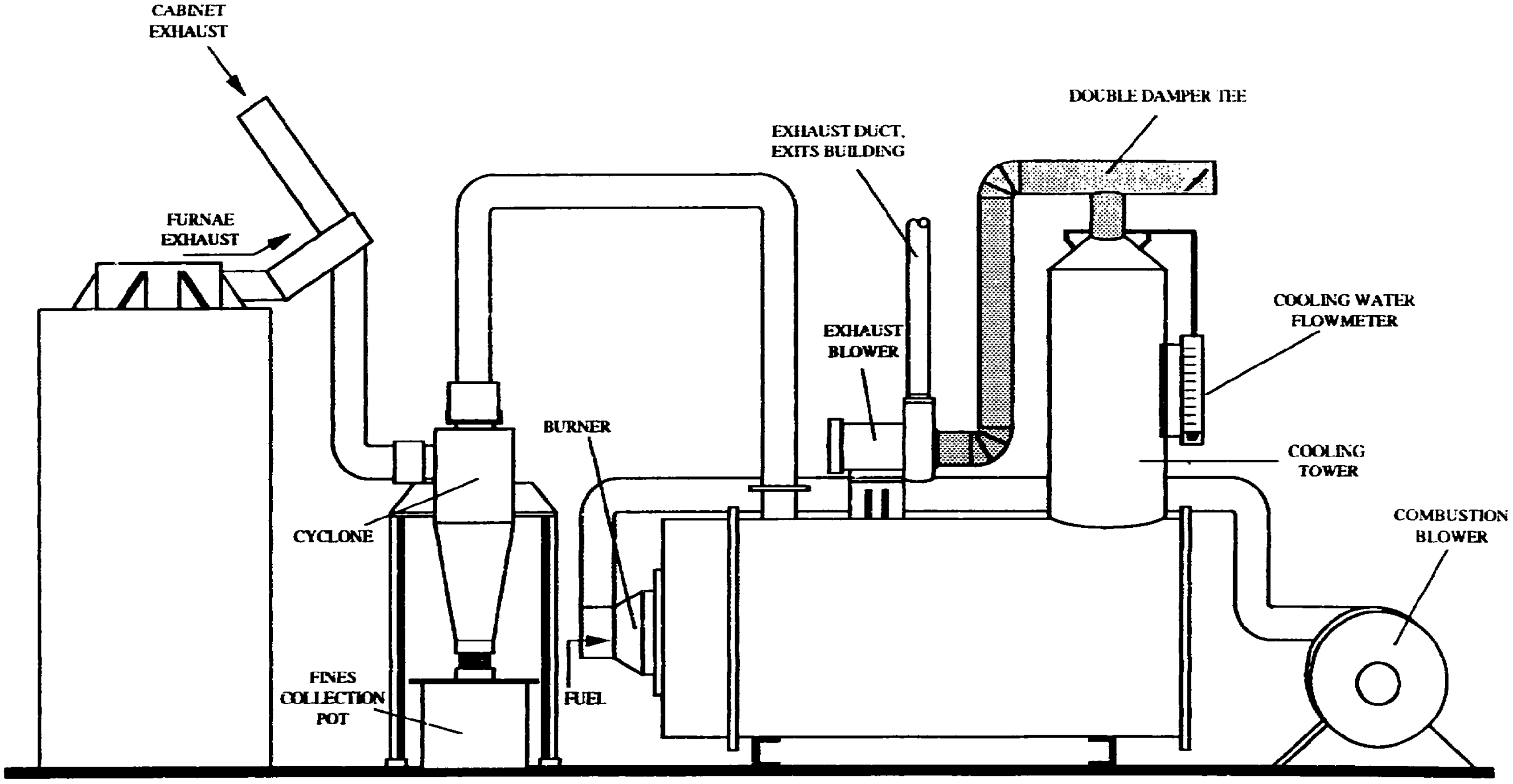
* CABLE SLOT IS CLOSED WITH A FLEXIBLE GLAND THAT ALLOWS MOVEMENT OF PARTS BASKET BETWEEN THE BEDS.

Figure 3 Fluidized Bed



NOTE: FLUIDIZED BED QUENCH BATH

Figure 4 FBPS Afterburner



rubber. Therefore, carbon monoxide and unburned hydrocarbons are generated during pyrolysis. These volatile organic constituents (VOCs) are combustible and are burned in the afterburner. The afterburner consists of a ceramic-lined fire-chamber, a propane-fueled burner, two blowers, and a water-fed cooling tower (Figure 4). A 3-horsepower, 200 cubic feet per minute (CFM) blower provides air to the burner while a 5-horsepower, 350 CFM blower exhausts the gases from the unit. The 21-inch diameter fire chamber is nearly nine feet long, and the attached cooling tower extends 4.7 feet above the chamber (Figure 4). A thermocouple above the outlet of the fire chamber ([illegible]T) and one before the exhaust blower (EBT) measures the temperatures in the unit. When operating properly, the afterburner reaches 1400-1600°F with an exhaust temperature below 150°F (Procedyne, 1990c). The gases from the afterburner are cooled in a water spray, or quench, prior to release to the atmosphere. The quench is required to prevent the hot gases from damaging the exhaust blower. This water spray may also scrub some particles or gases from the exhaust stream.

Because of the high temperatures reached in the afterburner and the introduction of flammable materials into the system, Procedyne, the system manufacturer, provides detailed precautions to be taken if upsets occur in the afterburner system (Procedyne, 1990c). The primary control uses the afterburner temperature; if the FCT indicates a temperature above 2,000°F the signal automatically shuts off the fluidizer air to the furnace. This action reduces the rate of coating decomposition; this decomposition generates flammable gases that cause the excessive heat generation. Excessive temperatures in the afterburner will damage the ceramic liner and the shell. According to the Procedyne's manual, in such a situation the operator must:

Not turn the afterburner off
Not lift cover
Not shut down furnace
Not shut down off-gas dilution system
Not shut down blower.

These actions will allow the afterburner-exhaust system to safely conduct the smoke from the pyrolysis out of the building. Apparently the pyrolysis is continued in a static bed until the afterburner temperature is reduced to 1600°F; the manufacturer's manual does not clearly explain how this occurs. If either the afterburner flame or the blower were turned off, unburned pyrolysis products may accumulate in the system to possibly form an explosive mixture. Since the excessive temperature condition is caused by too much organic material (polymers in the coatings) on the parts being stripped, subsequent loads in the system must be decreased. In the unlikely event that the flame is extinguished during pyrolysis, the pyrolysis should be continued with no flame, but with the exhaust blower on. This will conduct unburned gases out of the building to prevent accumulation of an explosive mixture.

After successful pyrolization, the work basket is transferred to the fluidized cooling bed. The cooling bed is a 48-inch deep, larger diameter (38-inch), cylindrical chamber also filled with alumina granules and fitted with water-cooled plate coils. This carbon-steel chamber is fitted on the bottom with a stainless-steel air-diffusion plate, and its top is open to the vented cabinet. The bed is cooled by process water that flows countercurrently through the coils and ambient air which fluidizes the bed particles. The work basket remains in the cooling bed for a period of 15 to 60 minutes or until the required temperature of 140°F is reached. According to the manufacturer, this cooling procedure significantly reduces the tendency for steel parts to oxidize and it speeds up the operating cycle (Procedyne, 1979).

Once cooled, the operator uses the hoist to raise the basket from the bed, opens the sliding port in the cabinet and uses an air nozzle to blow particles from the treated parts.

This step minimizes the loss of alumina from the unit; most of the particles blown off will return to the cooling bed. The cabinet doors are then opened, and the operator moves the basket to a holding stand. The bolt holding the basket to the retort cover must be removed, the cover must be set aside, and the basket may then be hooked to the work conveyor on the shot blast unit. The operator then pushes the conveyor on its monorail track into the blast cabinet or to a holding position. Because of the various steps to remove bolts, to hook and unhook the cover and basket, this part of the process is clumsy. Operation of the shot blast unit for 30 minutes should remove the inorganic coatings and char to prepare the parts for repainting. This unit is equipped with particulate filters to remove airborne contaminants to meet EPA compliance.

Table 1 summarizes the operation parameters, and Figure 1 is a process flowchart that not only identifies the major process components but also the utilities required to operate this complete system and the waste streams generated. Figures 2, 3 and 4 show additional details of the system.

2.1.2 Operability Tests and Results

To operate the FBPS on a continuous basis, the optimum operating parameters and production limits are required to provide data from which to calculate cycle times, loading limitations, and ultimately, the economics of operation. To develop the necessary effluent calculations for determining environmental impact, the feed rates of air and water, and quantity of bed media lost must also be measured. Any conditions that are unsafe or that would cause interruptions to the operation also must be identified. To obtain these data, the FBPS was operated on three occasions as described in Table 2.

January Operability Tests

During the acceptance test in January, the operation of the unit was demonstrated by representatives of the FBPS's manufacturer using assorted parts provided by LEAD. The objective of this run was to balance the system under load and establish equilibrium conditions acceptable to LEAD.

A basket of assorted parts was introduced into the FBPS at a temperature of approximately 750°F. Fluidizing air was maintained at approximately 400 SCFH. The afterburner temperature controller was set at 1400°F. Almost immediately, smoke began escaping from the FBPS cabinet.

To maintain a vacuum on the cabinet and minimize smoke release to the building, MP began reducing afterburner combustion air. Combustion air was reduced to the point of incomplete afterburner combustion as evidenced by the gray colored smoke in the FBPS exhaust but heavy smoke continued to be emitted from the FBPS cabinet.

The manufacturer's representative continued to adjust afterburner combustion air for the remainder of the runs. During the practice runs, paint and organics were effectively stripped from the parts based on visual observation. However, only a major readjustment of the fuel-air ratio mechanical linkage appeared to achieve acceptable equilibrium conditions without excessive smoking from the FBPS cabinet.

Smoke emissions continued to be a problem in future runs. It was concluded that the range of acceptable equilibrium operating conditions for the FBPS, as designed, is extremely narrow. As confirmed in subsequent test runs of the FBPS, any slight variation in operating conditions (e.g., fluidizing air to the cooling bed during stripping) will upset the sensitive smoke balance.

Table 1
FBPS Operation Parameters

Component	Cycle Time	Temperature	Load
Fluidized Bed Furnace	1.0 - 2.0 hours	750 - 850°F	500 lbs. of parts/cycle
Fluidized Bed Cooler	0.25 - 1.0 hours	Ambient	500 lbs. of parts/cycle
Afterburner Unit	0.75 - 1.0 hours	1400 - 1600°F	15 lbs. of paint organics/hr.
Low-Energy Shot Blast Unit	0.25 -0.5 hours	Ambient	500 lbs. of parts/cycle

Table 2
Fluidized Bed Paint Stripper Operability Tests

Date	Test	Participants
1/17/91	Equipment Acceptance	IT: John Murphy, Project Manager; Paul Mraz, Engineer LEAD: Dennis Reed, Engineer USATHAMA: Ronald Jackson, Project Officer Procedyne Corp.: Michael Paul
2/14/91	Operability	IT: John Murphy, Paul Mraz, and Duane Parker, Senior Chemist LEAD: Dennis Reed USATHAMA: Ronald Jackson
4/4/91	Operability, mass balance and effluent testing	IT: John Murphy and Duane Parker LEAD: Dennis Reed USATHAMA: Ronald Jackson and William Houser, Industrial Hygienist

February Operability Tests

In February, operability tests of the FBPS to obtain additional data were performed. Two tests were run. In the first of these tests, a basket of parts with a high loading of rubber and paint coatings was stripped with a fluid bed temperature of 750°F for one hour. The fluid bed was operated with a high rate of air flow (800 SCFH) as read on the rotameter.

Under these conditions a large amount of visible smoke was formed shortly after the parts were lowered into the fluidized bed, and much of the smoke escaped from the FBPS cabinet. Adjustments were made on the afterburner exhaust system, as the afterburner temperature approached 2000°F. Although the fluidizer air was reduced to approximately 400 SCFH, smoke continued to escape from the vent cabinet, and the exhaust from the FBPS exiting the building became gray in color. It was necessary to open the windows and the vehicle door of the building to clear the smoke from the area.

After an hour, the afterburner temperature decreased, and the smoke escaping from the cabinet moderated. Finally, after approximately two hours, the pyrolysis was complete and the basket was transferred to the quench bath.

Substantially all of the paint and rubber coatings had been removed from the parts, but the plating on certain parts had formed small beads on the surface. Apparently the metal in the plating had melted at the bath temperature, and the surface tension had caused the liquid to form globules. The type of plating was not identified, but, as shown in Table 3, cadmium and zinc could possibly have melted at these bed temperatures and replated on the surface.

After the completion of this test run the equipment was checked. Upon opening the cyclone pot, the cyclone, and the retort exhaust duct were found to be filled with the bed media (Figure 2). It was concluded that these media had built up, during the earlier test runs in January, and prevented the release of the pyrolysis gas through the retort duct. Therefore, much of the gas escaped from the vent cabinet rather than vent through the afterburner and stack system.

A second test run was made on February 14, 1991, once the afterburner temperature had dropped to 1500°F. In this run, a basket of several painted parts, and just a few rubber coated parts, were depainted at approximately 800°F. In this test with a clean cyclone pot and exhaust duct, the afterburner temperature remained in the range of 1500°F to 1700°F, and very little smoke escaped from the cabinet. The exhaust from the building stack was almost colorless.

April Operability Test

Although the primary purpose of the tests on April 4, 1991 was to sample and analyze the effluent streams for the purpose of defining the mass balance of the toxic heavy metal compounds entering and leaving the unit (see Sec. 2.1.3, below and Appendix A), additional operating experience was also obtained.

To identify known quantities of metal compounds in these tests, specially prepared, painted metal test panels were used. Because of the earlier operating experience, a preliminary start-up test of the system using ordinary military parts, plus one rubber-coated part, was performed to ensure that the unit would operate properly. No problems were encountered during this start-up run (Appendix A, Data Sheet, FBPS Start-Up, Section D-1, p. 7)

Table 3
Physical Properties of Substances in These Tests[a]

Material	Density, g./cm^3	M. P. °F	B. P. °F	Vapor Pressure mm. Hg 750 °F	850 °F
Aluminum	2.70	1221	4473	$< 10^{-6}$	-
Alumina, alpha	3.97[b]	3659	5396	$<10^{-20}$	-
Cadmium metal	8.64	610	1409	1.36	5.32
Chromium metal	7.20	3375	4842	$<10^{-8}$	-
Lead metal	11.34	621	3164	1.5×10^{-7}	2×10^{-6}
Steel, carbon	7.86	2760	-	$<10^{-15}$	-
Zinc metal	7.14	787	1665	0.07	0.07
Test paint components:					
Lead chromate	6.12	1551	4842	-	-
Alkyd resin	2.2	dec.	-	-	-

[a] Weast, 1980.

[b] Bulk density of 150 mesh alumina: 1.67 g/cm^3 (Wellborn, 1991).

The afterburner temperature increased from ambient to 1300°F within fifteen minutes after being ignited, and this temperature reached only 1405°F during the test run. Only a trace of smoke appeared at the top of the vent cabinet, and no visible smoke appeared in the exhaust from the building. At the end of the test, the parts appeared to be adequately depainted.

The three runs to study the mass balance also achieved acceptable equilibrium conditions while successfully stripping the paint from the panels. The afterburner remained below 1440°F, the exhaust temperature was easily maintained below 170°F, and no smoke escaped from the vent cabinet or from the building exhaust.

The batches of metal panels were weighed before painting, after painting, and after depainting. The results of depainting, shown in Table 4, indicated that 88 to 102 percent of the paint was removed in these tests. The values over 100 percent may indicate that small pieces of the panels may have been lost during the process. The panels from the first run, which were treated in the shot-blast cabinet, had a granular gray appearance. In the other two runs, traces of solid, that could be easily removed remained on the panels. On those panels from run. 2 (pyrolized at 725 to 767°F) the solids were nearly black while the solids on the panels from run 3 (pyrolized at 785 to 809°F) were a dirty yellow. Since a yellow paint was used in these tests, the yellow solid may be the pigment that remained after the organics were removed. The result at the higher temperature suggests that the decomposition is too rapid and leaves mainly pigment, rather than char, that adheres to the metal.

2.1.3 Effluent Test and Results

The waste streams generated by the FBPS were expected to be minimal because no hazardous solvents or chemicals are used in the process; however, the paint used on older military equipment often contains lead compounds and/or chromium compounds as pigments. In addition, some painted parts have been plated with cadmium or chromium. In certain processes some or all of the formulated and/or plated metal may be removed. These metal compounds are toxic substances that are regulated by the U.S. EPA as hazardous waste. Therefore, even if toxic solvents or reactants are significantly reduced in any process, some hazardous waste may still be generated upon paint removal. Nevertheless, minimization of generated hazardous waste was expected. The releases of toxicants to the environment were expected to be minor, and the exposure of the workers to hazardous reagents reduced.

To investigate these suppositions, a series of test runs was made in the FBPS. In these tests, metal panels were coated with measured amounts of paint to be depainted, and analyses of the effluents from the process were obtained (ITEP, 1991 and ITAQS, 1991a). The paint used was a yellow alkyd enamel containing lead chromate as a pigment (Appendix B, Table 1). Although present military specifications prohibit the use of lead compounds in paint, it met military specifications when it was manufactured in 1988.

Because some military parts depainted are cadmium plated, zinc coated (galvanized), or coated with zinc phosphate, panels were introduced into the FBPS containing measured quantities of these metals. For cadmium, steel panels, 4 by 8 by 0.09 inches were plated with cadmium at Red River Army Depot. The plating thicknesses were reported to be 0.25, 0.5, and 1.0 mils on particular panels. These thicknesses and density (see Table 3) were used to calculate the weight of cadmium on the panels introduced into the FBPS. The cadmium amounted to 9.0 grams per mil per panel (see Appendix A, Sec D-1, p.6).

Table 4
Paint Removal Results

Run No.	Temperature °F	Paint removal, percent (range)
1	753-777	102(98.9-104.8)
2	725-767	101(94.1-106.7)
3	785-809	87.8(78.6-96.9)

Zinc phosphate panels were prepared at LEAD, but they were found to contain too little zinc to be easily measured. They were therefore not used in testing.

Using these controlled quantities of toxic compounds, the fate of these toxic metals in the process was determined. In these tests, larger quantities of the toxic paints and platings were included than would normally be involved in a typical batch of parts to provide easily measured amounts of these metals.

The effluents from the FBPS include the water used to quench the afterburner gases. This water is released partially as heated water to the industrial water treatment plant (IWTP) and partially as steam up the stack. The water used to cool the fluidized cooling bed is discharged directly to the IWTP. If significant quantities of heavy metals, such as lead, chromium, cadmium or zinc, are present in this water, the stream may not be treatable in the IWTP. In such a situation, this water stream will have to be separately treated before transferring it to the IWTP. This water was analyzed.

The fluidized bed particles (alumina) in the furnace and the cooling bed are carried out into the cyclone during depainting and into the shop area when a basket full of parts are removed from the unit. Additionally, Procedyne advises that the media should be replaced once every two years. It will probably be necessary to dispose of the media as hazardous waste. Therefore, analyses for heavy metals in the discarded alumina from each of these tests was also performed. Spent steel-shot media used in the low-energy blast cabinet were also analyzed.

The U.S. EPA has established a method of analysis to determine if a waste is a categorical hazardous waste and subject to RCRA regulations. This test, the Toxicity Characteristic Leaching Procedure (TCLP), requires that materials that are solid be extracted with 20 times their weight of a dilute aqueous solution of acetic acid. Aqueous liquids are analyzed without further dilution. If the metals concentration in the extract in mg/L exceeds the regulatory standards, the solid or liquid is a toxic characteristic waste under RCRA regulations and is thus classified as hazardous. To determine the fate of the metals, the total concentration of the metals in the media was also determined (Fed. Register, 1991a.)

The exhaust gases from the stack may contain unburned hydrocarbons, particulates, and heavy metals and were, therefore, sampled and analyzed during these tests. [See the IT Air Quality Services Test Plan (ITAQS, 1991) for further details.]

2.1.3.1 Description of Effluent Test Procedures

The steel and aluminum test panels were prepared at LEAD. The panels were cut from metal stock. All were 4 by 8 inches by approximately 0.025 inches thick, and the corners were rounded with a radius of 1.25 inches A small hole was cut near the narrow end of each panel. The panels were labelled with a vibratory stylus in groups of 10; i.e., the first ten were labelled "A", the next ten, "B", etc. The batches of panels, along with ten hooks (steel paper clips), were then weighed to a precision of 0.1 gram. On March 22, 1991, the labels were covered with a small piece of masking tape and a thick coating of paint was applied by a LEAD operator using a Depot spray booth and spraying equipment. The 220 panels were partially dried in the shop drying oven. After the paint had dried for three days, the masking tape was removed and each batch, with hooks, was weighed again. Paint loadings varied from 29 to 65 grams per batch (Appendix A, Data Sheets, Section D-1, pp. 1 and 2).

Steel mesh was cut into a square approximately 3.5 feet square. The mesh was bent into a rectangular tube, approximately 12 inches on a side, to form a holder on which the panels could be attached. The test panels were hooked around the holder, and this apparatus was placed in the basket to be treated.

The air monitoring team set-up the gas sampling equipment on April 3, 1991, as described in their test plan (ITAQS, 1991a), and the tests were performed on April 4. No gas or water samples were taken during the start-up run that was made before the test panels were introduced. Once the start-up run was completed, a sample of the fluidized bed media was taken from the furnace, and a sample of stored, unused media was also taken.

In each of the three runs, six batches of ten painted panels each were used, and in both run numbers 2 and 3, six cadmium plated panels were used. The cadmium panels were not coated with paint. Each basket of panels was heated in the fluidized bed for one hour; the operating conditions are summarized in Table 5, and the complete data are listed in Appendix A.

Various samples were taken during these runs. In each run, the exhaust gases were analyzed continuously for oxygen, carbon dioxide, and total hydrocarbons (a flame ionization measurement). Particulates were collected on a filter for a gravimetric measurement, and the gases were sampled in aqueous solutions for non-filterable solids and vapors. In the laboratory, the particulates were digested with acids to completely dissolve any metals present; the solution from the digestion was then combined with the impinger liquids. An atomic absorption spectroscopy procedure or an inductively coupled argon plasma emission spectroscopy procedure is used to determine the quantity of the metal of interest.

Samples of the quench water were taken during each run, and a sample of the inlet water to the system was taken during run no. 2. Two samples of quench water were taken during run no. 3.

After runs no. 1 and 3 were completed, samples of the fluidizer bed media (FBM) were taken by dipping a sample from the hot bed with an aluminum scoop attached to a pole. No FBM sample was taken after run no. 2. When the assembly was removed from the FBPS in run no. 2, a few pieces of porous black material (ash) were found in the basket; this solid was submitted for metals analysis. Finally, a FBM sample was taken from the cyclone pot (Figure 1) after the completion of the four runs. The latter material comprises media that were carried out of the retort.

Various samples were taken during these runs. In each run, the exhaust gases were analyzed continuously for oxygen, carbon dioxide, and total hydrocarbons (a flame ionization measurement). Particulates were collected on a filter for a gravimetric measurement, and the gases were sampled in aqueous solutions for non-filterable solids and vapors. In the laboratory, the particulates were digested with acids to completely dissolve any metals present; the solution from the digestion was then combined with the impinger liquids. An atomic absorption spectroscopy procedure or an inductively coupled argon plasma emission spectroscopy procedure is used to determine the quantity of the metal of interest.

Table 5
Operating Conditions, April 4, 1991

Run No.	Retort temp. °F	Fluidizing Air CFM	Afterburner temp. °F	Afterburner exhaust[a] temp °F	Afterburner volume CFM
Start- up	705-761	6.67-7.33	1300-1405	A: 150-225	-
1	725-767	5.50-6.00	1393-1403	A: 151-152 S: 270	460
2	725-767	6.83-7.50	1401-1436	A: 151-152 S: 261	425
3	785-809	6.83-7.17	1420-1436	A: 149-165 S: 271	426

[a] Temperatures, as follows:

A: Temperature indicated by the afterburner thermocouple

S: Temperature measured in the exhaust stack at sample point, determined by ITAQS.

Samples of the quench water were taken during each run, and a sample of the inlet water to the system was taken during run no. 2. Two samples of quench water were taken during run no. 3.

After runs no. 1 and 3 were completed, samples of the fluidizer bed media (FBM) were taken by dipping a sample from the hot bed with an aluminum scoop attached to a pole. No FBM sample was taken after run no. 2. When the assembly was removed from the FBPS in run no. 2, a few pieces of porous black material (ash) were found in the basket; this solid was submitted for metals analysis. Finally, a FBM sample was taken from the cyclone pot (Figure 1) after the completion of the four runs. The latter material comprises media that were carried out of the retort.

The test panels from run no. 1 were further cleaned, after pyrolysis, in the shot-blast unit, while the panels from runs no. 2 and 3 were not cleaned any further. Because it was observed that the panels from the latter two runs were covered by loosely adhering solids, each batch of panels was wrapped in tared polyethylene film before it was weighed. Three weeks after these tests were completed, the solids from three batches of formerly painted panels were scraped with a microscope slide to produce small powdered samples. The very small quantities of solids on the polyethylene film were included in the scrapings. A glass slide was used as a scraper to minimize any metals that might be introduced into the sample from a metal scraper. These samples were analyzed for cadmium, chromium, lead, and zinc. One cadmium plated panel, from run no. 3, was also similarly scraped. The scrapings and another cadmium panel were submitted for microscopic examination and analysis.

2.1.3.2 Results of Effluent Analyses

The analyses of the stack gases that were determined during the run are summarized in Table 6. The results indicated that carbon dioxide was formed from the afterburner combustion, the combustion of hydrocarbons was complete (no detectable hydrocarbons were found), and a sizeable amount of water vapor was found in the exhaust gases. The water vapor results from both the combustion of propane and the vaporization of the quench water.

From the stack gas filtration and vapor collection in the impingers, quantities of particulates and metals in the stack gases were determined. These measurement results are shown in Tables 7 and 8.

Although EPA's regulations for "Burning of Hazardous Waste in Boilers and Industrial Furnaces" (Fed. Register, 1991b) would not strictly apply to the FBPS at LEAD, these regulatory standards provide a relevant guideline. The State of Pennsylvania would regulate these stack effluents and probably apply similar requirements. The concentration of particulates in the stack gases was found to be only a small fraction of the Federal limit, therefore the FBPS should not cause any significant environmental impact in the area of air pollution. In addition, the metals exiting the stack do not exceed the federal hourly standards, as shown in Table 8.

These levels of metals emission found are less than one percent of the standards, except for chromium, which reaches only 27 percent of the standard. No definite increasing trend of metal emissions occurred from run to run. Furthermore, cadmium and zinc present must have accumulated in the system from earlier tests, but only very small levels of these metals are being emitted.

Table 6
Stack Gas Data

Run No.	Composition[a]			
	H_2O %	O_2 %	CO_2 %	THC[b], ppm
1	19.1	19.0	1.0	ND
2	19.3	19.0	1.0	ND
3	19.4	19.0	1.0	ND
Air[c]	1.2	21.0	0.04	2

[a] Composition in volume percent, oxygen and carbon dioxide on a dry basis, except THC.

[b] THC: total hydrocarbons, as methane by flame ionization detector, parts per million by volume (dry basis). ND: none detected; detection limit was 13.8 ppm. That is equivalent to 0.009 lbs/hr.

[c] Reported components in air, same basis as above (Weast, 1980). Water represents the level present at 40 percent relative humidity at 68°F.

Table 7
Concentrations of Particulates and Metals in the FBPS Stack Gases

Run No.	Particulates		Metals, ug/M3		
	mg/M3	cadmium	chromium	lead	zinc
1	36.4	10.8	20.5	48.6	90.6
2	11.1	4.6	20.4	51.0	122
3	10.9	9.2	25.5	109	106
Regulatory std.[a]	180,000				

[a] From "Burning of Hazardous Waste in Boilers and Industrial Furnaces" (Fed. Register, 1991).

Table 8
FBPS Stack Mass Emissions, Weight per Hour

Run No.		Metal, mg/hr		
	cadmium	chromium	lead	zinc
1	5.0	9.5	22	42
2	2.0	8.6	22	54
3	3.9	8.6	22	54
Regulatory std[a].	260	40	4300	not regulated

[a] From "Burning of Hazardous Waste in Boilers and Industrial Furnaces" (Fed. Register, 1991b).

Table 9
Analyses of Quench Water

Run No.	Metal, mg/L cadmium	 chromium	 lead	 zinc
Inlet water	ND	ND	ND	0.12
1	0.007	0.045	0.21	0.18
2	0.003	0.018	ND	0.15
3A	ND	0.022	ND	0.11
3B	0.003	0.20	ND	0.10
Detection limit	0.002	0.006	0.2	0.008
MCL[a]	0.010	0.05	0.05	none listed

[a] MCL: maximum contaminant levels from regulations promulgated under the Clean Water Act (40 CFR Ch 1, 1990e).

The analysis of the quench water was performed according to the TCLP procedure (ITAS, 1991a). Because these samples are aqueous solutions, the results are equal to the contained concentrations of the analytes. As shown in Table 9, all of the levels of the metals were found to be below drinking water "maximum contaminant levels" (MCL) (40 CFR Part 141.11, 1990). Since the quench water and the non-contact cooling bath water is treated in the IWTP, this aqueous stream should not create a significant impact on the environment.

The analyses of the FBM from the various parts of the system and one sample of the shot-blast media are shown in Tables 10 and 11. The TCLP procedure was used to determine if the spent FBM would be categorized as a characteristic RCRA hazardous waste, while the total metals were determined to provide data for mass balance calculations.

The data in Table 10 indicate that the FBM reaches a level for lead, 7.5 mg/L, that exceeds the standard that classifies the solid as a RCRA hazardous waste after only three test runs. Therefore, spent FBM, floor sweepings of alumina spilled during operations, and material collected from the cyclone pot would all be classified as hazardous. The requirements of RCRA to properly store, ship, and dispose of these spent materials would apply.

To obtain the total concentrations of metals shown in Table 11, the samples were digested in acids to dissolve them completely before analysis (ITAS, 1991b). These values were used, along with the results on exhaust gases and quench water, to calculate the distribution of these metals in the system (see Section 2.1.4 below).

One sample of special significance was also obtained during these tests. After run no. 2, a few pieces of black porous material were found in the parts basket. It was assumed that these represented paint that consolidated during the pyrolysis into an "ash" large enough to be retained by the mesh of the basket (approximately 1/4-inch square). This ash was submitted to the laboratory for analysis, along with the other samples, and the TCLP was obtained first. This procedure consumed the sample so that the the total contained metals could not be obtained. From the TCLP result and both types of analyses on the FBM estimates of total metals contained were calculated. In the TCLP, the sample is extracted with 20 times its weight of a dilute aqueous acid solution, and the results reported in mg/L. In these analyses of the FBM samples, 85-97 percent of the cadmium, lead and zinc was found to be extracted, but only 20 percent of the chromium. The analytical results for the ash and estimated contained metals are shown in Table 12. This ash may be representative of the fine particles that will be mixed in with the FBM.

The panels from runs no. 2 and 3 were covered with granular solids that mostly adhered to the panels. A few of these granules fell from the panels and these were collected on plastic sheeting in which the panels were wrapped for weighing and storage. Since the panels from these runs were not cleaned further in the shot-blast unit, they were examined and the granules scraped off to reveal the character and composition of the pyrolysis products. The solids from run no. 2 appeared to be nearly black, while the solids from run no. 3 were yellow-gray color. The scrapings from one batch of steel (run no. 3) and from two batches of aluminum panels (one each from run no. 2 and no.3) were analyzed for total cadmium, chromium, lead, and zinc (ITAS, 1991c). The results of the analyses and the approximate quantities of solid recovered are shown in Table 13. Although less than a gram of solid was obtained from each of the aluminum panels, eleven grams were obtained from the steel panels. Since this quantity exceeds the weight gain of the panels (Appendix A) and it was a reddish material, it is assumed that most of this solid is rust (iron oxide).

Table 10
TCLP Analyses of Solids

Solid Media	Metal, mg/L cadmium	chromium	lead	zinc
Unused FBM	0.006	0.050	ND	0.17
Initial FBM[a]	0.25	0.021	3.4	0.47
After run no. 1	0.23	0.052	5.2	0.43
After run no. 3	0.41	0.30	7.5	0.30
FBM from cyclone[b]	0.47	0.20	8.2	0.67
Shot-blast media[c]	2.7	ND	ND	180
RCRA stds[d]	1.0	5.0	5.0	not regulated

[a] FBM from the furnace after the start-up run, but before run no. 1.

[b] FBM sample taken from the cyclone pot after run no. 3.

[c] A sample of steel shot taken from the shot-blast unit after the first, and only, set of panels were cleaned in the unit. The shot includes particles that had accumulated in earlier operability tests.

[d] The TCLP prescribes that if a waste exceeds these values in the extract, the waste is classed as a RCRA hazardous waste (Fed. Register, 1991a).

Table 11
Total Metals, Analyses of Solids

Solid Media	Metal, (ug/gm)			
	cadmium	chromium	lead	zinc
Unused FBM	0.28	3.0	ND	ND
Initial FBM[a]	5.4	6.8	60	7.9
After run no. 1	6.4	5.3	77	9.2
After run no. 3	9.2	19	37	3.0
FBM from cyclone[b]	11	37	260	18

[a] FBM from the furnace after the start-up run, but before run no. 1.

[b] FBM sample taken from the cyclone pot after run no. 3.

Table 12
Metals in the Special Ash Sample from the FBPS

Metal	TCLP, mg/l	Estimated Conc. ug/gm
Cadmium	1.1	20
Chromium	0.010	1.0
Lead	44	790
Zinc	2.8	50

Table 13
Analysis of Panel Scrapings

Sample	Panel Metal	Weight of Scrapings (gm)	Metal Content (wt. %) Cadmium	Chromium	Lead	Zinc
Run No. 2 Panel Batch X	Aluminum	0.26	0.09	3.0	17.0	0.2
Run No. 3 Panel Batch S	Aluminum	0.93	0.063	2.1	12.0	0.1
Run No. 3 Panel Batch D	Steel	11	0.06	1.5	8.6	0.079

The lead, chromium and zinc were found as expected since the paint contained each of these metals, However, cadmium was also found in this residue. The cadmium apparently resulted from the parts that were depainted during the operability tests or from the cadmium plated panels. These results should represent the composition of particles that may be dispersed into the plant area during the depainting operations.

Examination of the cadmium plated panels that had been treated in runs number 2 and 3, showed that the plating had apparently melted and then partly coalesced into beads to leave part of the surface unplated. To examine the surface deposits more carefully and to determine if the cadmium had changed chemically, samples were subjected to microscopy analysis (Gravrilovic, 1991, Appendix B). Two samples were submitted for analysis. One was scrapings from cadmium plated steel panel no. 4 from run no. 3. The other sample was one of the cadmium plated test panels from the process. The latter panel, which had been stored for six weeks, showed evidence of extensive corrosion. Photomicrographs, by visible light and by using the electron scanning technique, were made, and the composition of the particles was determined by electron microprobe analysis. This microprobe technique produces both a picture of the distribution of elements in the particles, and a quantitative measure of elemental concentration. This is possible because the electron beam used in the technique causes the elements in the particles to fluoresce at particular wavelengths in the in the X-ray region of the electromagnetic spectrum. The fluorescence can be either photographed or measured at various wavelengths to produce the needed information. The pictures are shown in Appendix B (Gavrilovic, 1991) and the analyses are listed in Table 14, below. The results indicate that nearly all of the cadmium remains as metal rather than being oxidized at the operational temperatures of the FBPS. The aluminum found in these surface deposits probably results from small amounts of the alumina in the fluidizer media that adhered to the surface. The small concentration of silicon that was found in the scrapings probably represents glass that was abraded from the microscope slide used as the scraper. The chlorine found in these particles was unexpected. Possibly, the chlorine resulted from either pickling of the steel with hydrochloric acid or from the chlorides in the plating bath that was used.

2.1.3.3 Estimation of Mass Balances of Metal Toxicants

Using the calculation of the total metals contained in the paints coated on the test panels, and the analyses of the exhaust gases, quench water, and FBM, mass balances were calculated for lead, chromium, and cadmium. No mass balance could be determined for zinc because too little zinc was contained in any paints used on the test panels. These mass balances are shown in Figures 5, 6 and 7.

The three runs were consolidated to provide an overall balance for each metal. The weights of lead and chromium in the char remaining on the paint were estimated by assuming that this material was primarily lead chromate pigment. The lead and chromium accountability equalled 66-67 percent. These values should be considered within the limits of the precision of all the measurements.

As an example of assumptions and measurements, the FBM in the retort was estimated by measuring that the FBM was six inches below the top and then using the bulk density and the dimensions to determine the weight of media. The FBM carried out into the cyclone was ignored in this calculation. Furthermore, the cadmium accountability is good (100.6%); it should be noted that because only 2.4 out of 69 grams of cadmium were added to the system, errors in the precision of the added quantity would be overwhelmed by the 69 grams that were in the system.

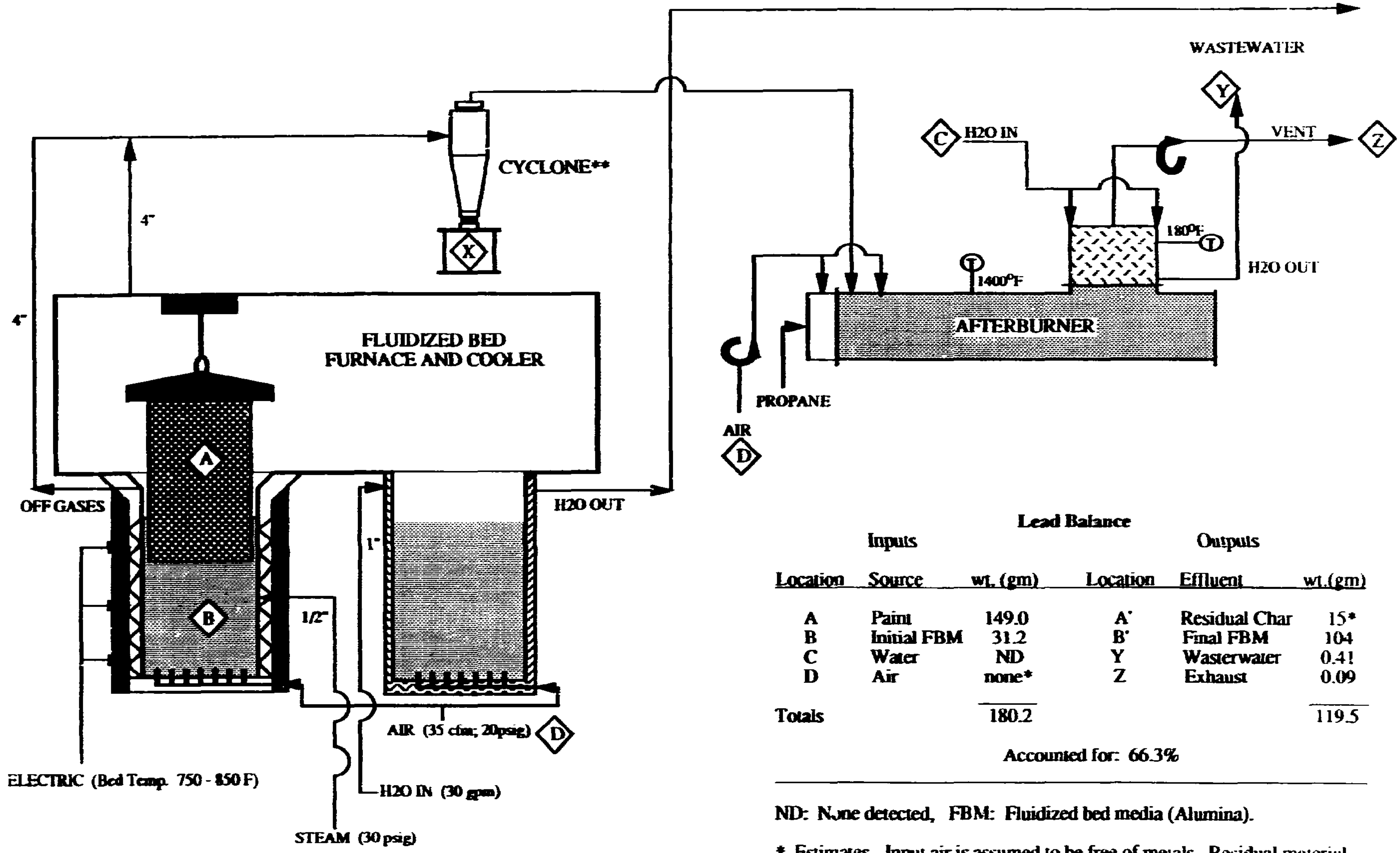
Table 14
Electron Microprobe Analysis of Materials from Cadmium Plating

	ELEMENTS % BY WEIGHT								
SAMPLE	Cd	Pb	Fe	Cr	Cl	S	Al	Si	C+O
Yellow scrapings [a] Sample No. SC-3	62.8	---	7.7	1.2	10.3	1.7	7.3	1.1	bal
Single metal particle[a] Sample No.. SC-3	99.9	---	---	---	---	---	---	---	bal
Letterkenny A.D.[b] Surface Deposits	9.0	6.9	1.0	3.5	4.7	---	37.5	---	bal.
Letterkenny A.D.[b] Dark Deposits	4.1	---	48.1	0.2	12.0	---	---	1.5	bal

[a] Sample No. SC-3
Scrapings from one Cd plate
Steel panel no. 4, Test Run no. 3, on April 4, 1991,
scraped on April 25, 1991.

[b] Test Panel, Fluidized Bed Paint, Stripping
Oven Letterkenny Army Depot,
Cadmium Plating Effects

Figure 5
Fluidized Bed Paint Stripper, Lead Balance (Runs 1, 2, & 3)



Lead Balance

Inputs			Outputs		
Location	Source	wt. (gm)	Location	Effluent	wt.(gm)
A	Paint	149.0	A'	Residual Char	15*
B	Initial FBM	31.2	B'	Final FBM	104
C	Water	ND	Y	Wastewater	0.41
D	Air	none*	Z	Exhaust	0.09
Totals		180.2			119.5

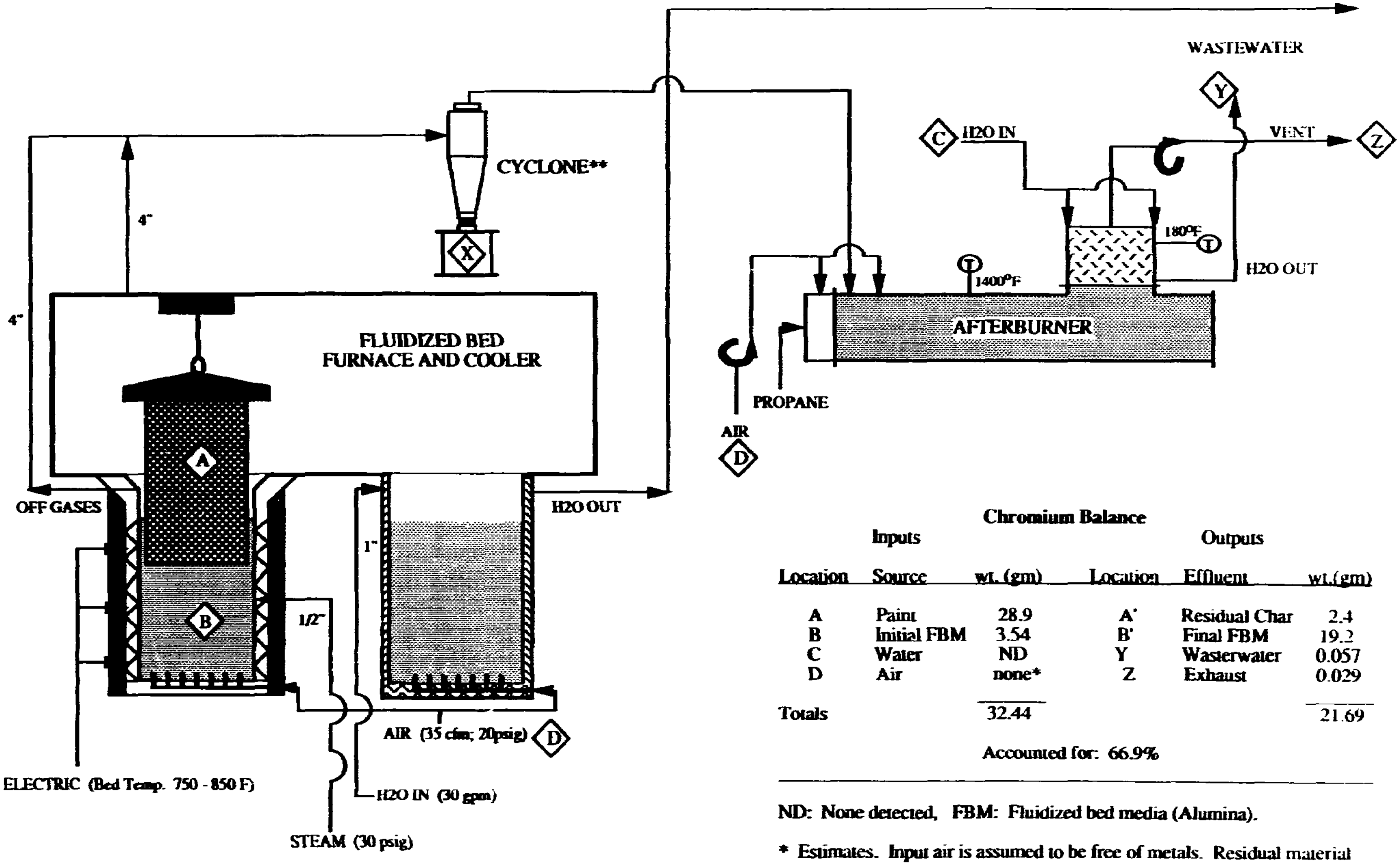
Accounted for: 66.3%

ND: None detected, FBM: Fluidized bed media (Alumina).

* Estimates. Input air is assumed to be free of metals. Residual material on all test panels was 32g (char); estimated to be 47% lead.

** Cyclone pot (X) collects FBM fines - quality was not measured.

Figure 6
Fluidized Bed Paint Stripper, Chromium Balance (Runs 1, 2, & 3)



Chromium Balance

Inputs			Outputs		
Location	Source	wt. (gm)	Location	Effluent	wt.(gm)
A	Paint	28.9	A'	Residual Char	2.4
B	Initial FBM	3.54	B'	Final FBM	19.2
C	Water	ND	Y	Wastewater	0.057
D	Air	none*	Z	Exhaust	0.029
Totals		32.44			21.69

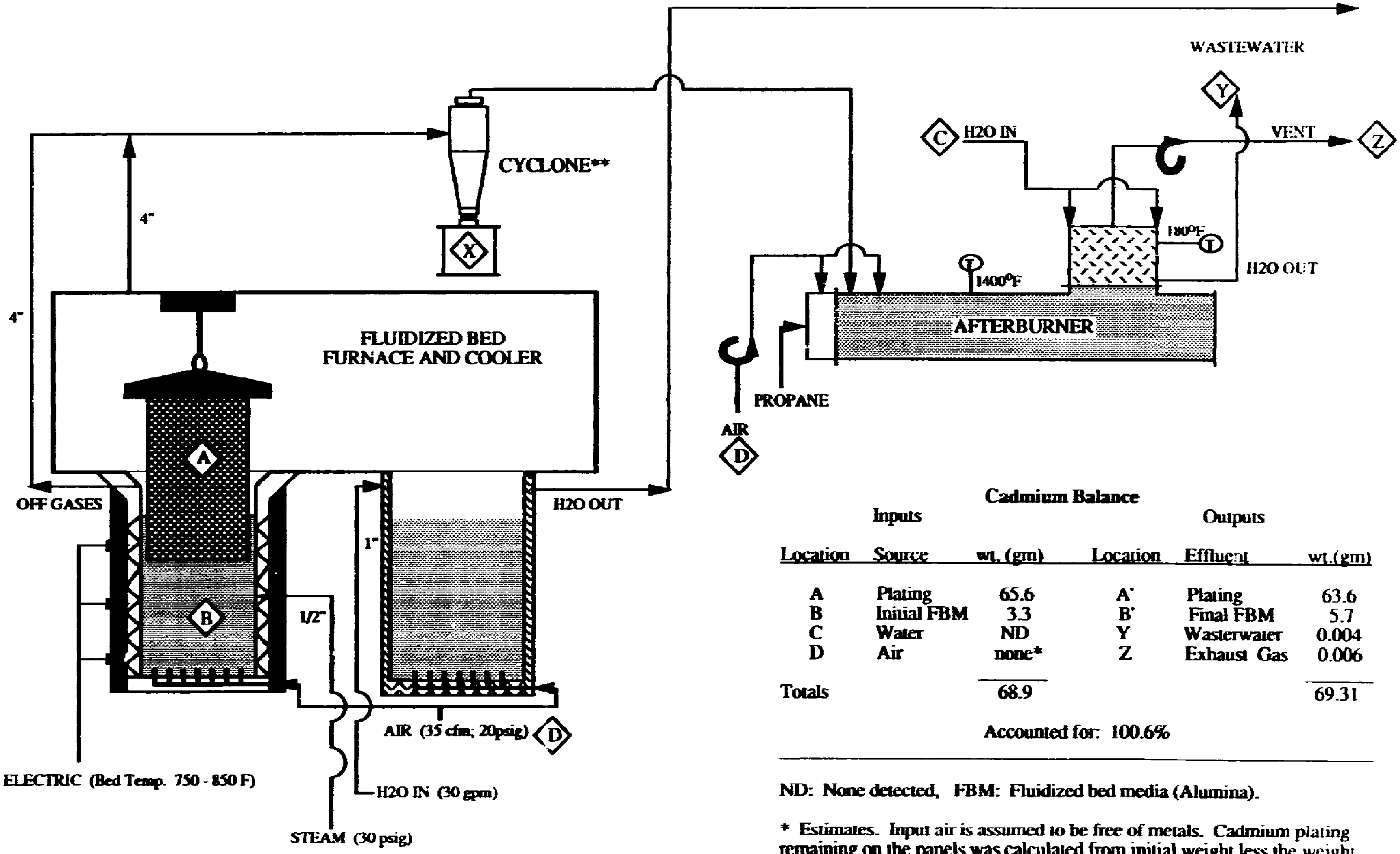
Accounted for: 66.9%

ND: None detected, FBM: Fluidized bed media (Alumina).

* Estimates. Input air is assumed to be free of metals. Residual material on all test panels was 32g (char); estimated to be 7.5% chromium.

** Cyclone pot (X) collects FBM fines - quality was not measured.

Figure 7
Fluidized Bed Paint Stripper, Cadmium Balance (Runs 2 & 3)



Cadmium Balance

Inputs			Outputs		
Location	Source	wt. (gm)	Location	Effluent	wt.(gm)
A	Plating	65.6	A'	Plating	63.6
B	Initial FBM	3.3	B'	Final FBM	5.7
C	Water	ND	Y	Wastewater	0.004
D	Air	none*	Z	Exhaust Gas	0.006
Totals		68.9			69.31

Accounted for: 100.6%

ND: None detected, FBM: Fluidized bed media (Alumina).

* Estimates. Input air is assumed to be free of metals. Cadmium plating remaining on the panels was calculated from initial weight less the weight loss (weight gains were ignored).

** Cyclone pot (X) collects FBM fines - quality was not measured.

2.1.4 Operating Cost of the Fluidized Bed Paint Stripper

The purpose of this section is to determine the cost to operate the FBPS based on existing operational data. Included in this section is the following information: 1) Listings of the basic operating and process-specific assumptions for calculations; and, 2) Spreadsheets which identify all costs incurred during operation based on the assumptions.

The FBPS requires one (1) full-time laborer. The critical path of the fluid bed process consumes approximately 2.25-hours of time and may process 20 uniform parts per cycle. A total of 7 treatment cycles may be completed in a single production day for a total of 140 parts. Once the operation is optimized, it expected that the critical path can be reduced to 1.5 hours, by reducing pyrolysis time, time in the shot-blast, and by arranging to cool a basket of parts while a second basket is being pyrolized.

The solid materials used in the system include alumina (fluidized bed media (FBM)) and steel shot that is used in the shot blast unit. According to the FBPS manufacturer (Mraz, 1990b), the FBM is lost from the unit by carry over to the cyclone and by drag-out on the parts and basket at a rate of approximately 20 gallons per week. Furthermore, the build-up of char in both fluidized beds will require that the FBM be replaced with fresh material once every two years. Pangborn (Minnich, 1991) reports that their shot-blast unit can be expected to consume 7.2 pounds of steel shot per hour of operation in the blast mode. This abrasive will become finely divided during the process with approximately 40 percent of it being collected in the "fines container" and the remainder being trapped as dust by the prefilter and the high efficiency particulate (HEPA) cartridge. Since some of the heavy metals from the paint char will contaminate both of these filters, they will be classed as RCRA hazardous solid waste. The usages and related costs of both these materials are shown in Tables 15 and 16, for scenarios 1 and 2 respectively. Because both filters are hazardous wastes, a significant cost of disposal, at approximately $0.45 per pound, will be incurred. Therefore, solid waste disposal can be expected to comprise six to seven percent of the cost of operating the FBPS.

Two scenarios are used in the cost analysis. The first scenario, the start-up phase operation, was developed based on the operability test results and data in the manufacturer's manuals. This scenario is based on observed test conditions from the operability tests conducted in Section 2.1.2. The second scenario was developed from a speculation of potential improvements to the system or operating procedures that can be achieved in a short time frame (less than six months) with minimal cost (less than $50,000). These changes would be expected to result in shorter pyrolysis times at higher temperatures, better parts basket handling, and optimized shot-blast operation. The costs developed for the latter case are less certain since all the proposed improvements would be subject to verification.

Electricity, air, water, and propane for the afterburner are the utilities used in the process. Electricity is used by the many motors in the system. Some of the motors will operate for only short periods of the work day while others must run continuously. The hours for each motor and their consumption of electricity per hour are shown in Tables 15 and 16. The largest quantity of electricity is consumed by the furnace heater; it amounts to approximately half of the total electricity required.

The electricity cost was calculated using these hour demand allocations for the specific unit operations and the given local kilowatt-hour rate.

A total of thirty gallons per minute (30 gpm) of water is required to operate the FBPS system. Ninety-nine percent (99%) or more of this water is used to cool the heated parts in the fluidized bed cooler (FBC) and quench the off-gases from the Afterburner.

Table 15
Fluidized Bed Paint Stripper
Cost Analysis, Start-Up Scenario

ASSUMPTIONS

Day	16 Hours
Year	300 days
Critical Path	2.25 hrs.; 7 Cycles per day
Capacity	(20) pans per Cycle; 140 pans per day
Process	(A) Model PCS-2448 Cleaning Furnace with Off-Gas Dilution System 750 F (1.5 hrs./Cycle)
	(B) Model PCS-2448 Cooling Bed (0.5 hrs./Cycle)
	(C) Model AB-30-2 Off-Gas Handling System*
	(D) Low Energy Blast System (0.5 hrs./Cycle)
	* This unit runs continuously to maintain operating temperature.

LABOR

Item	Process	Description	hrs./day	Rate/hr.	Cost		
					Unit	Day	Year
Operator	(A,B,C,D)	One Dedicated Operator For FBPS	16.00	1.00 man	$17.54	$280.64	$84,192.00
					TOTAL:	$280.64	$84,192.00

RAW MATERIALS

Item	Process	Description	hrs./day	Rate/hr.	Cost		
					Unit	Day	Year
Alumina	(A)	Alumina Replacement Every 24 months	16.00	0.13 lbs.	$1.20	$2.59	$776.40
	(B)	Aluminum Oxide Changeout Every 24-Months	16.00	0.38 lbs.	$1.20	$7.20	$2,160.00
	(A,B)	Aluminum Oxide Makeup (20- gal./week)	16.00	3.43 lbs.	$1.20	$65.86	$19,756.80
Steel shot	(D)	Steel Shot Make-up	3.50	7.20 lbs.	$0.25	$6.30	$1,890.00
					TOTAL:	$81.94	$24,583.20

UTILITY REQUIREMENTS

Item	Process	Description	hrs./day	Rate/hr.	Cost		
					Unit	Day	Year
Electric	(A)	27 KW at 440 V, 3 ph, 60 Hz (750 F)	16.00	27.00 kW	$0.05	$21.60	$6,480.00
	(C)	5 HP, 240/440 V, 3 ph, 60 Hz (Exhauster)	16.00	3.73 kW	$0.05	$2.98	$894.85
	(C)	3 HP, 240/440 V, 3 ph, 60 Hz (Burner Blower)	16.00	2.24 kW	$0.05	$1.79	$536.91
	(D)	3/4 HP, 460 V, 3 ph, 60 Hz (Rotator)	3.50	0.56 kW	$0.05	$0.10	$29.36
	(D)	1 HP, 460 V, 3 ph, 60 Hz (Elevator)	3.50	0.75 kW	$0.05	$0.13	$39.15
	(D)	3 HP, 460 V, 3 ph, 60 Hz (Exhauster)	16.00	1.12 kW	$0.05	$0.89	$268.46
	(D)	15 HP, 460 V, 3 ph, 60 Hz (Roto)	3.50	11.19 kW	$0.05	$1.96	$587.25
	(D)	15 HP, 460 V, 3 ph, 60 Hz (Roto)	3.50	11.19 kW	$0.05	$1.96	$587.25
	(D)	1/2 HP, 460 V, 3 ph, 60 Hz	3.50	0.37 kW	$0.05	$0.07	$19.57
Air	(A)	20 scfm at ambient; 8 scfm at 850 F (negligible cost)	16.00	8.00 scfm	$0.00	$0.00	$0.00
Water	(A)	3 gph at 30 psi supply	16.00	3.00 gal.	0.00046	$0.02	$6.62
	(B)	27 gpm at 30 psi supply	3.50	1,620.00 gal.	0.00046	$2.61	$782.46
	(C)	3 gpm at 30 psi supply	16.00	180.00 gal	0.00046	$1.32	$397.44
Propane	(C)	580,000 Btu/hr Startup	14.25	232.00 ft^3	$0.03	$99.18	$29,754.00
	(C)	60,000 Btu/hr Smokecycle	1.75	24.00 ft^3	$0.03	$1.26	$378.00
					TOTAL:	$135.87	$40,761.33

WASTE DISPOSAL / TREATMENT

Item	Process	Description	hrs./day	Rate/hr.	Cost		
					Unit	Day	Year
Water	(A)	3 gpm at 30 psi supply (50% Steam)	16.00	90.00 gal.	0.00465	$6.70	$2,008.80
	(B)	27 gpm at 30 psi supply	3.50	1,620.00 gal	0.00465	$26.37	$7,909.65
Alumina	(A, B)	Periodic disposal*	16.00	3.13 lbs.	$0.45	$22.54	$6,760.80
	(A)	Disposal Every 24 months	16.00	0.13 lbs.	$0.45	$0.97	$291.15
	(B)	Disposal Every 24 Months	16.00	0.37 lbs.	$0.45	$2.70	$808.88
Steel shot	(D)	Steel Shot Disposal**	3.50	7.20 lbs.	$0.45	$11.34	$3,402.00
					TOTAL:	$70.60	$21,181.28

COST PER PART ESTIMATIONS

Total Estimated Operating Costs Maximum	$569.06	$170,717.81
Total Parts Processed	140	42000
Cost per Part Processed	$4.06	$4.06

*Comprises floor sweepings, area clean-ups, etc.

**Equal to the make-up quantity; collected from both the fines (40%) and filtered dust (60%).

Table 16
Fluidized Bed Paint Stripper
Cost Analysis, Optimized Scenario

ASSUMPTIONS

Day	16 Hours
Year	300 days
Critical Path	1.5 hrs.; 10 Cycles per day
Capacity	(20) parts per Cycle; 200 parts per day
Process	(A) Model PCS-2448 Cleaning Furnace with Off-Gas Dilution System 850 F (1.0 hrs./Cycle) (B) Model PCS-2448 Cooling Bed (0.25 hrs./Cycle) (C) Model AB-30-2 Off-Gas Handling System * (D) Low Energy Blast System (0 25 hrs./Cycle) * This unit runs continuously to maintain operating temperature.

LABOR

Item	Process	Description	hrs./day	Rate/hr.	Cost Unit	Cost Day	Cost Year
Operator	(A,B)	One Dedicated Operator for FBPS	16.00	1.00 man	$17.54	$280.64	$84,192.00
					TOTAL:	$280.64	$84,192.00

RAW MATERIALS

Item	Process	Description	hrs./day	Rate/hr.	Cost Unit	Cost Day	Cost Year
Alumina	(A)	Alumina, Replacement Every 24 months	16.00	0.13 lbs.	$1.20	$2.59	$776.40
	(B)	Alumina, Replacement Every 24 months	16.00	0.37 lbs.	$1.20	$7.19	$2,157.00
	(A,B)	Aluminum Oxide Makeup (20 - gal./week)	16.00	3.43 lbs.	$1.20	$65.86	$19,756.80
Steel shot	(D)	Steel Shot Make-up	16.00	7.20 lbs.	$0.25	$28.80	$8,640.00
					TOTAL:	$104.43	$31,330.20

UTILITY REQUIREMENTS

Item	Process	Description	hrs./day	Rate/hr.	Cost Unit	Cost Day	Cost Year
Electric	(A)	27 KW at 440 V, 3 ph, 60 Hz	16.00	27.00 kW	$0.05	$21.60	$6,480.00
	(C)	5 HP, 240/440 V, 3 ph, 60 Hz (Exhauster)	16.00	3.73 kW	$0.05	$2.98	$894.85
	(C)	3 HP, 240/440 V, 3 ph, 60 Hz (Burner Blower)	16.00	2.24 kW	$0.05	$1.79	$536.91
	(D)	3/4 HP, 460 V, 3 ph, 60 Hz	2.50	0.56 kW	$0.05	$0.07	$20.97
	(D)	1 HP, 460 V, 3 ph, 60 Hz	2.50	0.75 kW	$0.05	$0.09	$27.96
	(D)	3 HP, 460 V, 3 ph, 60 Hz	16.00	1.12 kW	$0.05	$0.89	$268.45
	(D)	15 HP, 460 V, 3 ph, 60 Hz	2.50	11.19 kW	$0.05	$1.40	$419.46
	(D)	15 HP, 460 V, 3 ph, 60 Hz	2.50	11.19 kW	$0.05	$1.40	$419.46
	(D)	1/2 HP, 460 V, 3 ph, 60 Hz	2.50	0.37 kW	$0.05	$0.05	$13.98
Air	(A)	30 scfm at ambient; 8 scfm at 850F (negligible cost)	16.00	8.00 scfm	$0.00	$0.00	$0.00
Water	(A)	3 gph at 30 psi supply	16.00	3.00 gal.	0.00046	$0.02	$6.62
	(B)	27 gpm at 30 psi supply	1.25	1,620.00 gal.	0.00046	$0.93	$279.45
	(C)	3 gpm at 30 psi supply	10.00	180.00 gal	0.00046	$0.83	$248.40
Propane	(C)	580,000 Btu/hr Startup	13.50	232.00 ft^3	$0.03	$93.96	$28,188.00
	(C)	60,000 Btu/hr Smokecycle	2.50	24.00 ft^3	$0.03	$1.80	$540.00
					TOTAL:	$127.8[illegible]	$38,344.54

WASTE DISPOSAL / TREATMENT

Item	Process	Description	hrs./day	Rate/hr.	Cost Unit	Cost Day	Cost Year
Water	(A)	3 gpm at 30 psi supply (50% Steam)	10.00	90.00 gal.	0.00465	$4.19	$1,255.50
	(B)	27 gpm at 30 psi supply	1.25	1,620.00 gal	0.00465	$9.42	$2,824.88
Aluminum Oxide	(A, B)	Periodic disposal*	16.00	3.13 lbs.	$0.45	$22.54	$6,760.80
	(A)	Disposal Every 24 months	16.00	0.13 lbs.	$0.45	$0.97	$291.15
	(B)	Disposal Every 24 Months	16.00	0.37 lbs.	$0.45	$2.70	$808.92
Steel shot	(D)	Steel Shot Disposal**	2.50	7.20 lbs.	$0.45	$8.10	$2,430.00
					TOTAL:	$47.9[illegible]	$14,371.25

COST PER PART ESTIMATIONS

	Day	Year
Total Estimated Operating Costs Maximum	$560.79	$168,237.99
Total Parts Processed	200	60000
Cost per Part Processed	$2.80	$2.80

*Comprises floor sweepings, area clean-ups, etc.

**Equal to the make-up quantity; collected from both the fines (40%) and the filtered dust (60%).

Approximately 27 gpm is used to cool the heated parts as the fluidized cooling bed is in use. As shown in Table 15, the FBC operates for 3.5 hours during a normal production day. Therefore, approximately 5,760 gallons of water is needed per day. The afterburner requires 3-gpm or 180 gph to scrub the off-gases generated from pyrolization and combustion. This water is used continuously throughout the production day and is discharged to the industrial water treatment plant (IWTP) for disposal. The remaining water (0.05 gpm) is used as a "snuffer" for the fluidized furnace bed to eliminate an explosive atmosphere. In the utility usage, water is a minor component of the cost in either scenario.

The propane demand for the afterburner unit is dependent upon the off-gases supplied by the fluidized-bed furnace. During the 0.25-hour smokecycle, it was assumed the afterburner operates at a 60,000 Btu/hr propane demand. The remaining time, 0.25-hour start-up and throughout the two shifts it was assumed the afterburner operates at a 580,000 Btu/hr propane demand. The propane supply rate necessary to maintain the afterburner demand was based on the heat-of-combustion value generated by propane.

Although the afterburner flame could possibly be shutdown between periods of pyrolysis, the most recent operability tests indicated that the operating chamber temperature of 1400°F could not be achieved if propane was shut off after each run without heat-up periods that would significantly extend cycle times. However, continued production experience might prove that this assumption is incorrect, and some small cost reductions could be realized by reduced use of propane and electricity.

It is assumed the spent aluminum oxide from the fluidized beds and the steel shot from the low-energy blast cabinet will be disposed as a hazardous waste at the rate of $0.45 per pound. The water generated from the fluidized cooling bed is disposed to the IWTP. It was assumed that approximately 50% of the afterburner quench stream is discharged to the air as steam and the reminder 1.5-gpm is discharged to the IWTP. These were the only waste streams identified in the FBPS process.

Based on the assumptions described above and listed in Tables 15 and 16, the annual cost of operating the FBPS under scenario 1 is $170,717.81 per year for 42,000 parts or $4.06 per part processed. The annual cost under scenario 2 would be $168,237.99 for 60,000 parts or $2.80 per part processed.

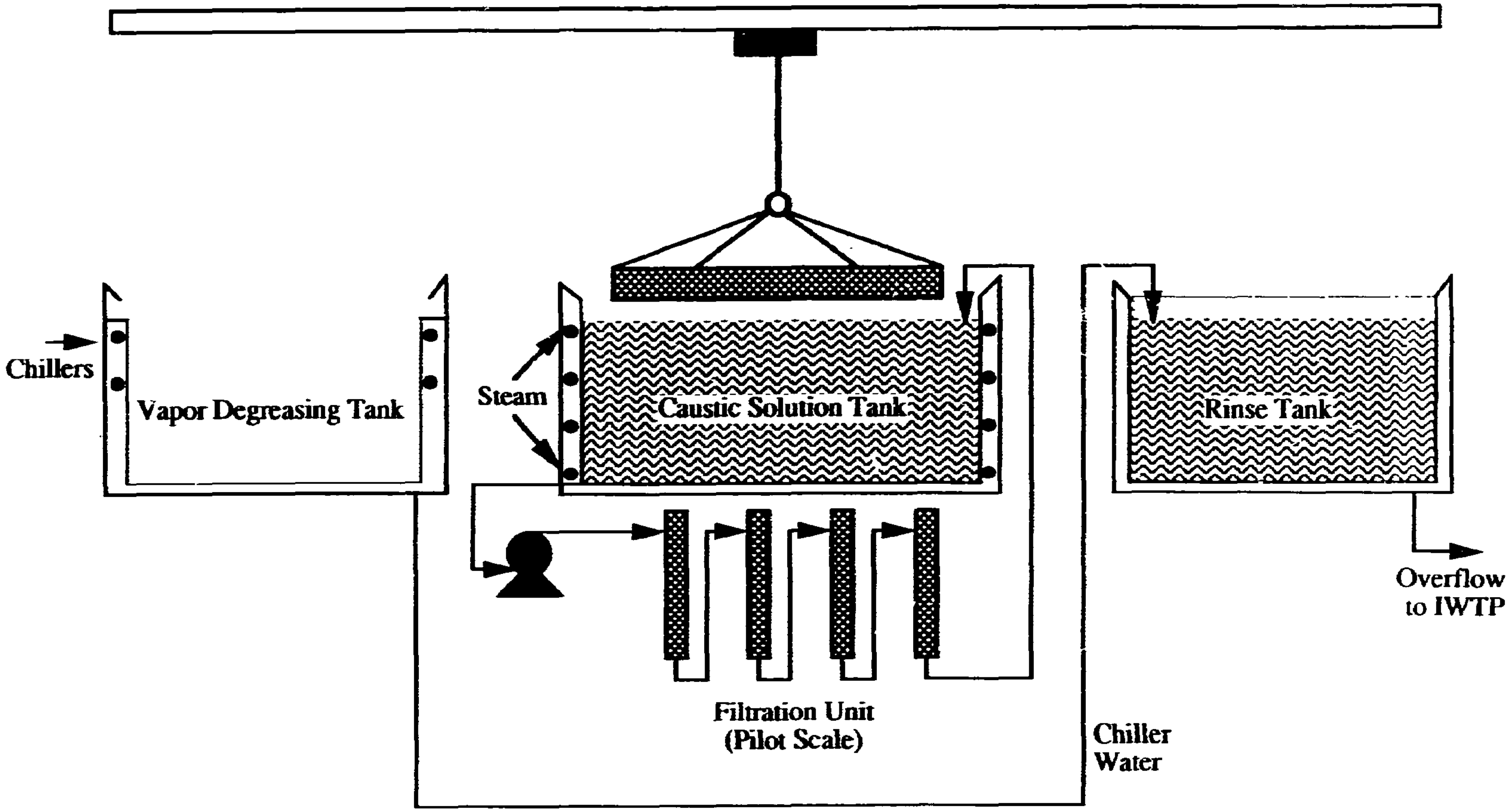
2.2. Caustic Stripping

2.2.1 Process Description

The Caustic Soda Stripping Process (CS) is a simple process that consists of the following major components: 1) A trichloroethane vapor degreasing unit, 2) A 3,000-gallon heated caustic solution tank; and 3) A 3,000-gallon rinse tank. A semi-automatic hoist is used to transfer parts from one tank to the other and also for loading and unloading baskets. Currently, a pilot scale filtration unit has been integrated into this paint stripping operation. Figure 8 presents a process flowchart for the caustic solution paint removal process. A discussion of the potential economic and environmental impact of the filtration unit is mentioned in Section IV. However, this pilot scale unit will not be considered during the description or cost estimation of the CS.

The CS process is a batch operation that requires a total cycle time of 2.5 hours. To begin the process, the parts are first placed in the vapor degreasing unit. Trichloroethane (TCE) is used in this unit to dissolve the grease and wash away the dirt from the parts.

Figure 8 Caustic Solution Process



The TCE vaporizes and is then condensed by a water coolant system to continually recycle it through the parts. After all grease and residues are removed, the work basket is placed in the 200°F caustic solution. In the 3,000-gallon tank, 2,500-gallons of specially formulated caustic solution is used. LEAD personnel use approximately 4000 lbs. of caustic flake a week to maintain the proper pH level to remove the paint and other coatings. The parts remain in the caustic bath for a period of 2.0 hours. This represents the critical path for the process and determines the maximum number of cycles each day. The organic and inorganic material removed from the parts are present as soluble products, suspended particles, and precipitate. These materials or contaminants decrease the lifespan of the caustic solution so that it must be periodically disposed of and replaced. After the cycle time has been completed, the work baskets are removed and are suspended over the solution tank to allow sufficient drainage. The work baskets are then transferred to the rinse tank. The total time for drainage and rinsing is 0.5 hours. The rinse tank is continually supplied by the coolant water from the vapor degreasing tank. Placement and removal of work baskets creates a periodic overflow from the rinsewater tank, which is discharged directly to the industrial water treatment plant (IWTP). After being rinsed, the CS cleaning process is complete and the parts are ready for painting. Table 17 summarizes the operation parameters for this process.

2.2.2 Effluents Produced

Because of its 200°F operating temperature, the caustic solution tank can process only steel parts. Aluminum parts are subject to severe corrosion and pitting. The caustic solution tank may process (strip and rinse) 100 parts in a total time of 3.0 hours. However, multiple baskets may be processed reducing the critical path time of this process to the retention time of the caustic solution tank, which is 2.0 hours. Therefore, a total of 8 cycles may be performed during a 16-hour production day.

The waste generated by the CS process is primarily spent caustic solution and sludge. Due to a gradual development of contaminants that impede the effectiveness of the caustic solution, the solution is disposed and replaced once every 4 to 6 months. To minimize the waste volume, the caustic solution is evaporated with heat in place (termed: "baked off") to approximately 1,200 gallons and is disposed off-site as a corrosive hazardous waste. To develop a new caustic solution, a mixture ratio of three pounds caustic flake and water to make one gallon of solution is used. Other waste streams generated by the CS process are the overflow from the rinse tank, which is discharged to the IWTP and is treated on-site, and the spent TCE and vapor degreasing residues disposed off-site as hazardous waste.

2.2.3 Cost Analysis of Caustic Stripping

In order to achieve an accurate and direct comparison, the number of variables between these paint stripping processes must be reduced to a minimum. Cost estimate calculations were based on both basic operating and process specific assumptions. The assumptions made for the specific paint stripping processes are discussed in the following subsections. The basic operating assumptions for all processes are listed in Table 15, 16 and 18.

As mentioned in the process description, both processes may treat steel parts but due to the FBPS operating temperature, certain alloys may not be acceptable. This issue is beyond the scope of this report therefore, the part materials are assumed to be consistent. The loading allowance for both processes is dependent upon the part size and geometry. To allow a direct comparison, the part dimensions are assumed to be uniform in size.

Table 17
Caustic Stripping Data

Component	Cycle Time	Temperature	Load
Vapor Degreasing	0.5 hours	158 - 165°F	100 parts / cycle
Caustic Tank	1.5 - 2.0 hours	200°F	100 parts / cycle
Rinse Tank	0.5 hour	Ambient	100 parts / cycle

Table 18
Caustic Stripping Tank
Cost Analysis

ASSUMPTIONS

Day	16 hours
Year	300 days
Critical Path	2.0 hrs.; 8 Cycles per day
Capacity	(100) parts per treatment; 800 parts per day
Process	(A) Vapor Degreaser (0.5 hrs./Cycle)
	(B) Caustic Stripping Tank at 200 F (1.5 hrs./Cycle)
	(C) Rinse Tank (0.5 hrs./Cycle)

LABOR

Item	Process	Description	hrs./day	Rate/hr.	Cost Unit	Day	Year
Operator	(A,B,C)	One Operator, 60% of his time	16.00	0.58 man	$17.54	$163.70	$49,109.19
					TOTAL:	$163.70	$49,109.19

RAW MATERIALS

Item	Process	Description	hrs./day	Rate/hr.	Cost Unit	Day	Year
Trichloroethane	(A)	Vapor Degreasing Chemical	4.00	0.58 gal.	$1.95	$4.55	$1,365.00
Caustic	(B)	Caustic Flake for Tank Regeneration Every 6 Months	16.00	3.13 lbs.	$0.06	$3.00	$900.00
Caustic	(B)	Make-up Caustic Flake (lbs. per day)	16.00	5.00 lbs.	$0.06	$4.80	$1,440.00
					TOTAL:	$7.80	$2,340.00

UTILITY REQUIREMENTS

Item	Process	Description	hrs./day	Rate/hr.	Cost Unit	Day	Year
Electric	(A)	Exhaust Blower (14 Amps, 460 V,3 ph)	4.00	11.00 kW	$0.05	$2.20	$660.00
	(A)	Refrigeration Unit	4.00	5.10 kW	$0.05	$1.02	$306.00
	(B)	7.5 HP Blower	16.00	5.59 kW	$0.05	$4.47	$1,341.60
Water	(A)	Chiller Water Pretreatment	16.00	250.00 gal.	0.00046	$1.84	$552.00
Air	(B)	Air Supplied for Agitation (Negligible cost)	16.00	0.00 scfm	$0.00	$0.00	$0.00
Steam	(A)	Steam Requirements (120 psi)	4.00	150000 Btu	0.00000532	$3.19	$957.60
	(B)	Steam Requirements (120 psi)	16.00	0 Btu	0.00000532	$0.00	$0.00
					TOTAL:	$12.72	$3,817.20

WASTE DISPOSAL AND TREATMENT

Item	Process	Description	hrs./day	Rate/hr.	Cost Unit	Day	Year
Trichloroethane	(A)	Spent Solvent Disposal	4.00	0.29 gal.	$1.00	$1.15	$343.75
Water / Sludge	(B)	Caustic Tank Disposal Every 6 months	16.00	0.55 gal.	$5.50	$48.03	$14,409.12
Water	(C)	Rinse Tank Overflow Disposal	16.00	250.00 gal.	0.0047	$18.80	$5,640.00
					TOTAL:	$66.83	$20,049.12

COST PER PART ESTIMATIONS

Total Estimated Operating Costs	$251.05	$75,315.51
Total Parts Processed	800	240,000
Cost per Part Processed	$0.31	$0.31

For this cost per part calculation, it is assumed that the critical path time for the CS process is 2.0 hours. Given a 16-hour work day, a total of 8 treatment cycles may be conducted through the duration of the day. It is estimated that each treatment cycle may process one-hundred 100 uniform parts for a total of 800 for the production day.

As described in the previous section, the caustic solution tank is a simple process that requires minimal labor and utility demand. As described by LEAD production managers, one laborer may operate three caustic solution tank and rinse units simultaneously. Therefore, the labor demand (x) to operate one (1) caustic solution tank and rinse unit is equal to one-third laborer (1/3x). The vapor degreasing unit, the initial step of the CS process, requires one full-time operator. However, the vapor degreasing unit supports three additional paint stripping processes, therefore, the labor demand (x) dedicated to the CS process is one-fourth (1/4x). Combining the labor demand of the caustic solution and rinses tanks (1/3x) with the labor demand of the vapor degreasing unit (1/4x) a total of seven-twelfths (7/12x) or 58% of one laborer is required for the CS process. This labor demand fraction was used to calculate the cost of labor for operation of the CS. The labor rate, $12.00 per hour is fully burdened. The same approach to estimate the labor demand for the vapor degreasing unit operation was also used to calculate the raw material, utility, and waste disposal cost estimates required to support the CS process.

To estimate the cost of raw materials, it is assumed the caustic solution tank is regenerated every 6-months. The solution consists of 3-lbs. of caustic flake to 1-gallon of solution. Only 2,500-gallons of solution is placed in the 3,000-gallon tank, therefore 7,500-lbs. of caustic flake is needed each time for regeneration. LEAD personnel will sometimes decant the caustic solution rather than baking to reduce the solution volume for disposal. This decant solution is then returned to the holding tank and used in the regeneration process. However, for this cost estimate a worse case, 100% regeneration, is assumed. During operation of the caustic solution tank, caustic flake is continually added to maintain the proper pH. Approximately 80-lbs. of caustic flake is added per day. This expense, as well as the material for regeneration, is listed as raw materials.

The utility requirements for the CS process are minimal. The steam requirements for the caustic solution tank were calculated given the pressure and diameter of the steam to which it passes into the unit operation. This cost estimate does not include any heat losses or steam quality reductions. The cost of the air supplied for agitation is assumed to be negligible.

Every 6-months the contaminated caustic solution is disposed. In order to reduce the volume for disposal, the solution is "baked down" (evaporated) to 45-50% of its original volume. This concentrated caustic solution (pH>14) and two 55-gallon drums of residual sludge residues are disposed as corrosive hazardous waste. Approximately 2,620-gallons of hazardous waste is disposed annually. The $5.50 per gallon disposal rate for the hazardous waste is provided by LEAD personnel. The rinsewater tank is steadily replenished with water from the vapor degreaser cooling unit at a rate of 250-gph. The overflow from the rinsewater tank is generated by the displacement of the water as the work baskets are placed in the tank. Assuming steady state operations that maintain a constant water level in the rinsewater tank, the 250-gph inflow from the vapor degreasing unit is equivalent to the overflow discharge rate to the IWTP.

Based on the assumptions discussed in Section 2.2.1, as listed in Table 18, the annual cost of operating the CS is $75,315.51 or $0.31 per part processed. This cost does not reflect recent improvements in the CS brought about by using filters for on-line sludge removal which would significantly reduce down-time and caustic usage.

3.0 Summary, Comparison and Conclusions

3.1 Cost Comparison

Initial capital and construction cost, as well as maintenance costs are outside of the scope of this study. However, such costs would be essential components in any decision-making process for choosing an appropriate paint stripping method. This cost comparison looks solely at and compares the annual operating costs for both the FBPS and CS.

The annual cost of operating the FBPS was determined in Section 2.1.4 to be \$170,718/year or \$4.06 per part processed. These numbers were based on operating conditions determined from the operability test of Section 2.1.2, conducted on the existing LEAD FBPS with no modifications, to be optimal in achieving desired paint removal while minimizing resource consumption and environmental impact.

A second scenario was set forth in Section 2.1.4 which evaluated the same FBPS but further optimized operating costs based on a speculation of process improvements which could be undertaken in a short timeframe (6 months to 1 year) with reasonable cost (less than \$50,000 total cost). These improvements could include modifications to the handling system to allow multiple and concurrent activities, improved controls on fuel and combustion air to the afterburner furnace, and expansion of vent system capacity.

The annual cost of operation of the FBPS under the second scenario was determined to be \$2.80 per part processed. The total annual cost changed slightly to \$168,238, but the total number of parts processed increased almost 50%.

However, even with process optimization, the cost to process a part through the FBPS at \$2.80 is still almost one order of magnitude greater than the CS at \$.31 per part processed. The annual cost of operation of the CS was determined in Section 2.2.3 to be \$75,315.51 or \$0.31 per part processed with four times as many parts processed per year (240,000 parts). Furthermore, this does not reflect additional reductions in operating costs based on recent improvements in the CS brought about through the use of filters for on-line sludge removal that reduce caustic consumption.

The FBPS involves more labor intensive operations due to greater handling requirements and controls and processes requiring increased operator attention. In addition, the FBPS is more energy consumptive in its present configuration requiring significant quantities of propane, electricity air and water for normal operations relative to the CS.

3.2 Operational Comparison

3.2.1 Materials Impact

In order to remove paint from metal parts in the FBPS, heating bed temperatures in excess of 650° F are required. Such temperatures were found, in this study and a parallel study at RRAD, to cause aluminum to lose its desired temperature hardness or temper. Because it is impractical to incorporate a heat treatment step in the LEAD paint removal operations to restore temper, it was determined that use of the FBPS for paint removal was appropriate only for non-aluminum alloy parts. This would also apply to any other temperature sensitive parts or alloys. The CS operates at 200°F and, therefore, has much less thermal impact on parts and alloys.

Rubber, plastic and other organic residues are completely removed and destroyed in the FBPS. Grease is removed from parts in the trichloroethane vapor unit at LEAD. However, rubber and plastic still must be removed from the parts prior to depainting in the CS, whether such materials are to be reused or not.

The FBPS is more sensitive to part shape, configuration and basket orientation than the CS. Certain shapes can cause temperature gradients across parts during pyrolysis with the FBPS thus inhibiting paint removal and possibly causing thermal and physical stress. In addition, residual FBM can only be removed from some parts by adding another cleaning step, while in others, such as those containing bearings, it is not removable through any reasonable efforts.

3.2.2 Worker Safety

The hot fluidized bed operates at 800 to 1,000°F. Metal parts processed in the bed are heated to bed operating temperature. The afterburner operates between 1,400 to 1,600°F and may sometimes reach 2,000°F. There is a potential for burns due to human contact with the FBPS surfaces and metal processed in the FBPS. The FBPS is designed with insulation and by configuration to shield workers from coming in contact with any surfaces hot enough (over 110°F) to cause burns.

The organic material in the FBPS is pyrolized in air, but the quantity of air does not contain sufficient oxygen to convert all of the carbon to carbon dioxide. Therefore, carbon monoxide will be present in the gases escaping from the top of the hot fluidized bed. The afterburner will normally convert the carbon monoxide to dioxide. Since carbon monoxide is a colorless, odorless highly poisonous gas, all leaks should be avoided, and the cabinet doors should be closed tightly. Other poisonous gases, such as nitrogen oxides and formaldehyde, may also be formed by the pyrolysis of certain paints.

The most significant worker exposure problem created by the FBPS is FBM dust. Under heavy gas load conditions (e.g., initial stages of paint stripping, air to the cooling bed during stripping), copious quantities of dust can be emitted from the FBPS cabinet and vent system. The quantity of dust is proportional to the gas load and extent of vent system restriction (e.g. plugged cyclone).

Dust is generally only a nuisance problem. In this case, the FBM dust can be and is usually classified as a "hazardous waste" under 40 CFR Section 261.24. This is so because of the lead and chrome containing paints stripped in the FBPS which quickly build up the concentrations of these metals in the bed to above regulatory acceptable levels within a few runs. This was verified in the environmental impact studies conducted on the FBPS in April, 1991. Therefore, FBPS workers and any other workers employed in the building housing the FBPS must be provided with the necessary respirators, equipment, and health monitoring as required under the OSHA requirements of 29 CFR Section 1910.1025 for workers exposed to lead.

Although it might be possible to prevent the FBM reaching hazardous levels by changing it after every few runs, this would be costly at $1.20/pound of alumina. Frequent changing of the FBM would make an already costly operation prohibitive. This will remain a problem, however, only as long as there is lead-containing paint to be stripped from parts. Depot personnel project this period to be approximately five years.

The FBPS is designed to safely pyrolize grease, oil, and other organic matter on part surfaces, and to burn the gaseous pyrolysis products in the afterburner. Overloading the system with organic matter can produce high temperature excursions that could damage the afterburner. In addition, overloading the system with organics could produce potentially dangerous emissions of incompletely burned organic matter.

If the organic matter is especially volatile or reactive (for example, fuel oil, gasoline, munitions, etc.) instantaneous overloading of the system and explosions are possible. If the afterburner is accidently extinguished during pyrolysis, which is an unlikely incident, flammable and potentially explosive gases may accumulate in the system.

Aside from the worker safety precautions normally undertaken for handling heated corrosive liquids (NaOH), the CS has no unique safety requirements. The CS and FBPS operators are required to use and wear the following safety equipment at all times while operating the FBPS or CS:

insulated gloves
insulated apron
face shield and safety glasses
long sleeve shirt with sleeves completely covering the arms
steel-toe safety shoes.

3.3 Hazardous Waste Generation

3.3.1 Quantities and Types

The paint used on older military equipment often contains lead compounds and/or chromium compounds as pigments. In addition, some painted parts have been plated with cadmium or chromium. In certain processes some or all of the formulated and/or the plated metal may be removed. These metal compounds are toxic substances that are regulated by the U.S. EPA as hazardous waste. Therefore, even though there are no toxic solvents or reactants in the process, some hazardous waste will still be generated upon paint removal.

A mass balance conducted around the FBPS found that the heavy metals did not concentrate in air emissions or water effluents sufficiently to classify these streams as "hazardous." However, heavy metals were found to concentrate in the FBM after only three runs.

Approximately 18,000 pounds per year of FBM, containing toxic quantities of cadmium, chromium, and lead, will be disposed of as a result of FBPS operations. This is compared to approximately 3,000 pounds per year of NaOH sludge containing heavy metals and organics from the CS.

3.3.2 Other Means to Depainting Waste Reduction

Molten Salt Bath Cleaning System

Process Description

The molten salt bath cleaning process completely removes paints, powder coatings, organics, polymers and residue from metal parts. At bath temperatures within the range of 600 to 1000°F most surface materials dissociate and are released from the molten bath surface as decomposition products. Some of these products may inter-react with the constituents of the molten bath to produce a clean surface free of all organic contamination. By varying the chemistry and temperature of the molten bath, the reaction rate is controlled, thus avoiding thermal-chemical damage to the product being cleaned.

The molten bath chemistry is selected for a given application and consists of a nitrate, caustic, and other additions to enhance the reaction process. While most of the reaction products are volatile, the volatile gases (if combustible) will ignite and burn off the bath surface under controlled conditions. As a result of the reaction between the molten salt and the organic material, the molten bath becomes contaminated with carbonates, pigments, and inert materials. These contaminations may exist as soluble products, as suspended particles, or as a precipitated product. If not removed, these contaminations will reduce the cleaning efficiency of the molten bath. Specially designed equipment is available to continuously remove these contaminants.

Results

Test batches were run at 600, 700 and 800°F for 2.5 minutes, 2 minutes and 1 minute, respectively. A combination of aluminum and steel panels and parts were stripped.

Paints and organics were completely removed from the aluminum panels. The surface hardness of these panels was measured before and after. These results are shown in Table 19.

It was concluded that although the molten bath cleaning system can remove paint and organics very quickly (in minutes), exposure of the aluminum to the high temperatures is still sufficient to reduce hardness in the panels. This is unacceptable to LEAD and eliminates the molten bath cleaning system as a viable alternative process for paintstripping of aluminum parts.

Likewise, the molten bath completely removed paint and organics from the steel panels. However, it did not remove rust and, at higher temperatures, formed black oxide on the surface of the panels. This characteristic renders the molten bath cleaning system unacceptable for stripping paint from the steel parts at LEAD because the addition of a rust removal step into the molten bath process would defeat the purpose of adopting the process as an alternative to the CS.

3.4 Conclusions

The objective of this study is to evaluate the viability of the FBPS as a method of removing paint from metal parts at Army depots to compare the operability, economic performance and environmental impact of the FBPS with existing paint removal systems and to derive conclusions regarding the appropriateness of replacing existing paint removal systems with the FBPS.

The following conclusions were derived from this study:

Conclusion 1:

The FBPS is <u>not</u> a suitable replacement for chlorinated solvent stripping systems currently used to remove paint from aluminum and aluminum alloy parts at Army Depots.

Table 19
Molten Salt Bath Cleaning System
Aluminum Hardness Results

Aluminum Alloy	Temperature °F	Time in Bath	R	R
5052-H32	600	2.5 min	15.4	11.8
	700	2 min	15.4	5.0
	800	1 min	15.0	2.2
6061-T6	600	2.5 min	53.1	18.6
	700	2 min	47.1	11.3
	800	1 min	6.9	6.9

Basis: This study, in conjunction with a similar study conducted at RRAD, found that aluminum and aluminum alloy parts when exposed to the 700 - 800°F temperatures of the FBPS for the 1-2 hours residence time required to pyrolize paint lost essentially all of their hardness or temper. It is possible to restore this property through the addition of a heat treatment step in the repainting process at the depot but this has been deemed impractical by DESCOM personnel.

A preliminary evaluation of the Molten Salt Bath as a paint removal alternative confirmed this conclusion regarding effect of temperature on aluminum hardness and gave some indication as to how temperature sensitive aluminum parts are. Exposure of aluminum to a temperature of 600°F for only 2.5 minutes caused a 65 percent hardness reduction. Exposure to 800°F for only 1 minute caused an 87 percent reduction.

Conclusion 2:

The FBPS can be used to remove paint from non-aluminum and non-heat sensitive parts but the cost is an order of magnitude greater to operate that its alternative for this purpose, the Caustic Stripping Process or CS.

Basis: The FBPS cost $4.06 per part cleaned as compare to $.31 per part for the CS. This disparity is due to the fact that the FBPS is more labor intensive and energy consumptive than the CS. Even the optimized scenario for the FBPS would result in a cost of $2.80 per part processed.

The FBPS requires 72% more labor due to greater handling requirements and the need for more operator attention. The FBPS also consumes more energy in the form of electricity and propane gas due to the greater number of motors incorporated into the system and high thermal requirements both for heating and pyrolysis of paints and combustion of unburned gases.

Conclusion 3:

In the course of removing paints, coatings, or platings containing toxic metals (e.g., lead, chromium, cadmium), the FBPS will cause the FBM to become a "hazardous" substance.

Basis: Although the FBPS does not incorporate toxic solvents or materials in its paint removal process, it does remove heavy metals formulated in paints and contained in coatings and platings from the surface of parts and deposit them, to some extent, into the FBM. The exact mechanism for each metal is not defined but significant increases in toxic metals concentration in the FBM have been observed after only three FBPS runs. There is no question that the pyrolysis of paints, coatings, or platings containing toxic metals in the FBPS will result in fluid bed material which exceeds the regulatory limits of 40 CFR 261.24 for these metals. This will cause the FBM to be classified as a hazardous waste. Of course, this will become less of a problem as the presence of paints containing lead and chrome diminish but must be taken into consideration until such time.

A mass balance conducted around the FBPS during its operation determined that the FBM containing toxic metals as well as the toxic metals themselves are not found in any significant concentrations in either the stack gases or effluent water to the IWTP.

Conclusion 4:

In the course of removing paints, coatings, and platings containing toxic metals, the FBPS will generate more solid hazardous waste requiring disposal than the CS.

Basis: As stated in the basis for Conclusion 3 above, the FBPS will generate toxic metal-contaminated FBM in the course of treating paints, coatings and platings containing toxic metals. It is estimated that the resulting solid hazardous waste requiring disposal will amount to about 20,000 pounds per year as compared to the 3,000 pounds per year of caustic sludge from the CS requiring disposal.

Conclusion 5:

FBPS workers and any workers in the building containing the FBPS will be subject to OSHA requirements for employees exposed to lead under 29 CFR 1910.1025.

Basis: As stated in the bases for Conclusions 3 and 4, when the FBPS removes paints, coatings or platings containing lead, the FBM rapidly increases in lead concentration and exceeds the threshold defining it to be a hazardous waste within the first few runs.

This means that the dust emitted from the FBPS cabinet is not only a hazardous waste by definition but contains high concentrations of lead. Although ambient air monitoring was not conducted during this study, the concentration of lead in the dust and the quantity of dust emitted from the FBPS would lead to an expectation of potential operator exposure in excess of the action level of 30 micrograms per cubic meter of air averaged over an 8-hour period and possibly as high as the permissible exposure limit of 50 micrograms per cubic meter.

In any case, the dust must be considered as a hazardous material containing lead and handling, monitoring and personal protection procedures as required by 29 CFR 1910.1025 should be implemented for all workers employed in any building housing the FBPS.

TEST PLAN FOR EVALUATING THE PROCEDYNE FLUIDIZED BED PAINT STRIPPER AT LETTERKENNY ARMY DEPOT

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May 1991

PREAMBLE

This "Test Plan for the Evaluating the Procedyne Fluidized Bed Paint Stripper at Letterkenny Army Depot" was originally prepared in August 1990, as revision number 0. The objectives of the project changed substantially and complete revisions of the test plan were required. The revisions are shown below.

Revision No.	Date	Type
1	April 1991	Complete revisions of Test Plan and Safety Plan - replaces all pages.
2	May 1991	Complete revision of Test Plan and Safety Plan - replaces all pages.

Revision No. 2
Section No. ____
Page ____ of ____
Date May 1991

CONTENTS

SECTION I. INTRODUCTION

This test plan provides specific information regarding evaluation of the fluidized bed paint stripper (FBPS) at the Letterkenny Army Depot (LEAD). Included is a brief introduction on how the fluidized bed works, a discussion of the test objectives, and specific test procedures and methodologies. The U.S. Army Toxic and Hazardous Material Agency (USATHAMA), through its contractor, International Technology, Environmental Programs (ITEP) will test and evaluate a Procedyne Corporation FBPS at the LEAD. The FBPS is a production unit used to remove paint, oils, and greases from metal parts by immersing the parts in a fluidized bed of aluminum oxide granules maintained at temperatures high enough to pyrolyze organic matter. Typical temperatures range from 700 to 1,000 °F with residence times in the bed of approximately one-two hours. There is insufficient oxygen in the bed to support complete combustion. Therefore, organic matter on the parts and in the coatings (paints and primers) are pyrolyzed in the FBPS to hydrocarbons, carbon, and carbon monoxide. An in-line gas-fired incinerator burns the carbon monoxide and hydrocarbon gases formed. The products of combustion are exhausted through a water quench scrubber to the atmosphere.

During the pyrolization, the binders (organic compounds) in the paints and primers are destroyed. Once the binders are destroyed, the part is left coated with a loosely adhering char composed of carbon and inorganic paint pigments. The char is removed using a low-energy shotblaster or other removal techniques, leaving the part ready for recoating.

The FBPS is an alternative to liquid-based paint stripping systems. Presently, a hot casutic soda (sodium hydroxide, NaOH) bath is used to remove old paint from steel parts. In this process, the pieces must first be degreased in a trichloroethane bath and dried before caustic treatment. Solvent-based paint stripping systems that use methylene chloride or other chlorinated solvents have been used, but this process is not installed at LEAD. The solvents physically swell and destroy the binding properties of the organic materials in the paint. Once destroyed, the remaining coating material is removed with washing action or shotblasting before recoating.

The caustic soda process destroys the binding materials (organic polymers) in the paints to release the pigments and other components as dissolved materials and fine particles. The process is limited to chemically stable materials such as steel and stainless steel; the caustic will corrode aluminum, zinc, and magnesium. The particles separate as a sludge which must be classified under federal laws as a hazardous waste. The sludge and waste solution is contaminated with toxic lead, chromium and, possibly, cadmium compounds that make up part of the paints. Because of the toxicity, it is hazardous and very costly to properly dispose of the sludge and depleted caustic solution.

Chlorinated paint stripping solvents are toxic and volatile. Methylene chloride, the most commonly used solvent, is especially volatile (boiling point 40 °C or 104 °F). The chemical paint stripping process and the solvent process both generate sludge. The sludge consists of stripped coatings and salts of materials used in the process, solvents or caustic soda. The sludge is listed as a categorical hazardous waste and must be disposed of as such. ITEP and USATHAMA believe that installation of the FBPS may reduce atmospheric releases of stripper compounds (mostly chlorinated solvents) and reduce the volume of hazardous wastes requiring disposal. Therefore, the objective of this test program is to evaluate the use of a FBPS to determine if the process will reduce hazardous waste while satisfactorily removing coatings (or assisting removal) and facilitate reuse of parts at the LEAD.

A FBPS is an alternative to chemical paint stripping. However, the FBPS uses high temperatures that may affect properties of certain parts (temper, hardness, metallurgy, physical dimensions etc.). A companion program at Red River Army Depot will address the effect of high temperatures and rapid cooling on metal properties. Preliminary studies have shown that aluminum alloys are adversely affected by the temperatures reached in the unit (see J. E. Spessard, Memorandum To: Project File, March 28, 1990). Therefore, this project at LEAD will concentrate on determining the FBPS's usefulness as a cost-effective, hazardous waste minimization process. This test plan defines how this will be done.

The test plan is a fluid document that will be revised as the testing progresses. This is Revision No. 1. The test plan will be maintained in a loose-leaf binder and periodically updated. Distribution of the document is controlled and each copy numbered and assigned to a specific user. Updates will be issued on an as needed basis to the plan holders. The plan holders will be responsible for replacing the revised pages and removing and discarding replaced pages. Each page will be identified by revision number, section, page number, and revision date. A revision history is included in the Preamble.

SECTION II. OBJECTIVES OF THE TEST PLAN

The objectives of these tests at LEAD are:

- To determine the economics of operating the FBPS for various parts/coating systems.
- To determine the impact on the environment of operating the FBPS.

The economics of operating the FBPS are to be analyzed to compare this process with the present caustic stripping process or any other new proposed process. To make this analysis we plan to make test runs with the unit to determine its method of operation and to obtain energy and materials useage data. The generation of hazardous waste may be a significant cost factor because of disposal or treatment costs. The same toxic components in the paint and metal parts (lead, chromium, and cadmium compounds) will accumulate in the process and must be properly disposed.

The impact of operating the FBPS on the environment must be evaluated as a comparison to other methods of paint stripping and to determine if any unacceptable environmental hazards are created. The FBPS may generate hazardous air emissions from unburned organics or particulates which may escape the in-line incinerator. Either one or both of these items may not be acceptable under state air regulations. Also, because of the old paints to be stripped, the particulates may contain toxic heavy metal compounds. Water from the unit (used mostly to quench the products of combustion) may contain toxic components that may not be acceptable to LEAD's industrial water treatment plant. Finally, the fluidizing material (specified by Procedyne as aluminum oxide) will become contaminated with heavy metal compounds. As the fluidizing material loses its effectiveness it will have to be discarded. The presence of heavy metals probably will cause the discarded material to be classified as a hazardous waste. Each of these effluents will be sampled and tested to determine the extent of the hazard.

A. Comparative Economics of Operating the FBPS

An economic analysis will be made to determine the cost of operating the FBPS and the caustic soda paint stripping system (CSPS). For our analysis data on the cycle times, labor rates, energy costs, raw material costs, and costs of waste disposal or treatment will be gathered. Treatment times for the FBPS will be obtained from Procedyne operating manuals and operability tests (see Section II), while the treatment times for the CSPS will be obtained from LEAD personnel. Energy, labor rates, and waste disposal/treatment costs will be obtained from LEAD's engineering and/or accounting departments. Raw materials costs will be obtained from vendor's or government supply contracts.

A detailed comparison of the costs of operating the FBPS system versus the CSPS system will be made. Variations in the methods of operating these systems will be considered. These variations may include techniques to optimize the system, methods to minimize the hazardous waste, and limits on the types of parts to be stripped. Estimates of operating other paint stripping systems of interest, such as molten salt baths or solvent based systems will be obtained from vendors where possible. Captial costs will not be included in these cost comparisons.

B. Environmental Impact of Operating the FBPS

The FBPS is equipped with an emissions control system to minimize environmental emissions. The system has two components, an afterburner to burn hydrocarbons and the pyrolysis products and a wet quench to reduce stack gas temperatures, which may reduce the particulate emissions. The afterburner is a propane gas fired combustion chamber designed to incinerate all combustible materials and convert them to water vapor and carbon dioxide. If the afterburner efficiency is not adequate, unburned hydrocarbons may exit the outlet stack.

Because the emission control system can control only a limited amount of the environmental emissions, it imposes limits on the amount and kind of materials that may be safely charged into the FBPS. The quench scrubber has limitations on the kind and quanity of material that it can effectively control. Particulates from the paint stripping may contain toxic heavy metal compounds because such metals are contained in old military paints or they may be generated by heat from platings used on parts.

Cadmium and zinc are common plating metals used on parts planned for processing in the FBPS. At normal bed temperatures, these metals might volatilize and/or oxidize and leave the bed. In the afterburner any metal vapors might be converted to oxides and pass to the quench scrubber. The scrubber is expected to have a low collection efficiency on the metal oxide particles found in the process. To keep emissions of these oxides to reasonable levels the amount of the metals charged into the FBPS must be controlled.

Lead and chromium compounds are also used in coatings processed in the FBPS. The fate of these metals will be determined during the project. It is theorized that most of these metals will remain with the char on the parts; however, even a minor percentage of these toxic materials expelled into the air may be of regulatory concern. Accidental releases to adjacent areas may be hazardous to workers employed at LEAD.

Some of the toxic metals or organics in the stack afterburner effluent will be removed from the stack gases by the quench water. These materials will then enter LEAD's industrial water treatment plant (IWTP). The toxic or hazardous solids that remain in the char will contaminate the fluidizer bed material (FBM). If the heavy metals or certain organics are found to be extractable from the FBM by the TCLP test prescribed by the US Environmental Protection Agency the spent FBM will have to be stored, treated, and/or disposed of as hazardous waste. The TCLP test is the Toxicity Characteristic Leaching Procdeure (see Federal Register 55: 11798-11877, March 29, 1990) that measures the concentration that results upon extracting a waste with an acidic aqueous solution.

To obtain the data for determination of the impact of operating the FBPS on the environment, paint stripping tests will be made as describd in Section III. Specially prepared test panels will be used to insure that known amounts of toxic materials will be present in the unit. Larger quantities of lead-containing paint than would represent normal loading will be used to insure that measureable concentrations of toxic materials will be present. Samples will be taken from the stack gases, from the quench water, and of the FBM.

The results of the tests will be used to prepare operating instructions. The operator will be responsible for regulating the quantity of these metals charged into the bed. Suspect parts will be visually inspected to determine if they do or could have plating. If the part is suspect it will be treated as if it is plated. The operator will determine how many of the particular parts can be charged to the FBPS and limit the charge to that amount. The project manager and staff will work with the FBPS operator to develop specific written instructions for controlling the amount of cadmium and zinc charged in the FBPS.

SECTION III. OPERATIONAL TESTS

Operating tests of the FBPS were made on January 17th and February 14th, 1991. The project team from ITEP, Mr. Ron Jackson of USATHAMA, and Dennis Reed of LEAD participated in these tests. The orignal test plan (#0, August 1990) along with the operating manuals provided by the Procedyne Corporation were used as a guide. The "Operating Instruction" sections of Procedyne's Manuals are attached as Appendix A to this Test Plan.

Although the operating instructions are in Appendix A, the general steps for operating the FBPS are outlined below.

1. Preparation (2-3 hours before stripping)

   a. With power off, fill (if needed), or add to, the furnace retort and quench bath enough aluminum oxide fluidizing media (150 mesh) to make the depth of 48 inches.

   b. Check the following: 1) that propane supply is adequate, 2) all gas and liquid lines are tight, 3) plant air and water are available, 4) that the gas outlet ducts are not clogged and that the cyclone and fines pot is empty.

   c. Turn on the power at the main control board.

   d. Close the cabinet doors on the unit and adjust the fluidizing air (the FBM should appear to "boil" in a rolling manner).

   e. Turn on the furnace power.

   f. Allow the fulidizer bed to reach the prescribed temperature (controlled by the instrument set-point) - reduce the air flow, incrementally, to prevent toss-out of the FBM as the temperature increases.

2. After-burner (AB) start-up.

   Start-up the after-burner by carefully following Procedyne's instructions (see diagram). Generally, 1) start the AB before any paint stripping is done; 2) turn on the exhaust blower; 3) turn-on and adjust the water to the cooler; 4) turn-on main gas line, power switch, and start switch; 5) allow temperature to reach 1400 °F; 6) adjust air damper to maintain temperatures of 1400-1600 °F.

WARNINGS:

- Start the exhaust blower and quench water before igniting the flame.

- If the burner is accidentally extingushed (an unlikely ocurrence, usually caused by no propane fuel) during a cleaning cycle, DO NOT ATTEMPT TO RE-IGNITE THE FLAME, because an over-pressure or explosion may result. Continue operation of the furnace, fluidizer air, and exhaust blower. (This will exhaust smoke and possibly flammable gases up the stack.) A rapid restart of the flame may be possible under certain operating conditions - see the Procedyne manual for instructions.

- The after-burner is designed for continuous operation at 1400-1600 °F. If the after-burner temperature approaches 2000 °F, the after-burner limit circuit will automatically turn the FBPS fluidizing air off. To safely continue the operation: DO NOT TURN AFTERBURNER OFF, DO NOT LIFT COVER, DO NOT SHUT DOWN FURNACE, DO NOT SHUT DOWN THE OFF-GAS DILUTION SYSTEM, AND DO NOT SHUT DOWN THE BLOWER. The AB should slowly decrease in temperature, but the system will still conduct smoke from the system and out of the building. The fluidizer air may be safely restarted after the AB temperature is below 1600 °F. (This condition indicates that too much paint or other organics, such as rubber coatings, was charged to the unit. Parts charged must be better controlled in subsequent batches.)

3. Cleaning cycle

a. Load painted parts into the fluidizer basket (see the Procedyne manual for loading arrangement).

b. Open the cabinet doors, transfer the basket into the cabinet, close the doors, and lower the basket into the hot fluidized bed.

c. Adjust the air supply to the AB as the pyrolysis begins - this adjustment, usually a reduction, prevents an overpressure in the cabinet. The overpressure will cause smoke to escape into the building.

d. When the pyrolysis is complete (tests during start-up of this unit will be required to determine the prescribed stripping time for the process.) remove the basket from the retort and lower it into the fluidized quench bed.

e. When the parts are cooled to 150 °F or lower, remove the basket from the quench bed, open the cabinet, blow excess FBM from the parts, and transfer the basket out of the cabinet.

4. Shot-blast cleaning

The basket is transfered into the low energy shot-blast unit. This cleaning operation is performed according to Pangborn's operating manual.

Four loads of parts were stripped during these two tests. The paint removal, and rubber coating removal, appeared to be adequate. We judged that these parts would be ready for repainting, but some plated parts (probably plated with cadmium or zinc) showed melted beads of metal on the surface. We did find that air-flow to the after-burner must be carefully controlled by adjusting the dampers to prevent smoke release into the building. Also the outlet system must be checked before operating because the media is easily carried over into the cyclone and fines pot. In the first February test, this system was full from the earlier operation; the FBM blocked the gas effluent duct, and large amounts of smoke were expelled into the building. Before the second run that day the FBM was removed, and the smoke was exhausted as designed.

SECTION IV. ENVIRONMENTAL EFFLUENT TESTS.

The environmental effluent tests will be made by operating the FBPS as described in the Procedyne manuals with the modifications described above in Section III. Specially prepared and painted steel and aluminum test panels will be used to provide painted surfaces. Separate cadmium plated and zinc phosphated steel pieces will be included to provide a source of those metals. Yellow enamel, formerly meeting military specifications, that contains lead chromate (see Appendix B for composition) will be used as the paint in these tests. The samples of the gases, water, and FBM will be taken and analyzed as described in "ATMOSPHERIC EMMISSION SITE TEST PLAN AND QUALITY ASSURANCE PROJECT PLAN FOR FLUIDIZED-BED PAINT REMOVAL DEMONSTRATION TESTS, LETTERKENNY ARMY DEPOT, CHAMBERSBURG, PENNSYLVANIA", by IT Air Quality Servces, PN 805644 (ITAQS) that is attached to this Test Plan. The test panel preparation and FBSS operation are described below.

A. Test Panel Preparation

1) Painted panels. The steel and aluminum test panels were prepared under the direction of Mr. Dennis Reed at LEAD. The panels were cut from metal stock. All were 4 in. by 8 in. by approximately 0.025 in. thick, and the corners were rounded, with a radius of 1.25 in. A small hole was cut near the narrow end of each panel. The panels were labelled with a vibratory stylus in groups of 10; that is, the first ten were labelled "A", the next ten, "B", etc. The batches of panels, along with ten hooks (steel paper clips), were then weighed to a precision of 0.1 gram. On March 22nd, 1991 the labels were covered with a small piece of masking tape and a thick coating of paint was applied by an LEAD operater with the use of the Depot spray booth and spraying equipment. The 220 panels were partially dried in the shop drying oven. ITEP personnel and Mr. Jackson from USATHAMA observed and assisted this operation. After the the paint had dried for three days the masking tape was removed and each batch, with hooks, was weighed again (see Appendix C, for the data). Paint loadings varied from 29 to 65 grams per batch.

2) Plated panels. Steel panels, 4 in. by 8 in., thin guage, squared corners, were plated with cadmium at Red River Army Depot under the direction of Mr. Ed Hanna. Plating thicknesses were reported to be 0.3 mil to 1.0 mil.

B. Test Procedure

The sampling and FBSS cycle are described in the ITAQS test plan; the FBSS will be operated as described in Section II. The procedures to measure the test panels are described below.

The FBPS has not been operated with this quantity of paint in tests to date. Therefore, we plan to strip painted scrap parts in the FBPS before performing the effluent testing. For this test, the parts will be stripped in the fluidized bed for approximately 60 minutes at 800 °F. The result of this test will be used to judge the smoke handling capability of the unit. Based on the above preliminary test, we will determine the number of panels to be charged into the basket for the effluent tests.

For each of the two or three effluent tests, four to six batches of painted test panels, several cadmium plated panels, and several zinc phosphated panels will be hung on a mesh cage various levels, from bottom to top. The paint will be stripped as described in Section II and in the ITAQS Test Plan. After completion of the process, each batch of panels will be weighed (to 0.1 g.) after they are cooled to room temperature. If time permits, weights of the batches after the stripping step, but before the sand-blast cleaning will also be obtained. The appearance of the panels will be recorded. The loss of weight will determine the amount of paint and/or metal that is removed in this process. The results can then be used to calculate the quantities of hazardous materials that enter the FBSS. The results of chemical analysis on the effluents will then allow us to estimate the fate of the hazardous components.

SAFETY PLAN FOR THE PROCEDYNE FLUIDIZED BED PAINT STRIPPER AT LETTERKENNY ARMY DEPOT

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CONTENTS

SECTION I. GENERAL

This safety plan is for the Procedyne fluidized bed paint stripping system (FBPS). It is intended to provide instructions on how to work safely around the equipment for all persons, including Letterkenny Army Depot (LEAD) employees responsible for operating and maintaining the system.

The safety plan supplements rather than replaces other safety requirements for LEAD, the building, and the building area. All other safety requirements are included by general reference. For example, safely operating the FBPS does not require hearing protection. However, if hearing protection were required in the area, then by reference employees operating and maintaining the FBPS would also be required to use hearing protection. Safe operation of the FBPS does involve lifting heavy metal parts. Thus, by reference employees working on the FBPS would use the established safety procedures for lifting heavy metal parts.

The safety plan cites and emphasizes some, but not all, operation and maintenance (O&M) procedures. However, the safety plan includes, by reference all required O&M procedures. All O&M work shall be done by qualified personnel. The safety plan is not a substitute for established manuals and procedures. Persons using this safety plan should refer to the O&M manual for the fluidizing bed and/or the Test Plan for a description of the FBPS system and the LEAD safety manuals. For these tests we will be using O&M manuals provided by the Procedyne Corporation and the Pangborn Company. Separate manuals are available 1) the fluidized bed furnace, 2) the afterburner, 3) the fluidized quench bath, and 4) the low-energy shot blast unit (Pangborn). The reader should study these manuals and the Test Plan before reading this Safety Plan.

SECTION II. POTENTIAL HAZARDS

The hot fluidized bed operates at 800 to 1,000 °F. Metal parts processed in the bed are heated to bed operating temperature. The afterburner operates between 1,400 to 1,600 °F and may sometimes reach 2,000 °F. There is a potential for burns due to human contact with the FBPS surfaces and metal processed in the FBPS. The FBPS is designed with insulation and by configuration, to shield workers from coming in contact with any surfaces hot enough (over 110 °F) to cause burns.

The organic material in the FBPS is pyrolized in air, but the quantity of air does not contain sufficient oxygen to convert all of the carbon to carbon dioxide. Therefore, carbon monoxide will be present in the gases escaping from the top of the hot fluidized bed. The afterburner will normally convert the carbon monoxide to the dioxide. Since carbon monoxde is a colorless, odorless highly poisonous gas, all leaks should be repaired before starting the unit, and the cabinet doors should be closed tightly. Other poisonous gases, such as nitrogen oxides and formaldehyde, may also be formed by the pyrolysis of certan paints.

The FBPS is designed to safely pyrolize grease, oil, and other organic matter on part surfaces, and to burn the gaseous pyrolysis products in the afterburner. Overloading the system with organic matter can produce high temperature excursions that could damage the afterburner and could also produce potentially dangerous emissions of incompletely burned organic matter. To prevent damage to the afterburner the instrumentation controlling the unit will shut off the fluidizing air if the chamber reaches 2000 °F.

If the organic matter is especially volatile or reactive (for example, fuel oil, gasoline, munitions, etc.) instantaneous overloading of the system and explosions are possible. If the afterburner is accidently extingushed during pyrolysis, an unlikely incident, flammable, and potentially explosive gases may accumulate in the system.

The hot fluidized bed uses high voltage (480 V) circuits for heating. Therefore, electrical shock is a potential hazard.

Some parts introduced into the FBPS will be painted with older paints that contain toxic lead and chromium compounds. Also pieces electroplated with cadmium and zinc, which are toxic (especially cadmium) may be stripped. The latter metals may be volatile at FBPS temperature and there is a potential for atmospheric emissions of these metals. In the afterburner these toxic metals may be converted to their oxides. Particles of the latter, and the lead and chromium compounds may all form fine particles which may cause the smoke from the unit to be toxic.

Some parts are heavy and there is a potential for injuries due to lifting, moving, and carrying these parts in an unsafe manner. Established Depot safety procedures for lifting and carrying heavy objects must be followed.

SECTION III. SAFETY EQUIPMENT

The operator of the FBPS is required to use and wear the following safety equipment at all times while operating the FBPS:

- insulated gloves
- insulated apron
- face shield and safety glasses
- long sleeve shirt with the sleeves completely covering the arms
- steel-toe safety shoes

All maintenance employees shall wear and use the same safety equipment as the operations employees, unless the maintenance supervisor verifies and accepts responsibility that the equipment is being shut down and is at ambient temperature. In this event, only steel toed safety shoes are required.

SECTION IV. SAFETY PROCEDURES

The following safety procedures shall be taken by all operations personnel in the FBPS area:

- All required safety equipment will be worn while employees are in the work area. This equipment shall be in good condition and worn properly. For example, the face shield must completely cover the face and shirt sleeves must completely cover the arms.

- All surfaces of the FBPS shall be considered hot. All parts removed from the FBPS shall be handled as if hot.

- In the event that any part of the FBPS is operating outside design specifications, the FBPS system shall be shut down using the required emergency shut down procedures in the O&M manuals. For safe shut-down, proper precautions must be taken to prevent expulsion of toxic materials into the work area, and to prevent explosions that may injure personnel. If smoke leaks from the unit into the work area, doors and windows should be opened to dilute the gases, and the furnace heat and gas feed should be reduced. The dampers on the afterburner should be immediately adjusted to maximize the operation of the exhaust blower to remove the smoke from the unit. (Adjustments to the operating instructions should be made to prevent reoccurence of upset conditions that lead to smoke release. The pyrolysis time and temperature may need readjustment to prevent overloading the afterburner or better control of quantities or conditions of parts stripped may be required. Too much grease or rubber may overload the system.)

- Anyone that experiences breathing difficulties or becomes uncomfortable from exposure to the smoke or other gases leaking from the unit, must immediately be moved from the work area into fresh air. Medical assistance should be promptly sought if any breathing problems persist.

- Parts having closed or sealed areas, cavities, and other components shall not be introduced into the system unless the supervisor responsible for the FBPS has verified and accepted there is no possibility of damage caused by them. Damage can be caused by explosives released as a result of heating confined water or combustible materials.

The following safety procedures shall be taken by all maintenance personnel in the FBPS area:

- All required safety equipment will be worn when working on the FBPS unless a maintenance supervisor confirms and accepts responsibility that the system is shut down and is at ambient temperature, and is cleared of pyrolysis gases.

- Required safety equipment will be in good condition and worn properly. For example, the face shield must completely cover the face, and shirt sleeves must completely cover the arms.

- All electrical circuits, air supply, and bleed lines must be shut off while servicing the FBPS. Switches and valves must be padlocked shut and the keys must be in the possession of the maintenance employees servicing the FBPS.

- All air supply and bleed lines, electrical power circuits, gas supply, and bleed lines that are shut off must have conspicuous, easily read signs giving clear warning that they are shut off because of maintenance work in progress. These signs will be removed by maintenance personnel when maintenance work is complete and before starting up any portion of the FBPS.

Data sheet
Test Samples for FBSS

Date Painted: 22 March 1991

Date Stripped: 4 April 1991
Metal: Steel, 10 4 by 8 in. panels

Sample ID No.	Weights, grams				
	Initial	Coated	Paint, net	Lead, wt.*	Chromium, wt.*
A	1437.9	1468.1	30.2	5.8	1.1
B	1417.3	1445.9	28.6	5.5	1.1
C	1437.3	1472.2	34.9	6.7	1.3
D	1421.5	1480.5	59.0	11.3	2.2
E	1412.4	1477.7	65.3	12.5	2.4
F	1415.9	1474.6	58.7	11.3	2.2
G	1425.5	1453.1	27.6	5.3	1.0
H	1430.7	1486.2	55.5	10.7	2.1
I	1430.0	1487.3	57.3	11.0	2.1
J	1446.9	1500.0	53.1	10.2	2.0
K	1441.4	1485.6	44.2	8.5	1.6

*Calculated from the analysis of the paint.

Data sheet
Test Samples for FBSS

Date Painted: 22 March 1991

Date Stripped: 4 April 1991
Metal: Alumium, 10 4 by 8 in. panels

Sample ID No.	Weights, grams				
	Initial	Coated	Paint, net	Lead, wt.*	Chromium, wt.*
L	416.2	450.8	34.6	6.6	1.3
M	417.3	448.9	31.6	6.1	1.2
N	417.7	448.1	30.4	5.8	1.1
O	416.4	445.3	28.9	5.6	1.1
P	415.8	445.4	29.6	5.7	1.1
R	416.9	464.7	47.8	9.2	1.8
S	416.5	468.3	51.8	9.9	1.9
T	416.3	466.6	50.3	9.7	1.9
U	416.7	447.7	31.0	6.0	1.2
V	415.2	467.6	52.4	10.1	2.0
X	414.9	461.7	46.8	9.0	1.7

---

*Calculated from the analysis of the paint.

Data sheet
Test Samples from the FBSS, Run No. 1

Date Painted: 22 March 1991

Date Stripped: 4 April 1991, 1322 to 1422 hours
10 - 4 by 8 in. metal panels

Sample ID No.	Weights, grams				
/Metal	Paint, net*	Initial**	from FBSS#	from Shot-blast	Gain(+)/Loss(-)
P/Al	29.6	415.8	ND	416.0	+0.2
R/Al	47.8	416.9	ND	416.4	-0.5
V/Al	52.4	415.2	ND	415.0	-0.2
G/steel	27.6	1425.5	ND	1425.5	+0.0
J/steel	53.1	1446.9	ND	1442.9	-4.0
K/steel	44.2	1441.4	ND	1440.4	-1.0

Notes:

*Net weight of paint on all 10 panels

** Uncoated weight.

#ND: not determined, weights from the fluidized bed stripping system.

Data sheet
Test Samples from the FBSS, Run No. 2

Date Painted: 22 March 1991

Date Stripped: 4 April 1991, 1508 to 1609 hours
10 - 4 by 8 in. metal panels

Sample ID No.	Weights, grams					
/Metal	Paint, net*	Initial**	from FBSS#	Tare #	Net, from FBSS##	Gain(+)/Loss(-)
F/steel	58.7	1415.9	1424.4	5.5	1418.9	+3.0
H/steel	55.5	1430.7	1433.8	10.2	1423.6	-7.1
I/steel	57.3	1430.0	1436.1	5.1	1431.0	+1.0
L/Al	34.6	416.2	424.9	8.8	416.1	-0.1
N/Al	30.4	417.7	428.1	9.9	418.2	+0.5
X/Al	46.8	414.9	421.7	6.2	415.5	+0.6

Notes:

*Net weight of paint on all 10 panels

** Uncoated weight.

#These panels were wrapped in PE sheet before weighing, the tare is the weight of the plastic.

##Net weight, all 10 panels, from FBSS, panels were not treated in the shot-blast unit.

Data Sheet
Cadmium Plated Test Samples, runs No. 2 and 3

Unpainted samples
Date Stripped: 4 April 1991, 1508 to 1609 (#2) and 1635 to 1735 (#3) hours
4 by 8 in. steel panels, cadmium plated

			Weight, grams		
Run No.	Sample No.	Cd thickness mils	Initial weight	Final weight	Gain(+)/Loss(-)
2	1	1.00	367.68	367.28	-0.40
2	2	0.50	359.74	359.72	-0.02
2	5	0.50	363.66	363.46	-0.20
2	6	0.25	362.36	362.25	-0.11
2	7	0.50	357.38	357.32	-0.06
2	10	0.50	365.68	365.41	-0.27
Total loss of cadmium (ignores gains)					-1.06
3	3	0.50	360.04	360.05	+0.01
3	4	1.00	358.21	357.90	-0.31
3	8	1.00	349.30	349.25	-0.05
3	9	0.25	362.87	362.89	+0.02
3	11	1.00	364.33	363.75	-0.58
3	12	0.25	351.29	351.59	+0.30
Total loss of cadmium (ignores gains)					-0.94

Note:

The plated panels were a golden bronze before pyrolysis, and they turned brown upon pryolysis. Based on the guage of the plating, a 1.0 mil coating should contain 9.0 grams of cadmium.

Data Sheet
FBPS Start-Up

Date: April 4, 1991

Time	Furnace		After-burner temperatures, °F		Comments
hours	Temp., °F	Air Flow, SCFH	Chamber	Exhaust	
925	450	NR	NR	NR	Furnace heat on, exhaust blower on
933	491	570	NR	NR	Air flow on
1030	600	570	NR	NR	Bed volume was low, added more alumina
1044	539	410	NR	NR	
1125	656	420	1230	190	After-burner turned on
1135	679	440	1263	165	Painted scrap loaded into basket
1140	705	430	1300	184	Scrap lowered into fluidized bed
1145	719	440	1391	222	Pyrolyzing
1150	723	440	1402	210	Pyrolyzing
1158	711	440	1405	225	Pyrolyzing
1207	734	440	1403	167	Pyrolyzing
1217	750	400	1397	159	Pyrolyzing
1238	761	400	1405	150	Parts removed

Data Sheet
FBPS Test Run No. 1

Date: April 4, 1991

Time	Furnace		After-burner temperatures, °F		Water flow*	Comments
hours	Temp., °F	Air Flow, SCFH	Chamber	Exhaust	gpm	
1310	751	330	1399	145	2.95	
1320	750	330	1400	148	NR	
1322	757	330	1401	148	3.00	Basket with samples lowered into bed
1325	776	340	1393	154	NR	Pyrolyzing
1334	763	340	1400	158	NR	Water: 5.0 gal., in 126 sec., sample W-1
1351	774	340	1402	150	2.75	Pyrolyzing, erratic water flow
1400	777	350	1397	152	NR	Pyrolyzing
1414	749	360	1397	148	2.90	Pryolyzing
1422	753	360	1403	151	NR	Basket with samples removed
1430						Sampled fluidized bed, No. FBM-2

Note:

*Rate of flow of quench water, rotameter.

NR: no reading made.

Data Sheet
FBPS Test Run No. 2

Date: April 4, 1991

Time	Furnace		After-burner temperatures, °F		Water flow*	Comments
hours	Temp., °F	Air Flow, SCFH	Chamber	Exhaust	gpm	
1506	750	340	1399	152	NR	Fluidizing air flow increased
1508	767	450	NR	NR	NR	Basket with samples lowered into furnac
1509	757	410	1436	NR	NR	Pyrolyzing
1510	762	410	1422	151	3 0	Photo taken of stack emissions.
1515	725	420	1405	NR	NR	Pyrolyzing
1519	NR	NR	NR	NR	NR	Sampled quench water outlet, W-2
1522	NR	NR	NR	NR	NR	Sampled water inlet, W-3
1535	755	410	1407	152	3.0	Pyrolyzing
1609	738	410	1401	152	3.0	Basket out.

Note:

*Rate of flow of quench water, rotameter.

NR. no reading made.

Data Sheet
FBPS Test Run No. 3

Date: April 4, 1991

Time	Furnace		After-burner temperatures, °F		Water flow*	Comments
hours	Temp., °F	Air Flow, SCFH	Chamber	Exhaust	gpm	
1634	802	410	1403	153	NR	Start
1635	NR	NR	1436	165	NR	Basket & samples lowered into furnace
1638	785	430	1420	NR	3.0	Photo taken of stack emissions.
1645	NR	NR	NR	NR	NR	Sampled quench water outlet, W-4
1710	809	430	1432	149	NR	Pyrolyzing
1715	NR	NR	NR	NR	NR	Sampled quench water outlet, W-5.
1735	NR	NR	NR	NR	NR	Basket with samples was removed.
1742	803	off	236	NR	NR	Fluidizer air was shut-off, unit shut-down.

Note:

*Rate of flow of quench water, rotameter.

NR: no reading made.

IT INTERNATIONAL
TECHNOLOGY
CORPORATION

ATMOSPHERIC EMISSION TEST REPORT
FLUIDIZED-BED PAINT REMOVAL DEMONSTRATION TESTS
LETTERKENNY ARMY DEPOT
CHAMBERSBURG, PENNSYLVANIA

by

IT Air Quality Services
11499 Chester Road
Cincinnati, Ohio 45246

Contract No. DAAA15-88-D-0001
Task Order No. 0007
JTN 816006-002

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June 1991

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INTRODUCTION

On April 4, 1991, personnel from IT Air Quality Services conducted a series of atmospheric emission tests on a pilot fluidized-bed paint stripper (FBPS) located at the Letterkenny Army Depot near Chambersburg, Pennsylvania. Triplicate tests were conducted downstream of a gas-fired afterburner to determine the concentration and mass emission rate of particulate matter and select trace metals (cadmium, total chromium, lead, and zinc). Tests were also conducted to measure total hydrocarbon (THC) emissions. Volumetric gas flow rates, temperature, moisture content, and composition (oxygen and carbon dioxide) were also measured in conjunction with the particulate tests. In addition, select types of process samples (virgin bed material, process bed material, ash, and quench water) were collected during each test and subjected to metals analyses for material balance purposes. Attached Appendices A through E contain all calculations, field data sheets, laboratory data, methods procedures, and calibration data.

Summary of Results and Test Methods Used

Tables 1 through 3 summarize the emission test results. Table 1 presents the measured flue gas conditions, Table 2 presents the particulate and metals emission results, and Table 3 summarizes the THC test results. Process sample analytical results are contained in Appendix C.

TABLE 1. SUMMARY OF FLUE GAS CONDITIONS AT THE AFTERBURNER OUTLET (April 4, 1991)

		Volumetric flow rate				Composition, %	
Run No.	Time (24-h)	acfm[a]	dscfm[b]	Temperature, °F	Moisture, %	O_2	CO_2
AOPM-1	1324-1424	460	271	270	19.1	19.0	1.0
AOPM-2	1509-1609	425	253	261	19.3	19.0	1.0
AOPM-3	1635-1735	426	250	271	19.4	19.0	1.0

[a] acfm = Actual cubic feet per minute.

[b] dscfm = Dry standard cubic feet per minute. Standard conditions are 68°F, 29.92 in.Hg, and zero percent moisture.

TABLE 2. SUMMARY OF PARTICULATE AND METALS EMISSIONS AT THE AFTERBURNER OUTLET (April 4, 1991)

Test No.	Time (24-h)	Particulate emissions			Metals emissions							
		Concentration		Mass emission rate, lb/h	Concentration, µg/m^3				Mass emission rate, lb/h			
		gr/dscf	mg/m^3		Cd	Cr	Pb	Zn	Cd	Cr	Pb	Zn
AOPM-1	1324-1424	0.015	34.6	0.035	10.8	20.5	48.6	90.6	1.1E-05	2.1E-05	4.9E-05	9.2E-05
AOPM-2	1509-1609	0.0049	11.1	0.011	4.6	20.4	51.0	122	4.3E-06	1.9E-05	4.8E-05	1.2E-04
AOPM-3	1635-1735	0.0047	10.9	0.010	9.2	25.5	109	106	8.6E-06	2.4E-05	1.0E-04	9.9E-05

TABLE 3. SUMMARY OF TOTAL HYDROCARBON EMISSION DATA (April 4, 1991)

Run No.	Time (24-h)	THC concentration, ppm (dry)[a]	Average volumetric gas flow rate, dscfm[b]	THC mass emission rate, lb/h
AOPM-1	1324-1424	<13.8	258	<0.009
AOPM-2	1509-1609	<13.8	258	<0.009
AOPM-3	1635-1735	<13.8	258	<0.009

[a] Parts per million by volume (dry basis) as methane. Less than (<) denotes less than instrument detection limit for 0- to 500-ppm range (13.8 ppm).

[b] dscfm = Dry standard cubic feet per minute.

The multimetals/particulate procedures followed those in the U.S. Environmental Protection Agency's (EPA's) "Methodology for the Determination of Trace Metal Emissions From Stationary Source Combustion Processes."* The sampling train was a Method 5 train with two impingers containing a 5 percent nitric acid (HNO_3)/10 percent hydrogen peroxide (H_2O_2) solution. The train uses a quartz fiber filter and a borosilicate glass sampling nozzle to minimize potential blank contamination. Samples were analyzed first for filterable particulate by U.S. EPA Method 5** procedures and then for the specified metals (chromium, cadmium, lead, and zinc) by using both atomic absorption (AA) and inductively coupled argon spectroscopy (ICAS) analysis techniques. Flue gas data were measured concurrently with the particulate/metals measurements.

A Beckman Model 402 continuous-flame ionization analyzer was used to measure THC concentration per Method 25A.** The analyzer pump, particulate filter, and detector are housed in a temperature-controlled oven, which is maintained at 300°F for this test.

The monitor was assembled and calibrated with methane per method specifications. The system sampling probe was located at the centroid of the sampling duct.

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* Methodology for Determination of Trace Metal Emissions From Stationary Source Combustion Processes, September 1989.

** 40 CFR 60, Appendix A, July 1990.

Sample data were recorded continuously for each test using a strip-chart recorder. As noted in Table 3, hydrocarbon emissions were less than 13.8 ppm, which represents the detection limit for the instrument on a 0- to 500-ppm range.

No major problems were encountered during the test program, and results are considered representative of emissions at the time of testing. It should be noted that because of a lack of adequate scaffolding to access both ports, particulate measurements were made using only one of two available sampling ports. A total of four sampling points were used to traverse the cross-sectional area of the 5.75-in.-inside-diameter (i.d.) round duct. Each point was sampled twice over a 60-minute sampling period.

Data Quality Assurance

The procedures described in the Quality Assurance Project Plan were followed in all field sampling analyses.

Routine Reference Method quality control (QC) procedures were followed throughout the test program. These included, but were not limited to, the following:

- Calibration of field sampling equipment. Sampling equipment was calibrated according to the procedures of the "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III," EPA 600/4-72-027B, August 1977. Calibration guidelines and results are described in more detail in Appendix E.

- Onsite audits of dry gas meters, thermocouples, and digital indicators (see Appendix B).

- Train configuration and calculation checks.

- Onsite QC checks of the sampling train and leak checks of the pitot tube and Orsat line.

- Use of designated equipment and reagents.

The sampling equipment and procedures met all the guidelines established in the reference methods.

The laboratory quality assurance (QA) procedures outlined in the Quality Assurance Project Plan were followed for each type of analysis.

The QC procedures used in the sample analysis in this test program included, but were not limited to, the following:

- Use of designated analytical equipment and experienced laboratory personnel.
- Internal and external audits to ensure accuracy in sampling and analysis.
- Reagent, filter, and field blanks to determine blank levels.
- Spiked samples to determine the effect of sample handling and the matrix effect.
- Duplicate analysis of selected samples.

QA/QC data are presented in Appendix C.

COMPUTER PRINTOUTS AND EXAMPLE CALCULATIONS

Nomenclature and Dimensions

A_n = Cross-sectional area of nozzle, ft^2

A_s = Cross-sectional area of stack, ft^2

B_{ws} = Proportion by volume of water vapor in the gas stream, dimensionless

C_p = Pitot tube coefficient, dimensionless

C_s = Concentration of pollutant in stack gas - grains per dry standard cubic foot, gr/dscf

%C = Percent of carbon by weight, dry basis

%CO = Percent of carbon monoxide by volume, dry basis

$\%CO_2$ = Percent of carbon dioxide by volume, dry basis

D_n = Sampling nozzle diameter, inches

D_s = Stack diameter, inches

F = Factor representing a ratio of the volume of dry flue gases generated to the calorific value of the fuel combusted, expressed as dry standard cubic feet per million Btu of heat input, dscf/10^6 Btu

GCV = Gross calorific value of the fuel combusted on a dry basis, Btu/lb

%H = Percent of hydrogen by weight, dry basis

ΔH = Average pressure drop across the sampling meter flow orifice - inches of water, in. H_20

HHV = Higher heating value on an as-received basis, Btu/lb

%ISO = Percent of isokinetic sampling

L_a = Maximum acceptable leakage rate for either a pretest leak check of for a leak check following a component change; equal to 0.020 cubic foot per minute of 4% of the average sampling rate, whichever is less

M_d = Dry molecular weight, lb/lb-mole

m_f = fuel firing rate (measured coal to boiler), lb of coal per hour

M_n = Total amount of pollutant matter collected - milligrams, mg

M_s = Molecular weight of stack gas (wet basis), lb/lb-mole

%N = Percent of nitrogen by weight, dry basis

(continued)

Nomenclature and Dimensions

$\%N_2$ = Percent of nitrogen by volume, dry basis

$\%O$ = Percent of oxygen by weight, dry basis

$\%O_2$ = Percent of oxygen by volume, dry basis

ΔP = Velocity head of stack gas - inches of water, in.H_2O

P_{bar} = Barometric pressure - inches of mercury, in.Hg

P_{stat} = (also P_{si}) Static stack gas pressure - inches of water, in.H_2O

P_s = Absolute stack gas pressure - inches of mercury, in.Hg

P_{std} = Gas pressure at standard conditions - 29.92 inches of mercury, in.Hg

pmr = Pollutant matter emission rate - pounds per hour, lb/h

Q_H = Total heat input - million Btu per hour, 10^6 Btu/h

Q_s = Volumetric flow rate - wet basis at stack conditions - actual cubic feet per minute, acfm

Q_{std} = Volumetric flow rate - dry basis at standard conditions - dry standard cubic feet per minute, dscfm

°R = degrees Rankine = degrees Fahrenheit + 460, °F + 460

$\%S$ = Percent of sulfur by weight, dry basis

T_m = Average temperature of dry gas meter, °R

T_s = Average temperature of stack gas, °R

T_{std} = Temperature at standard conditions, 528 °R

V_{lc} = Total volume of liquid collected in impingers and silica gel, ml

V_m = Volume of dry gas sampled at meter conditions - cubic feet, ft^3

V_{mstd} = Volume of dry gas sampled at standard conditions - cubic feet, ft^3

V_s = Average stack gas velocity at stack conditions - feet per second, ft/s

V_{wstd} = Volume of water vapor at standard conditions - cubic feet, ft^3

Y = Dry gas meter calibration correction factor

θ = Total sampling time, minutes

Example Calculations for Pollutant Emissions

1. Volume of dry gas samples corrected to standard conditions. Note: Vm must be corrected for leakage if any leakage rates exceed La.

$$Vmstd = 17.647 \times Vm \times Y\left[\frac{Pbar + \frac{\Delta H}{13.6}}{Tm}\right]$$

2. Volume of water vapor at standard conditions, ft^3.

$$Vwstd = 0.04707 \times Vlc$$

3. Moisture content in stack gas.

$$Bws = \frac{Vwstd}{Vwstd + Vmstd}$$

4. Dry molecular weight of stack gas.

$$Md = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2 + \%CO)$$

5. Molecular weight of stack gas.

$$Ms = Md(1 - Bws) + 18Bws$$

6. Stack velocity at stack conditions, ft/s.

$$Vs = (85.49)(Cp)\left(avg\sqrt{\Delta P}\right)\sqrt{\frac{Ts}{(Ps)(Ms)}}$$

7. Stack gas volumetric flow rate at stack conditions, cfm. Note: As = square feet.

$$Qs = 60 \times Vs \times As$$

8. Dry stack gas volumetric flow rate at standard conditions, cfm.

$$Qstd = (17.647)(Qs)\left(\frac{Ps}{Ts}\right)(1 - Bws)$$

9. Concentration in micrograms per cubic meter, $\mu g/m^3$

$$Cs = (35.315)\left(\frac{Mn}{Vmstd}\right)$$

(continued)

10. Pollutant mass emission rate, lb/h.

$$pmr = Cs \times \left(6.243 \times 10^{-11}\right) \times Qstd \times 60$$

11. Isokinetic variation, %

$$ISO = \frac{(100)(Ts)\left[(0.0002669\ Vlc) + \left(\frac{Vm}{Tm}\right)(Y)\left(Pbar + \left(\frac{\Delta H}{13.6}\right)\right)\right]}{(60)(\varnothing)(Vs)(Ps)(An)}$$

CORRECTION FACTORS

$$17.647 = \left(\frac{Tstd}{Pstd}\right)$$

$$0.04707 = \left(\frac{ft^3}{ml}\right)$$

0.44 = molecular weight of CO_2/100

0.32 = molecular weight of O_2/100

0.28 = molecular weight of N_2/100

18 = molecular weight of water (H_2O)

$$85.49 = \left[\frac{(lb/lb-mole)(in.Hg)}{(°R)(in.H_2O)}\right]^{\frac{1}{2}}$$

0.01543 = grains per milligram (gr/mg)

$$0.002669 = \frac{(in.Hg.)(ft^3)}{(ml)(°R)}$$

validated 3/8/91

IT AIR QUALITY SERVICES
EMISSION TEST REPORT

FIELD DATA

Plant: Letterkenny, AD
Sampling location: Afterburner Outlet
Test time (start-stop): 1324-1424

Date: 4/4/91
Run number: AOPM-1

Sample type: Part./Metals
Bar. press. (in. Hg): 30.08
Static press. (in. H20): 0.690
Filter number(s): 9170001
Stack inside dia. (in.): 5.75
Pitot tube coeff.: 0.99
Total H2O collected (ml): 163.7
% O2 by volume (dry): 19.0

Volume correction (cu. ft.): 0.000
Meter calibration factor: 0.984
Data interval (min.): 7.5
Nozzle dia. (in.): 0.255
Meter box number: FT-3
Number of traverse points: 8
% CO2 by volume (dry): 1.0
% CO by volume (dry): 0.0

Sample time (min)	Gas meter reading (cu. ft.)	Velocity head ΔP (in. H2O)	Orifice drop actual ΔH (in. H2O)	Stack Temp. (°F)	Dry gas meter temp. (°F)	
					inlet	outlet
0.0	594.366					
7.5	597.110	0.100	0.31	269	77	78
15.0	601.740	0.350	1.09	266	77	77
22.5	606.600	0.360	1.12	267	78	77
30.0	610.370	0.250	0.77	279	81	78
37.5	614.350	0.250	0.78	270	85	79
45.0	619.500	0.400	1.20	271	87	80
52.5	624.640	0.410	1.28	271	88	81
60.0	628.189	0.200	0.63	266	89	83
60.0	**33.823**	**0.290**	**0.90**	**270**	**83**	**79**

IT AIR QUALITY SERVICES
EMISSION TEST REPORT

validated 3/8/91

FIELD DATA

Plant: Letterkenny, AD
Sampling location: Afterburner Outlet
Test time (start-stop): 1509-1609

Date: 4/4/91
Run number: AOPM-2

Sample type: Part./Metals
Bar. press. (in. Hg): 30.08
Static press. (in. H20): 0.690
Filter number(s): 9170003
Stack inside dia. (in.): 5.75
Pitot tube coeff.: 0.84
Total H2O collected (ml): 176.0
% O2 by volume (dry): 19.0

Volume correction (cu. ft.): 0.000
Meter calibration factor: 0.984
Data interval (min.): 7.5
Nozzle dia. (in.): 0.265
Meter box number: FT-3
Number of traverse points: 8
% CO2 by volume (dry): 1.0
% CO by volume (dry): 0.0

Sample time (min)	Gas meter reading (cu. ft.)	Velocity head ΔP (in. H2O)	Orifice drop actual ΔH (in. H2O)	Stack Temp. (°F)	Dry gas meter temp. (°F)	
					inlet	outlet
0.0	631.447					
7.5	635.230	0.380	1.21	258	84	85
15.0	641.130	0.350	1.11	262	86	83
22.5	645.750	0.370	1.17	262	88	83
30.0	650.550	0.300	0.95	262	90	84
37.5	654.720	0.300	0.85	262	91	85
45.0	659.560	0.400	1.14	261	92	86
52.5	664.260	0.410	1.17	264	92	87
60.0	667.660	0.200	0.57	260	93	88
60.0	**36.213**	**0.339**	**1.02**	**261**	**90**	**85**

validated 3/8/91

IT AIR QUALITY SERVICES
EMISSION TEST REPORT

FIELD DATA

Plant: **Letterkenny, AD**
Sampling location: **Afterburner Outlet**
Test time (start-stop): **1635-1735**

Date: **4/4/91**
Run number: **AOPM-3**

Sample type: **Part./Metals**
Bar. press. (in. Hg): **30.08**
Static press. (in. H20): **0.690**
Filter number(s): **9170002**
Stack inside dia. (in.): **5.75**
Pitot tube coeff.: **0.84**
Total H2O collected (ml): **169.4**
% O2 by volume (dry): **19.0**

Volume correction (cu. ft.): **0.000**
Meter calibration factor: **0.984**
Data interval (min.): **7.5**
Nozzle dia. (in.): **0.265**
Meter box number: **FT-3**
Number of traverse points: **8**
% CO2 by volume (dry): **1.0**
% CO by volume (dry): **0.0**

Sample time (min)	Gas meter reading (cu. ft.)	Velocity head ΔP (in. H2O)	Orifice drop actual ΔH (in. H2O)	Stack Temp. (°F)	Dry gas meter temp. (°F)	
					inlet	outlet
0.0	667.812					
7.5	671.400	0.230	0.66	264	90	90
15.0	676.100	0.360	1.02	270	89	88
22.5	681.000	0.390	1.10	270	90	88
30.0	685.220	0.320	0.90	275	91	87
37.5	689.350	0.320	0.90	276	91	88
45.0	693.040	0.400	1.13	273	93	88
52.5	699.000	0.420	1.18	272	93	88
60.0	702.650	0.240	0.68	268	92	89
60.0	**34.838**	**0.335**	**0.95**	**271**	**91**	**88**

IT AIR QUALITY SERVICES
EMISSION TEST REPORT

validated 3/8/91

TEST RESULTS

Plant: **Letterkenny, AD**
Sampling location: **Afterburner Outlet**

	Test date(s):	4/4/91	4/4/91	4/4/91	
		Run Numbers			
		AOPM-1	AOPM-2	AOPM-3	AVERAGE
Ø	Net time of test (min)	60.0	60.0	60.0	
NP	Net sampling points	8	8	8	
Y	Meter calibration factor	0.984	0.984	0.984	
Dn	Sampling nozzle diameter (in)	0.255	0.265	0.265	
Cp	Pitot tube coefficient	0.99	0.84	0.84	
ΔH	Average orifice pressure drop (in. H_2O)	0.90	1.02	0.95	0.96
Vm	Volume of dry gas sampled at meter conditions (cu. ft.)	33.823	36.213	34.838	34.958
Tm	Average gas meter temperature (°F)	80.9	87.3	89.7	86.0
Vmstd	Volume of dry gas sampled at standard conditions (scf)	32.731	34.646	33.181	33.519
Vlc	Total H_2O collected in impingers and silica gel (ml)	163.7	176.0	169.4	169.7
Vwstd	Volume of water vapor at standard conditions (scf)	7.705	8.284	7.974	7.988
Bws	Percent moisture by volume, as measured	19.06	19.30	19.38	19.24
	Percent moisture by volume, at saturation	100.00	100.00	100.00	100.00
	Percent moisture by volume, used in calculations	19.06	19.30	19.38	19.24
Fmd	Mole fraction of dry gas	0.809	0.807	0.806	0.808
%CO_2	Percent CO_2 by volume (dry)	1.0	1.0	1.0	1.0
%O_2	Percent O_2 by volume (dry)	19.0	19.0	19.0	19.0
%CO	Percent CO by volume (dry)	0.0	0.0	0.0	0.0
%N_2	Percent N_2 by volume (dry)	80.0	80.0	80.0	80.0
Md	Molecular weight - dry stack gas	28.92	28.92	28.92	28.92
Ms	Molecular weight - stack gas	26.84	26.81	26.80	26.82
Pbar	Barometric pressure (in. Hg)	30.08	30.08	30.08	30.08
Psi	Static pressure of stack gas (in. H_2O)	0.690	0.690	0.690	0.690
Ps	Stack pressure - absolute (in. Hg)	30.13	30.13	30.13	30.13
Ts	Average stack gas temperature (°F)	269.9	261.4	271.0	267.4

IT AIR QUALITY SERVICES
EMISSION TEST REPORT

validated 3/8/91

TEST RESULTS

Plant: **Letterkenny, AD**
Sampling location: **Afterburner Outlet**

Test date(s): 4/4/91 4/4/91 4/4/91

			Run Numbers AOPM-1	AOPM-2	AOPM-3	AVERAGE
Vh	Average square root of velocity head (in. H2O)	....	0.5285	0.5790	0.5757	**0.5611**
Vs	Average stack gas velocity (feet/sec.)	....	42.49	39.29	39.33	**40.37**
As	Stack area (sq. in.)	....	26.0	26.0	26.0	**26.0**
Qs	Actual stack flow rate (acfm)	....	460	425	426	**437**
Qsstd	Stack flow rate - dry (scfm)	....	271	253	250	**258**
ISO	Percent isokinetic	....	102.3	107.5	104.3	**104.7**

		Mass of pollutant	=	32.1	10.9	10.2	
		If below detection limits, replace 0 with 1.		0	0	0	
Mn	**Particulate**	**mass**	**mg**	**32.1**	**10.9**	**10.2**	
Cs	**Particulate**	**concentration**	**gr/dscf**	**1.513E-02**	**4.854E-03**	**4.743E-03**	**8.243E-03**
Pmr	**Particulate**	**emission rate**	**lb/h**	**3.516E-02**	**1.052E-02**	**1.015E-02**	**1.861E-02**
		Mass of pollutant	=	10.0	4.5	8.6	
		If below detection limits, replace 0 with 1.		0	0	0	
Mn	**Cadmium**	**mass**	**µg**	**10.0**	**4.5**	**8.6**	
Cs	**Cadmium**	**concentration**	**µg/m3**	**10.789**	**4.587**	**9.153**	**8.176**
Pmr	**Cadmium**	**emission rate**	**lb/h**	**1.095E-05**	**4.344E-06**	**8.556E-06**	**7.951E-06**
		Mass of pollutant	=	19.0	20.0	24.0	
		If below detection limits, replace 0 with 1.		0	0	0	
Mn	**Chromium**	**mass**	**µg**	**19.0**	**20.0**	**24.0**	
Cs	**Chromium**	**concentration**	**µg/m3**	**20.500**	**20.386**	**25.544**	**22.143**
Pmr	**Chromium**	**emission rate**	**lb/h**	**2.081E-05**	**1.931E-05**	**2.388E-05**	**2.133E-05**

BLY
5-6-91

IT AIR QUALITY SERVICES
EMISSION TEST REPORT

validated 3/8/91

TEST RESULTS

Plant: **Letterkenny, AD**
Sampling location: **Afterburner Outlet**

Test date(s): **4/4/91** **4/4/91** **4/4/91**

				Run Numbers			
				AOPM-1	**AOPM-2**	**AOPM-3**	**AVERAGE**
		Mass of pollutant	=	45.0	50.0	102.0	
		If below detection limits, replace 0 with 1.		0	0	0	
Mn	**Lead**	**mass**	µg	**45.0**	**50.0**	**102.0**	
Cs	**Lead**	**concentration**	µg/m3	**48.552**	**50.965**	**108.560**	**69.359**
Pmr	**Lead**	**emission rate**	lb/h	**4.930E-05**	**4.826E-05**	**1.015E-04**	**6.634E-05**
		Mass of pollutant	=	84.0	120.0	100.0	
		If below detection limits, replace 0 with 1.		0	0	0	
Mn	**Zinc**	**mass**	µg	**84.0**	**120.0**	**100.0**	
Cs	**Zinc**	**concentration**	µg/m3	**90.630**	**122.315**	**106.432**	**106.459**
Pmr	**Zinc**	**emission rate**	lb/h	**9.202E-05**	**1.158E-04**	**9.948E-05**	**1.024E-04**
		Mass of pollutant	=	0.0	0.0	0.0	
		If below detection limits, replace 0 with 1.		0	0	0	
Mn	**<pollutant>**	**mass**	mg	**0.0**	**0.0**	**0.0**	
Cs	**<pollutant>**	**concentration**	gr/dscf	**0.000E+00**	**0.000E+00**	**0.000E+00**	**0.000E+00**
Pmr	**<pollutant>**	**emission rate**	lb/h	**0.000E+00**	**0.000E+00**	**0.000E+00**	**0.000E+00**
		Mass of pollutant	=	0.0	0.0	0.0	
		If below detection limits, replace 0 with 1.		0	0	0	
Mn	**<pollutant>**	**mass**	mg	**0.0**	**0.0**	**0.0**	
Cs	**<pollutant>**	**concentration**	gr/dscf	**0.000E+00**	**0.000E+00**	**0.000E+00**	**0.000E+00**
Pmr	**<pollutant>**	**emission rate**	lb/h	**0.000E+00**	**0.000E+00**	**0.000E+00**	**0.000E+00**
		Mass of pollutant	=	0.0	0.0	0.0	
		If below detection limits, replace 0 with 1.		0	0	0	
Mn	**<pollutant>**	**mass**	mg	**0.0**	**0.0**	**0.0**	
Cs	**<pollutant>**	**concentration**	gr/dscf	**0.000E+00**	**0.000E+00**	**0.000E+00**	**0.000E+00**
Pmr	**<pollutant>**	**emission rate**	lb/h	**0.000E+00**	**0.000E+00**	**0.000E+00**	**0.000E+00**

BZH
5-6-91

FIELD DATA SHEETS

TRAVERSE POINT LOCATION FOR CIRCULAR DUCTS

ant *Letterkenny Army Depot*

Date *4/3/91*

Sampling location *Afterburner Outlet*

Inside of far wall to outside of nipple *5 3/4"*

Inside of near wall to outside of nipple (nipple length):

- NA -

Stack inside diameter, inches *5 3/4"*

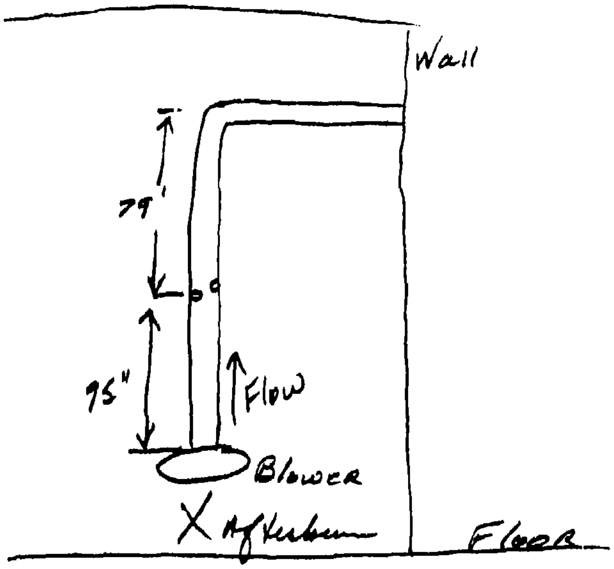
Distance downstream from flow disturbance (Distance B):

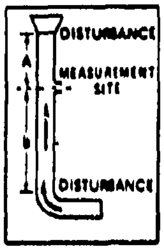
95" inches / diameter = ________ dd

Distance upstream from flow disturbance (Distance A):

79 ft. inches / diameter = ________ dd

Calculated by *SB*





SCHEMATIC OF SAMPLING LOCATION

TRAVERSE POINT NUMBER	FRACTION OF STACK I.D.	STACK I.D.	PRODUCT OF COLUMNS 2 AND 3 (TO NEAREST 1/8 INCH)	NIPPLE LENGTH	TRAVERSE POINT LOCATION FROM OUTSIDE OF NIPPLE (SUM OF COLUMNS 4 & 5)
1	.067	5 3/4"	0.385	NA	0.5
2	.25		1.44		1 3/8"
3	.75		4.31		4 1/4"
4	.933		5.36		5 3/8"

FIELD AUDIT REPORT: DRY GAS METER
BY CRITICAL ORIFICE

DATE: 4/3/91

CLIENT: USATHAMA (LetterKenny)

BAROMETRIC PRESSURE (P_{bar}): 30.11 in.Hg

METER BOX NO. FT-3

ORIFICE NO. 1

PRETEST Y: .984 ΔH@ 1.75 in.H_2O

ORIFICE K FACTOR: 4.738×10⁻⁴

AUDITOR: 83

Orifice manometer reading ΔH, in.H_2O	Dry gas meter reading V_i/V_f, ft³	Temperatures: Ambient T_{ai}/T_{af}, °F	Ambient Average T_a, °F	Dry gas meter Inlet T_{ii}/T_{if}, °F	Dry gas meter Outlet T_{oi}/T_{of}, °F	Dry gas meter Average T_m, °F	Duration of run θ min.
1.65 @ 22" Hg	576.5	60	63.5	59	55	59.25	15:36.06
	588.10	67		64	59		15.601

Dry gas meter V_m, ft³	$V_{m_{std}}$, ft³	$V_{m_{act}}$, ft³	Audit, Y	Y deviation, %	Audit ΔH@, in.H_2O	ΔH@ Deviation, in.H_2O
11.6	11.918	11.702	0.981	0.3 ✓	1.68	-0.07 ✓

$$V_{m_{std}} = \frac{17.647(V_m)(\overset{30.11}{P_{bar}} + \overset{1.65}{\cancel{\Delta H}}/13.6)}{(\underset{59.25}{\cancel{T_m}} + 460)} = 11.918 \text{ ft}^3$$

$$V_{m_{act}} = \frac{1203(\theta)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 11.702 \text{ ft}^3$$

$$\text{Audit } Y = \frac{V_{m_{act}}}{V_{m_{std}}} = \qquad Y \text{ deviation} = \frac{\overset{\text{Pre}}{\cancel{\text{Audit}}}\ Y - \overset{\text{audit}}{\cancel{\text{Pretest}}}\ Y}{\text{Pretest } Y} \times 100 =$$

$$\text{Audit } \Delta H@ = (0.0317)(\Delta H)(P_{bar})(T_m + 460)\left[\frac{\theta}{Y\,(V_m)(P_{bar} + \Delta H/13.6)}\right]^2 = 1.68 \text{ in.}H_2O$$

Audit Y must be in the range, pretest Y ±0.05 Y.
Audit ΔH@ must be in the range pretest ΔH@ ±0.15 inches H_2O.

THERMOCOUPLE DIGITAL INDICATOR
AUDIT DATA SHEET

Date 4/3/91 Indicator No. FT-3 Operator (SB)

STALK ONLY * Test Point No.	Millivolt signal*	Equivalent temperature, °F*	Digital indicator temperature reading, °F	Difference, %
1		0	-4	–
2		100 200	98 199	0.36 0.15
3		300 400	298 397	0,39 0,35
4		500 600	499 599	0,10 0.09

* Others Checked (Filter, Probe, Amp.) ⇒ ok (SB) 4/3/91

Percent difference must be less than or equal to 0.5%.

Percent difference:

$$\frac{(\text{Equivalent temperature }^\circ R - \text{Digital indicator temperature reading }^\circ R)(100\%)}{(\text{Equivalent temperature }^\circ R)}$$

Where °R = °F + 460°F

* These values are to be obtained from the calibration data sheet for the calibration device.

EMISSION TESTING FIELD DATA

PLANT AND CITY	DATE	SAMPLING LOCATION	SAMPLE TYPE	RUN NUMBER
Letterkenny AD	4/4/91	Afterburner Outlet	Part./Metals	AOPM-1

OPERATOR(S)	BAR. PRESS. (in. Hg)	STATIC PRESS. (in. H$_2$O)	AMB. TEMP. (°F)	FILTER NUMBER(S)	STACK INSIDE DIA. (in.)		PITOT TUBE Cp	PROBE LENGTH AND TYPE	NOZZLE I.D.	NOZZLE NUMBER
(B)/PF	30.08	~~±1.5~~ +0.69	65	9170001	5 3/4		.99	2' Glass	.255	#1 Glass

PITOT => std.

MOISTURE (%)	METER BOX NO.	METER ΔH@	METER CAL FACTOR (Y)	THERM. NO.	PITOT NO.	IMP. THERM. NO.	ORSAT NO.	TRAIN LEAK CHECK (INITIAL) in. Hg	TRAIN LEAK CHECK (INITIAL) CFM	TRAIN LEAK CHECK (FINAL) in. Hg	TRAIN LEAK CHECK (FINAL) CFM	K FACTOR	PROBE HEAT (°F)	BOX HEAT (°F)	PITOT LEAK CHECK INIT.	PITOT LEAK CHECK FINAL
10	FT-3	1.75	.984	646	502	I-13	–	16	0.004	4	0.01	4.2	250	250	/	/

TRAVERSE POINT NUMBER	SAMPLING TIME, min.	CLOCK TIME (24-hr CLOCK)	GAS METER READING (Vm), ft^3	0.29 ave. VELOCITY HEAD (ΔP), in. H$_2$O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H$_2$O DESIRED	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H$_2$O ACTUAL	STACK TEMP. (Ts), °F	DRY GAS METER TEMPERATURE INLET (Tm in), °F	DRY GAS METER TEMPERATURE OUTLET (Tm out), °F	PUMP VACUUM, in. Hg	SAMPLE BOX TEMP., °F	IMPINGER TEMP., °F
	0	1324	594.366									
A-1	7.5		597.11	~~24~~ .10	0.31	0.31	269	77	78	1.0	253	79
2	15		601.74	.35	1.09	1.09	266	77	77	1.5	254	68
3	22.5		606.60	.36	1.12	1.12	267	78	77	2	253	67
4	30	1354	610.37	.25	0.77	0.77	279	81	78	2	255	71
A 4	37.5		614.35	.25	0.78	0.78	270	85	79	2	254	75
3	45		619.50	.40	1.40	1.40	271	87	80	2	253	67
2	52.5		624.64	.41	1.28	1.28	271	88	81	3	253	66
1	60	1424	628.189	.20	0.63	0.63	266	89	83	2	253	65

x.72

x.65

X1-04-060

~~LEAD~~ PART/METALS SAMPLE RECOVERY AND INTEGRITY SHEET

Plant Letterkenny Army Depot Sample date 4-4-91
Sample location Afterburner outlet Recovery date 4-4-91
Run number ABPM-1 Recovered by DF/KB
Filter number(s) 9170001

MOISTURE

	Impingers 1	2	3		Silica gel 4 * with cap.	
Final volume (wt)	254.4	572.6	500.2	ml (g)	Final wt 719.1	g
Initial volume (wt)	121.2	553.2	497.8	ml (g)	Initial wt 710.4	g
Net volume (wt)	133.2	19.4	2.4	ml (g)	Net wt 8.7	g
					5	% spent

Description of impinger water CLEAR

Total moisture 163.7 g

RECOVERED SAMPLE

Filter container number(s) 15361 B Sealed ✓
Description of particulate on filter light yellowish; some loose sand (Al_2O_3) particles.

Acetone probe rinse container no.	15361 A	Liquid level marked	✓
Acetone blank container no.	15360 A	Liquid level marked	✓
0.1 N HNO_3 probe rinse container no.	N/A	Liquid level marked	
Impinger contents container no.	15362 A	Liquid level marked	✓
0.1 ~~N HNO_3~~ HNO_3/H_2O_2 blank container no.	15359 A	Liquid level marked	✓

Samples stored and locked
Remarks FILTER BLANK CONTAINER NO. 15359 B

LABORATORY CUSTODY

Received by Nicholas W. Plummer IAS Date 4/19/91 09:31 am
Remarks Samples received in good condition, however no chain-of-custody seals were present on individual samples or shipping containers. NWP

EMISSION TESTING FIELD DATA

PLANT AND CITY	DATE	SAMPLING LOCATION	SAMPLE TYPE	RUN NUMBER
Letterkenny AD	4/4/91	Afterburner Outlet	Part./Metals	AOPM-2

OPERATOR(S)	BAR. PRESS. (in. Hg)	STATIC PRESS. (in. H_2O)	AMB. TEMP. (°F)	FILTER NUMBER(S)	STACK INSIDE DIA. (in.)		PITOT ⇒ S-Type TUBE Cp	PROBE LENGTH AND TYPE	NOZZLE I.D.	NOZZLE NUMBER
RJ/PF	30.08	+.69	70	917 0003	5 3/4"		.84	3' Glass	.265	#2 Glass

MOISTURE (%)	METER BOX NO.	METER ΔH@	METER CAL. FACTOR (Y)	THERM. NO.	PITOT NO.	IMP. THERM. NO.	ORSAT NO.	TRAIN LEAK CHECK (INITIAL) in. Hg	TRAIN LEAK CHECK (INITIAL) CFM	TRAIN LEAK CHECK (FINAL) in. Hg	TRAIN LEAK CHECK (FINAL) CFM	K FACTOR	PROBE HEAT (°F)	BOX HEAT (°F)	PITOT LEAK CHECK INIT.	PITOT LEAK CHECK FINAL
10	FT3	1.75	.984	646	502	I-13	—	15	0.0	5	0.0	4.2	250	250	—	—

3.75 ⇒ Change @ pt. 5 for Bias Correction

TRAVERSE POINT NUMBER	SAMPLING TIME, min.	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft³	VELOCITY HEAD (ΔP), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O DESIRED	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O ACTUAL	STACK TEMP. (T_s), °F	DRY GAS METER TEMPERATURE INLET (T_m in), °F	DRY GAS METER TEMPERATURE OUTLET (T_m out), °F	PUMP VACUUM, in. Hg	SAMPLE BOX TEMP., °F	IMPINGER TEMP., °F
	0	1509	631.447									
A1	7.5		635.23	.38	1.21	1.21	258	84	85	2	238	70
2	15		641.13	.35	1.11	1.11	262	86	83	2	241	67
3	22.5		645.75	.37	1.17	1.17	262	88	83	2	252	66
4	30	1539	650.55	.30	0.95	0.95	262	90	84	2	257	65
~~A~~ 4	37.5		654.72	.30	0.85	0.85	262	91	85	2	256	64
3	45		659.56	.40	1.14	1.14	261	92	86	2	257	68
2	52.5		664.26	.41	1.17	1.17	264	92	87	3	256	66
1	60	1609	667.666	.20	0.57	0.57	260	93	88	2	257	67
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			.									
			.									

XI-04-060

~~LEAD~~ PART/METALS SAMPLE RECOVERY AND INTEGRITY SHEET

Plant Letterkenny Army Depot Sample date 4-4-91
Sample location Afterburner outlet Recovery date 4-4-91
Run number ACAM-2 Recovered by PF/GB
Filter number(s) 9170003

MOISTURE

Impingers	1	2	3		Silica gel	4	
Final volume (wt)	722.6	609.7	490.3	ml (g)	Final wt	721.1	g
Initial volume (wt)	590.2	583.1	486.7	ml (g)	Initial wt	707.7	g
Net volume (wt)	132.4	26.6	3.6	ml (g)	Net wt	13.4	g
Description of impinger water	clear					50	% spent

Total moisture 176.0 g

RECOVERED SAMPLE

Filter container number(s) 15363 B Sealed ✓
Description of particulate on filter light yellowish some loose sand

Acetone probe rinse container no.	15363 A	Liquid level marked	✓
Acetone blank container no.	15360 A	Liquid level marked	✓
0.1 N HNO_3 probe rinse container no.	NA	Liquid level marked	
Impinger contents container no.	15364 A	Liquid level marked	✓
0.1 N ~~HNO_3~~ HNO_3/H_2O_2 blank container no.	15359 A	Liquid level marked	✓

Samples stored and locked
Remarks

LABORATORY CUSTODY

Received by Phillip W. Plummer [illegible] Date 4/9/91 09:30am
Remarks Samples received in good condition, however no chain-of-custody seals were present either on individual samples or shipping containers. NWP

EMISSION TESTING FIELD DATA

PLANT AND CITY	DATE	SAMPLING LOCATION	SAMPLE TYPE	RUN NUMBER
Letterkenny AD	4/4/91	Afterburner Outlet	Part./Metals	AOPM-3

OPERATOR(S)	BAR. PRESS. (in. Hg)	STATIC PRESS. (in. H_2O)	AMB. TEMP. (°F)	FILTER NUMBER(S)	STACK INSIDE DIA. (in.)		PITOT TUBE Cp	PROBE LENGTH AND TYPE	NOZZLE I.D.	NOZZLE NUMBER
83/PF	30.08	+.69	70	9170002	5 3/4		.84	2' Glass	~~[illegible]~~ .263	#1 Glass

MOISTURE (%)	METER BOX NO.	METER ΔH@	METER CAL. FACTOR (Y)	THERM. NO.	PITOT NO.	IMP. THERM. NO.	ORSAT NO.	TRAIN LEAK CHECK (INITIAL) in. Hg	TRAIN LEAK CHECK (INITIAL) CFM	TRAIN LEAK CHECK (FINAL) in. Hg	TRAIN LEAK CHECK (FINAL) CFM	K FACTOR	PROBE HEAT (°F)	BOX HEAT (°F)	PITOT LEAK CHECK INIT.	PITOT LEAK CHECK FINAL
10	FT3	1.75	.984	641	502	I-13	–	17	0.001	5	0.0	3.75	250	250	✓	✓

TRAVERSE POINT NUMBER	SAMPLING TIME, min.	CLOCK TIME (24-hr CLOCK)	GAS METER READING (Vm), ft³	VELOCITY HEAD (ΔP), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O DESIRED	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O ACTUAL	STACK TEMP. (Ts), °F	DRY GAS METER TEMPERATURE INLET (T_m in), °F	DRY GAS METER TEMPERATURE OUTLET (T_m out), °F	PUMP VACUUM, in. Hg	SAMPLE BOX TEMP., °F	IMPINGER TEMP., °F
	0	1635	667.812									
A-1	7.5		671.40	.23 .28	0.66	0.66	264	92	90	2	252	62
2	15		676.10	.34 .60	1.02	1.02	270	89	88	2	256	60
3	22.5		681.00	.39 .60	1.10	1.10	270	90	88	2	257	55
4	30	1705	685.22	.32 .26	0.90	0.90	275	91	87	2	256	55
B-4	37.5		689.35	.32 .25	0.90	0.90	276	91	88	3	257	58
3	45		693.04	.40 .60	1.13	1.13	273	93	88	3	250	60
2	52.5		699.00	.42 .80	1.18	1.18	272	93	88	3	249	51
1	60	1735	702.650	.24 .30	0.68	0.68	268	~~89~~ 92	89	2	243	69

X1-04-060

~~LEAD~~ PART/METALS SAMPLE RECOVERY AND INTEGRITY SHEET

Plant Letterkenny Army Depot   Sample date 4-4-91
Sample location AFTERBURNER OUTLET   Recovery date 4-4-91
Run number ACAA-3   Recovered by AF/CB
Filter number(s) 411G002

MOISTURE

Impingers	1	2	3	
Final volume (wt)	787.7	616.5	491.9	ml (g)
Initial volume (wt)	600.0	595.6	490.	ml (g)
Net volume (wt)	187.7	20.9	1.9	ml (g)

Description of impinger water Clear

Silica gel		
Final wt	724.9	g
Initial wt	716.0	g
Net wt	8.9	g
	10	% spent

Total moisture 219.4 g

RECOVERED SAMPLE

Filter container number(s) 15365 B   Sealed ✓
Description of particulate on filter LIGHT YELLOWISH TINT SOME SAND

Acetone probe rinse container no.	15365 A	Liquid level marked	✓
Acetone blank container no.	15360 A	Liquid level marked	✓
0.1 N HNO3 probe rinse container no.	N/A	Liquid level marked	
Impinger contents container no.	15366 A	Liquid level marked	✓
0.1 N HNO3/H2O2 blank container no.	15359 A	Liquid level marked	✓

Samples stored and locked ✓
Remarks

LABORATORY CUSTODY

Received by Nichole W. Plummer ITAS   Date 4/9/91 0930
Remarks Samples received in good condition, without chain of custody seals on individual samples or shipping container NWP

INITIAL CEM CALIBRATION AND PERFORMANCE EVALUATION

Plant LETTERKENNY ARMY DEPOT
Location CHAMBERSBURG, PA
Date 4 4 91
Operator R Fitzgerald
PN 8251014

Parameter SO_2, CO_2, O_2, NO_x, [✓ THC]
Monitor BECKMAN 402
Span value [✓ ppm] or % 567.3
Chart scale 100
Pbar, in.Hg 30.08

Cylinder No.	Cal. gas conc., ppm or %	Chart divisions: Direct injection to monitor	Chart divisions: Injection through system	Concentration predicted by equation,* Direct	Concentration predicted by equation,* System	Calibration error,** % of span	Sampling system bias,*** % of span
ALM 96855	501	88.0	90.8	501.6	512.4	-.1	-1.9
ALM 008765	300	55.0	56.8	298.6	309.1	.2	-1.9
ALM 000191	99.93	21.8	23.0	100.4	107.6	-.1	-1.3
	0	5.0	6.3	.12	7.9	-.02	-1.4

* Perform linear regression of pretest cal. gas concentration vs. chart divisions to determine following equation:

y = mx + b x = ppm y = chart division

567.3 ppm

For data reduction:

$$\text{Pollutant ppm/\%} = \frac{(\text{Chart division} - b)}{m} = \frac{(\text{CD} - 4.98)}{(.1475)}$$

Correlation coef. = .99999

Calculation concentration predicted by equation using actual chart response obtained from each calibration gas response.

$$\text{** Calibration error, \% span} = \frac{(\text{Concentration of cal. gas, ppm} - \text{predicted conc., ppm})}{\text{Span, ppm}} \times 100$$

Acceptable limit = ±2% each gas (THC limit is ±5%).

*** Sampling system bias =

$$\frac{(\text{Direct injection gas conc.} - \text{system injection gas conc.}) \times 100}{\text{Span value}}$$

Acceptable limit ≤5% of span

Minimum detectable limit = 2 percent of span or 11.3 [✓ ppm] or % (circle one)

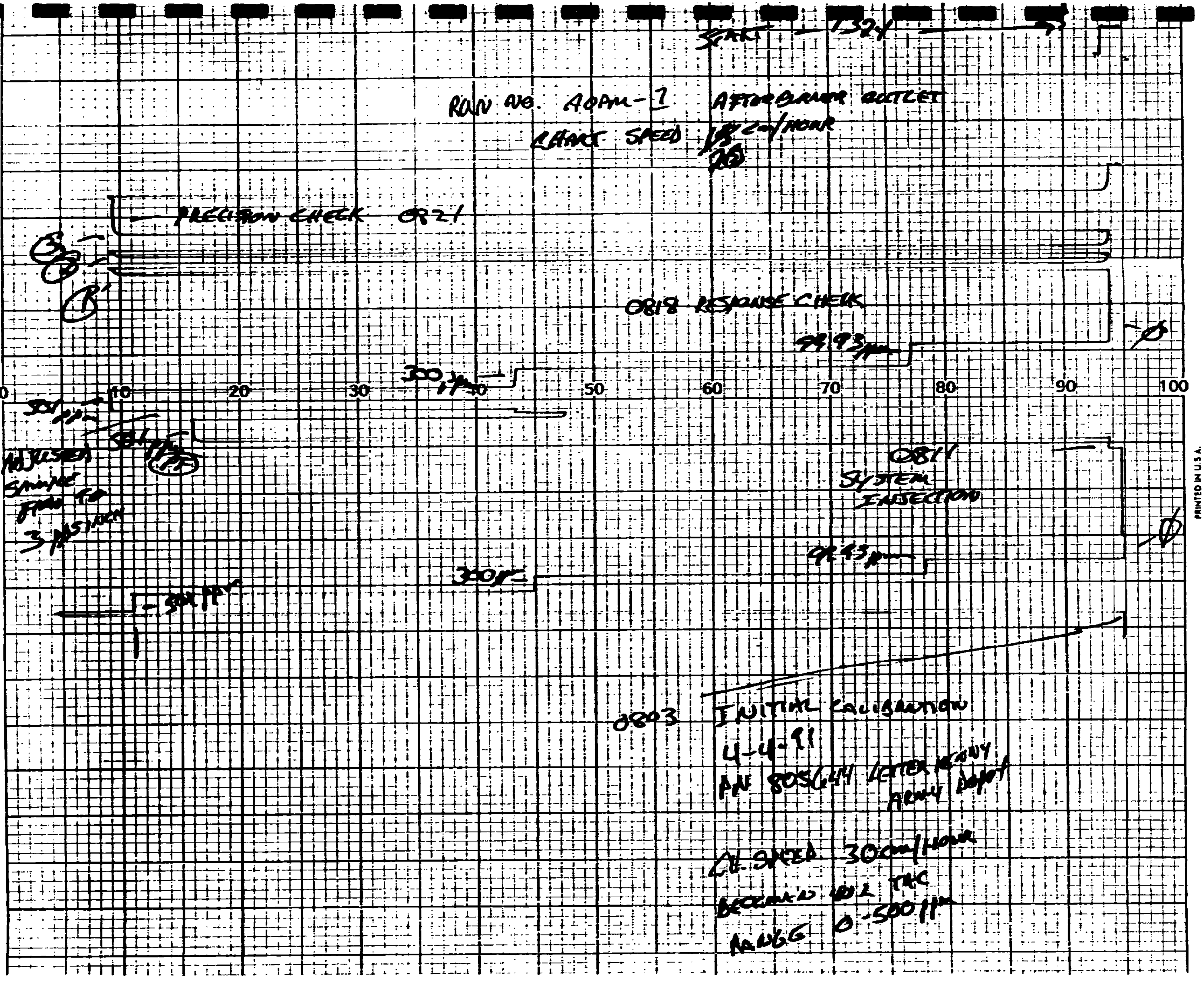
Rise time to 95% of response for high cal. gas injected through system (return to zero after each injection):

8.5 s, 8.5 s, 8.5 s Avg. 8.5 s

Precision, % scale = difference in chart division response for two repeated injections of the same gas concentration = 90.8 - 90.5 = .3 % (clock time = 0821)

COMMENTS:

JK
4-8-91


START — 1324
RUN NO. ADAM-1 AFTERBURNER OUTLET
CHART SPEED 1/8 20 cm/HOUR
PRECISION CHECK 0821
3
B
B'
0818 RESPONSE CHECK
98.93ppm
–0
300 ppm
0
10
20
30
40
50
60
70
80
90
100
301 ppm
301 ppm
ADJUSTED SPIKE FLOW TO 3 MIS/INCH
0811
SYSTEM INJECTION
–0
98.93ppm
300ppm
–301 ppm
0803 INITIAL CALIBRATION
4-4-91
AN 805644 LETTERKENNY ARMY DEPOT
CH. SPEED 300cm/HOUR
BECKMAN 402 THC
RANGE 0-500 ppm
PRINTED IN U.S.A.

Plant Letterkenny Army Depot

Location E Afterburner Outlet

Date 4-11-91

Operator D. Fitzgerald

PN 805164N

Time, Pretest 0811 Post-test 1741

Run No. AOPM-1, AOPM-2, AOPM-3

Parameter SO_2, CO_2, O_2, NO_x, [✓ THC]

Monitor Beckman 402

Span value [✓ ppm] or % 555.9

Chart scale 100 ~~555.9~~

Pbar, in.Hg 30.08

Tamb, °F 70°

Cylinder No.	Cal. gas conc., ppm or %	Chart divisions		Concentration predicted by equation*		Analyzer calibration error,** % of span	Drift,*** % of span
		Pretest	Posttest	Pretest	Posttest		
ALM 016855	501	90.8	88.5	501.4	487.7	-.07	2.5
ALM 006755	300	56.8	55.5	299.8	292.1	04	1.4
ALM 006791	99.93	23.0	22.8	99.5	98.3	.08	.22
	0	6.3	6.3	.5	.5	-.09	0

* Perform linear regression of pretest cal. gas concentration vs. chart divisions to determine following equation:

$y = mx + b$ x = ppm y = chart division

For data reduction:

$$\text{Pollutant ppm/\%} = \frac{(\text{Chart division} - b)}{m} = \frac{(CD - 6.22)}{(.1687)}$$

Correlation coef. = 99999

** Analyzer cal. error, % span = $\frac{(\text{Cal. gas conc.} - \text{conc. predicted}) \times 100}{\text{Span value}}$

Acceptable limit = ≤2% of span (±5% for THC).

*** Drift % span = $\frac{(\text{Posttest cal. response} - \text{initial cal. response}) \times 100}{\text{Span value}}$

Acceptable limit ≤3% of span

Minimum detectable limit = 2% of span or 11.1 [✓ ppm] or % (circle one)

Maximum zero drift = 0 % of span or ______ ppm or % (circle one)

Maximum cal. drift = 25 % of span or ______ ppm or % (circle one)

COMMENTS: Pretest or posttest (circle one) calibration used to quantitate sample data. Posttest is used if drift exceeds limits and if posttest yields higher concentrations.

JK
4-8-91

CEM DATA REDUCTION SHEET FOR BAG ANALYSIS OR STEADY READINGS

Date 4·4·91 Parameter SO_2, NO_x,* CO_2, O_2, [✓ THC], CO

Operator P. Fitzgerald PN 805644 Location AFTERBURNER OUTLET

Pollutant ppm/% $= \frac{(\text{Chart division - b})}{m} = \frac{(\text{CD} - 6.22)}{(.1687)}$

Run No.	Time** (24-H)	Average chart division	Conc.	Comments
AOAM-1	1324-1334	8.5	13.5	
	1334-1344	7.8	9.4	UNDER THE DETECTION LIMIT OF 11.1 ppm
	1344-1354	7.8	9.4	
	1354-1404	7.8	9.4	
	1404-1414	7.8	9.4	
	1414 1424	7.5	7.6	
AOAM-2	1507-1519	7.0	4.6	BELOW THE DETECTION LIMIT
	1519-1529	6.8	3.4	
	1529-1539	6.8	3.4	
	1535-1549	6.8	3.4	
	1549-1559	6.8	3.4	
	1559 - [illegible]	6.8	3.4	

* For NO_x indicate whether NO, NO + NO_2, or NO_2 for specific interval.

** Indicate whether time interval is from beginning of first time to beginning of second time or to end of second time (circle one, or describe alternate).

Calculated by on 4-4-91 Checked by JK on 4-8-91

JK 4-8-91

CEM DATA REDUCTION SHEET FOR BAG ANALYSIS OR STEADY READINGS

Date 4-4-91 Parameter SO_2, NO_x,* CO_2, O_2, [✓ THC] CO

Operator P. Fitzgerald PN 805644 Location AFTERBURNER OUTLET

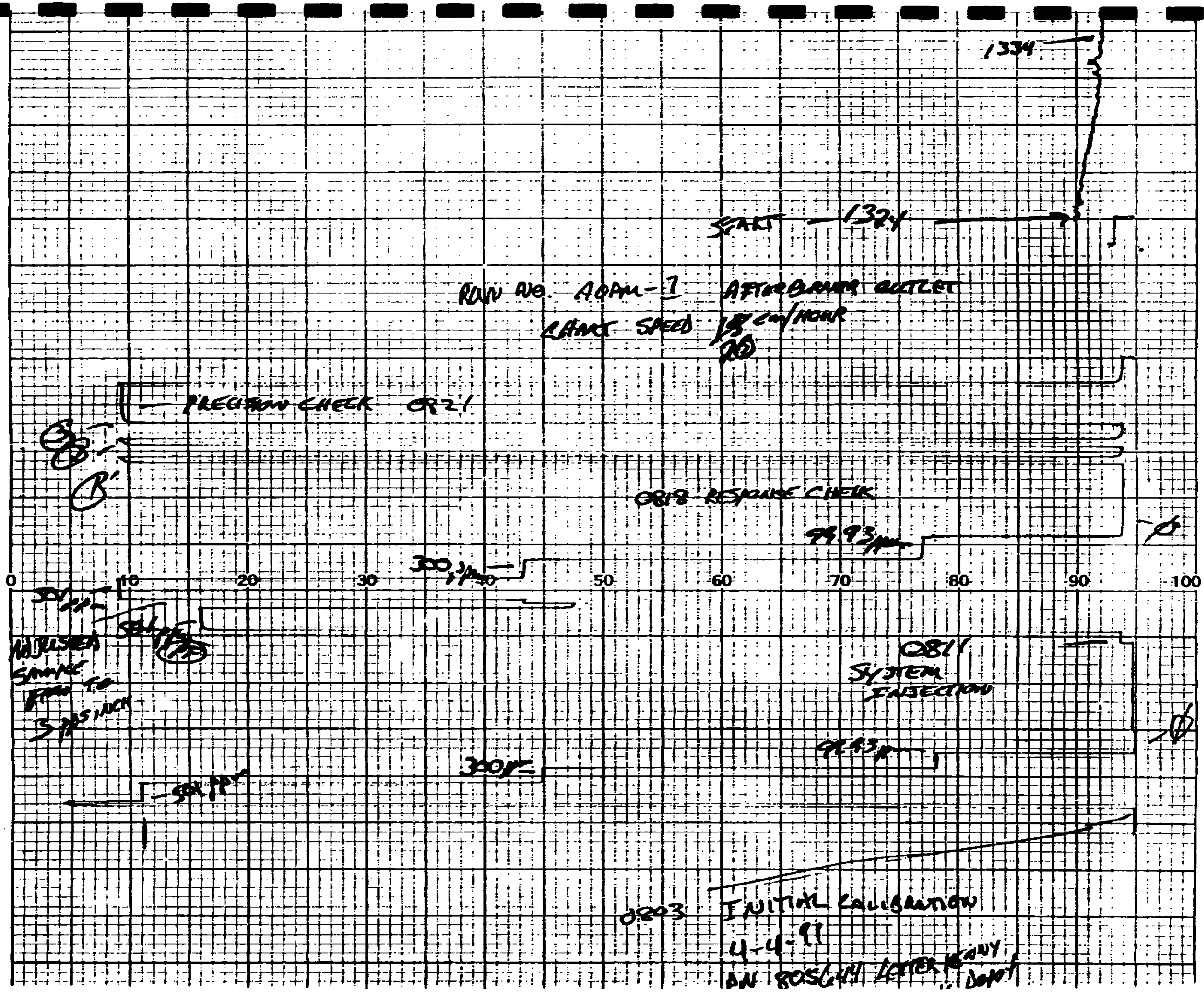
Pollutant ppm/% $= \frac{(\text{Chart division} - b)}{m} = \frac{(CD - 6.22)}{(.1687)}$

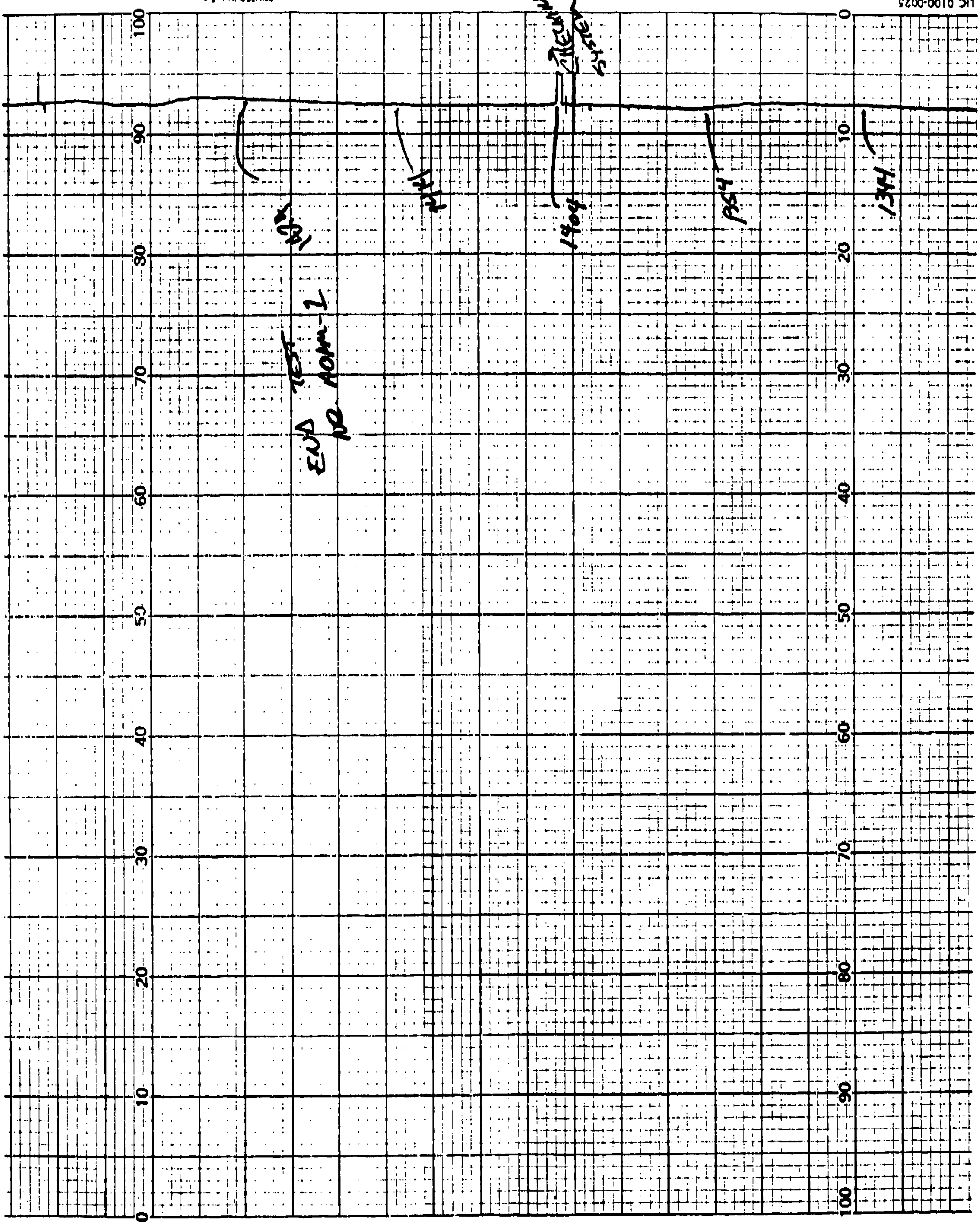
Run No.	Time** (24-H)	Average chart division	Conc.	Comments
ACAM-3	1635-1645	6.8	3.4	BELOW DETECTION LIMIT
	1645-1655	6.5	1.7	↓
	1655-1705	6.5	1.7	
	1705-1715	6.5	1.7	
	1715-1725	6.8	3.4	
	1725-1735	6.8	3.4	

* For NO_x indicate whether NO, NO + NO_2, or NO_2 for specific interval.

** Indicate whether time interval is from beginning of first time to beginning of second time or to end of second time (circle one, or describe alternate).

Calculated by P. Fitzgerald on 4-4-91 Checked by JK on 4-8-91


1334
START — 1324
RUN NO. ADAM-1 AFTERBURNER OUTLET
CHART SPEED 1/8 cm/HOUR 20
PRECISION CHECK 0821
B
B
0818 RESPONSE CHECK
99.93 ppm
300 ppm
0
0
10
20
30
40
50
60
70
80
90
100
300 ppm
SEL 1/PE
ADJUSTED SAMPLE FLOW TO 3 SCFH
0811
SYSTEM INJECTION
99.93 ppm
300 ppm
50 ppm
0803 INITIAL CALIBRATION
4-4-91
AN BOSCH LATER ... DEPT



END TEST
DR. AOM-1
1424
1414
1404
CHECK W
SYSTEM
1354
1344
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100

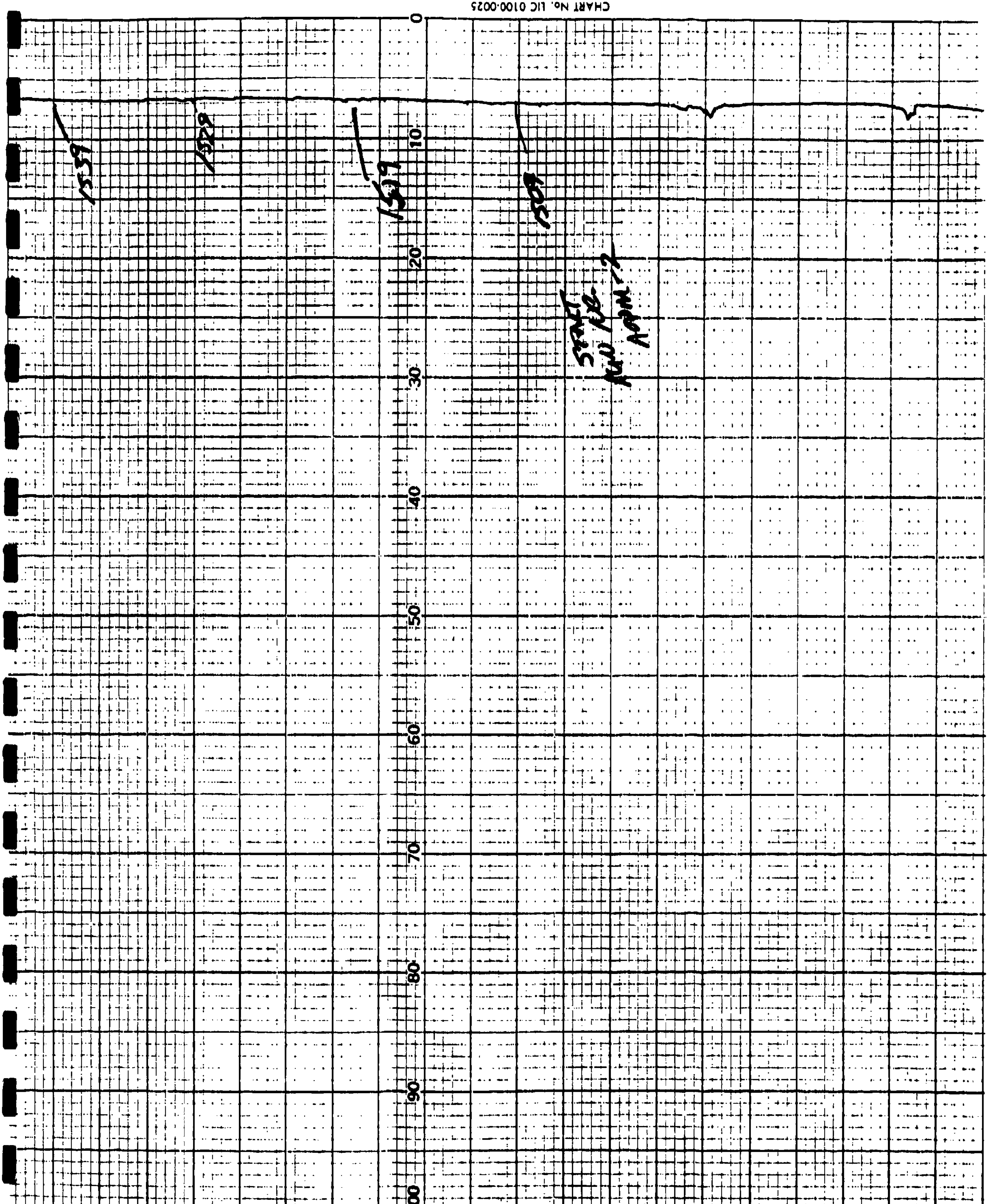


CHART No. LIC 0100-0025
0
10
20
30
40
50
60
70
80
90
100
1539
1529
1519
1508
START
RUN #2
ADPM-12

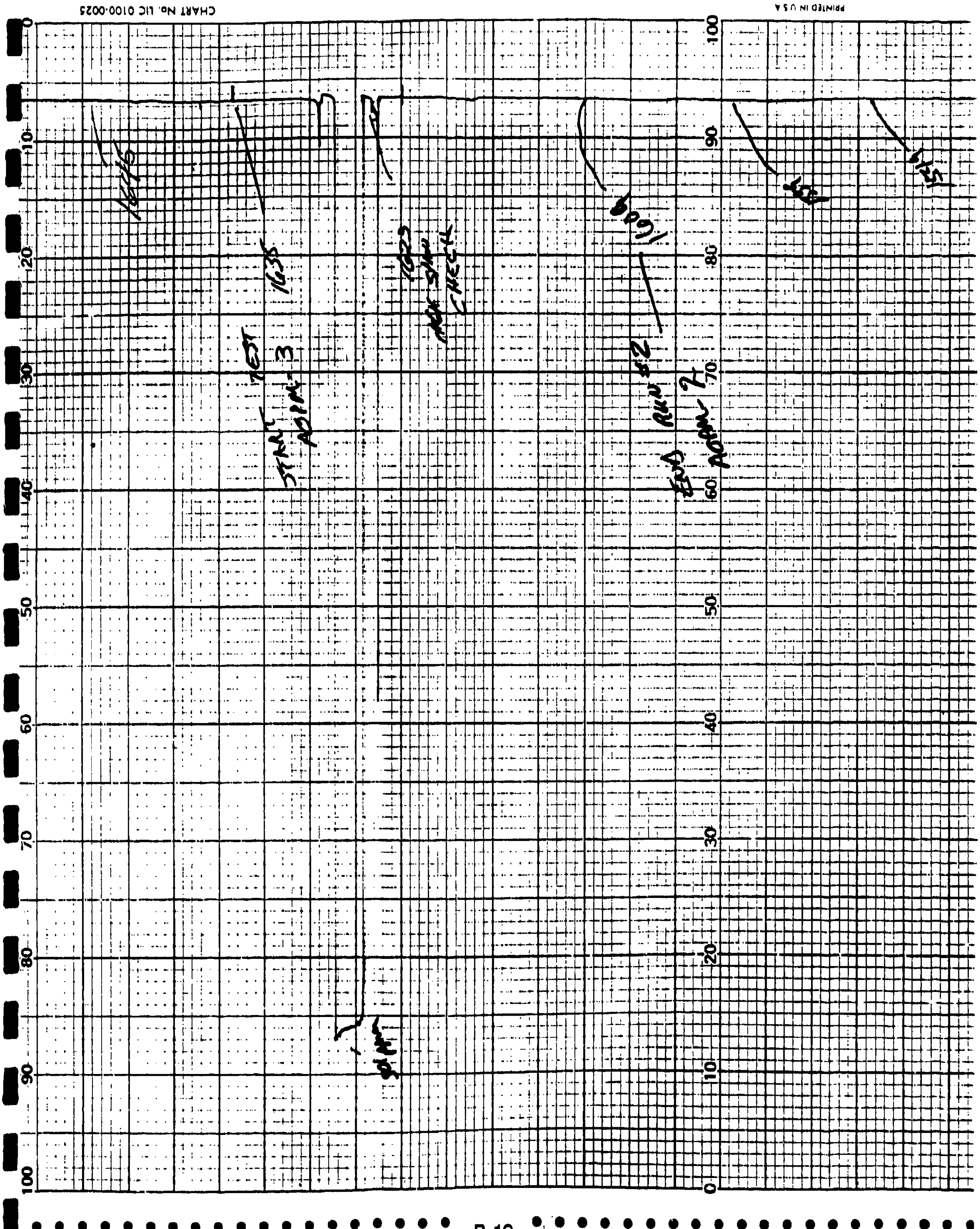
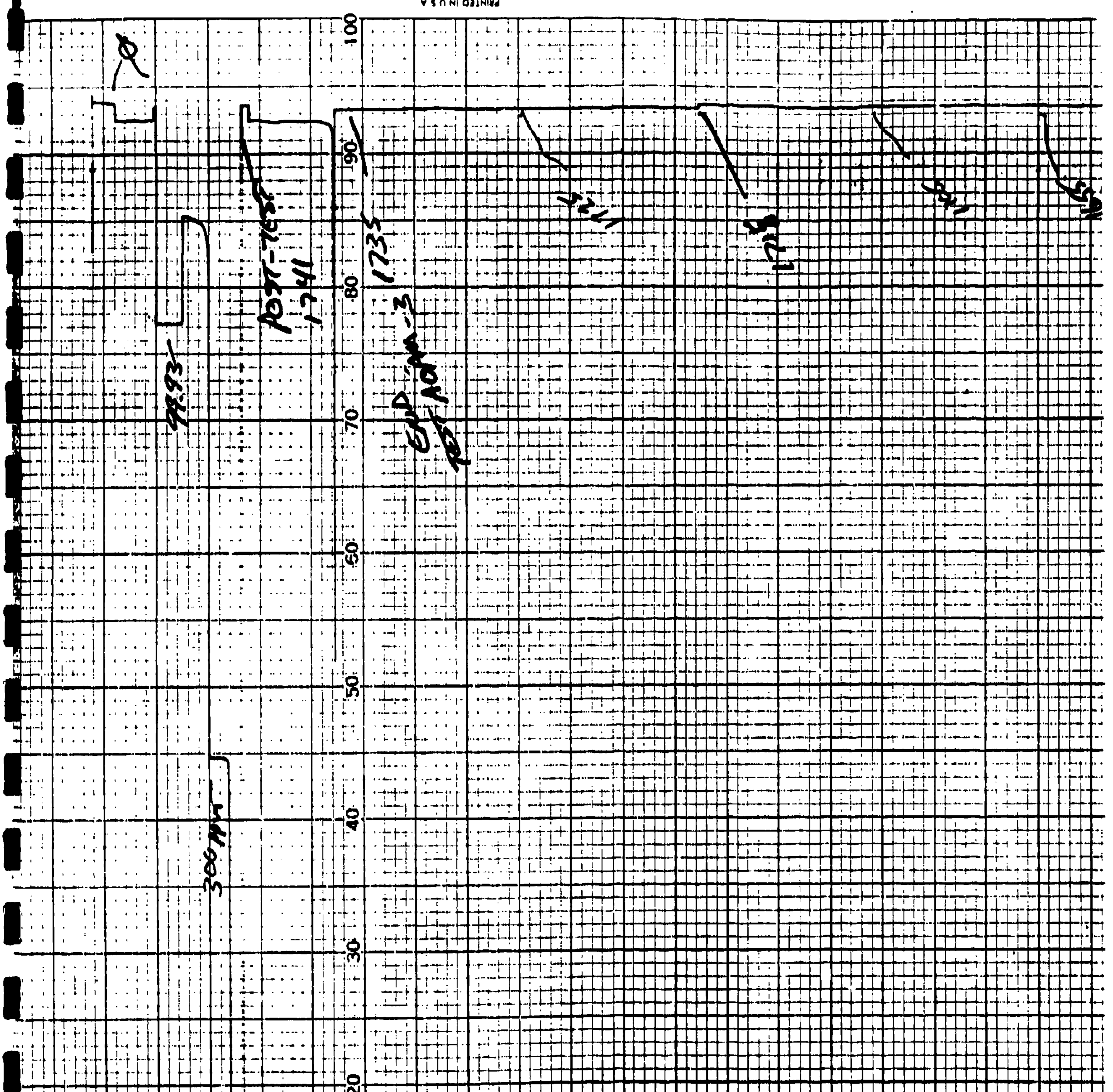


CHART No. LIC 0100-0025
PRINTED IN U S A
0
10
20
30
40
50
60
70
80
90
100
100
90
80
70
60
50
40
30
20
10
0
1646
START TEST 1635
ADIM- 3
1623
MAX SPAN CHECK
50 ppm
1609
END RUN #2
ADIM 2
1500
1451


PRINTED IN U.S.A.
100
90
80
70
60
50
40
30
20
10
0
0
99.93
300 ppm
300ppm
POST-TEST
1741
1735
END ADMA-3
TEST
1727
1718
1708

INITIAL CEM CALIBRATION AND PERFORMANCE EVALUATION

Plant LETTERKENNY ARMY DEPOT
Location CHAMBERSBURG, PA
Date 4-4-91
Operator A Fitzgerald
PN 805604

Parameter SO_2, CO_2, O_2, NO_x, [✓ THC]
Monitor BECKMAN 402
Span value [✓ ppm] or % 567.3
Chart scale 100
Pbar, in.Hg 30.08

Cylinder No.	Cal. gas conc., ppm or %	Chart divisions		Concentration predicted by equation,*		Calibration error,** % of span	Sampling system bias,*** % of span
		Direct injection to monitor	Injection through system	Direct	System		
ALM016855	501	89.0	90.8	501.6	512.4	-.1	-1.9
ALM008755	300	55.0	56.8	296.6	309.4	.2	-1.9
ALM000191	99.93	19.8	23.0	100.4	107.6	-.1	-1.3
	0	5.0	6.3	.12	7.9	-.02	-1.4

* Perform linear regression of pretest cal. gas concentration vs. chart divisions to determine following equation:

$y = mx + b$ x = ppm y = chart division

100 CD = 567.3 ppm

For data reduction:

$$\text{Pollutant ppm/\%} = \frac{(\text{Chart division} - b)}{m} = \frac{(CD - 4.98)}{(.1475)}$$

Correlation coef. = .99999

Calculation concentration predicted by equation using actual chart response obtained from each calibration gas response.

$$\text{** Calibration error, \% span} = \frac{(\text{Concentration of cal. gas, ppm} - \text{predicted conc., ppm})}{\text{Span, ppm}} \times 100$$

Acceptable limit = ±2% each gas (THC limit is ±5%).

*** Sampling system bias =

$$\frac{(\text{Direct injection gas conc.} - \text{system injection gas conc.}) \times 100}{\text{Span value}}$$

Acceptable limit $\leq$5% of span

Minimum detectable limit = 2 percent of span or 11.3 [✓ ppm] or % (circle one)

Rise time to 95% of response for high cal. gas injected through system (return to zero after each injection):

8.8 s, 8.5 s, 8.5 s Avg. 8.6 s

Precision, % scale = difference in chart division response for two repeated injections of the same gas concentration = 90.8 - 90.5 = .3 %
(clock time = 0821)

COMMENTS:

JK
4-8-91

Plant LETTERKENNY ARMY DEPOT
Location E AFTERBURNER OUTLET
Date 4-4-91
Operator P. Fitzgerald
PN 805644
Time, Pretest 0811 Post-test 1741
Run No. AOPM-1, AOPM-2, AOAM-3

Parameter SO_2, CO_2, O_2, NO_x, [✓ THC]
Monitor BECKMAN 402
Span value [✓ ppm] or % 555.9
Chart scale 100 ~~555.9~~
Pbar, in.Hg 30.08
Tamb, °F 70°

Cylinder No.	Cal. gas conc., ppm or %	Chart divisions Pretest	Chart divisions Posttest	Concentration predicted by equation* Pretest	Concentration predicted by equation* Posttest	Analyzer calibration error,** % of span	Drift,*** % of span
ALM 016855	501	90.8	88.5	501.4	487.7	-.07	2.5
ALM 008255	300	56.8	55.5	299.8	292.1	.04	1.4
ALM 000791	99.93	23.0	22.8	99.5	98.3	.08	-.22
	0	6.3	6.3	.5	.5	-.09	0

* Perform linear regression of pretest cal. gas concentration vs. chart divisions to determine following equation:

$y = mx + b$ $x = \text{ppm}$ $y = \text{chart division}$

For data reduction:

$$\text{Pollutant ppm/\%} = \frac{(\text{Chart division} - b)}{m} = \frac{(CD - 6.22)}{.1687}$$

Correlation coef. = 99999

$$** \text{ Analyzer cal. error, \% span} = \frac{(\text{Cal. gas conc.} - \text{conc. predicted}) \times 100}{\text{Span value}}$$

Acceptable limit = ≤2% of span (±5% for THC).

$$*** \text{ Drift \% span} = \frac{(\text{Posttest cal. response} - \text{initial cal. response}) \times 100}{\text{Span value}}$$

Acceptable limit ≤3% of span
Minimum detectable limit = 2% of span or 11.1 [✓ ppm] or % (circle one)
Maximum zero drift = 0 % of span or ______ ppm or % (circle one)
Maximum cal. drift = 25 % of span or ______ ppm or % (circle one)

COMMENTS: Pretest or posttest (circle one) calibration used to quantitate sample data. Posttest is used if drift exceeds limits and if posttest yields higher concentrations.

JK
4-8-91

CEM DATA REDUCTION SHEET FOR BAG ANALYSIS OR STEADY READINGS

Date 4-4-91 Parameter SO_2, NO_x,* CO_2, O_2, [✓ THC], CO

Operator P. Fitzgerald PN 805644 Location AFTERBURNER OUTLET

Pollutant ppm/% = $\frac{(\text{Chart division - b})}{m} = \frac{(CD - 6.22)}{(.1687)}$

Run No.	Time** (24-H)	Average chart division	Conc.	Comments
ADAM-1	1324-1334	8.5	13.5	
	1334-1344	7.8	9.4	UNDER THE DETECTION LIMIT OF 11.1 PPM
	1344-1354	7.8	9.4	↓
	1354-1404	7.8	9.4	
	1404-1414	7.8	9.4	
	1414-1424	7.5	7.6	
ADAM-2	1509-1519	7.0	4.6	BELOW THE DETECTION LIMIT
	1519-1529	6.8	3.4	↓
	1529-1539	6.8	3.4	
	1539-1549	6.8	3.4	
	1549-1559	6.8	3.4	
	1559-[illegible]	6.8	3.4	

* For NO_x indicate whether NO, NO + NO_2, or NO_2 for specific interval.

** Indicate whether time interval is from beginning of first time to beginning of second time or to end of second time (circle one, or describe alternate).

Calculated by P. Fitzgerald on 4-9-91 Checked by JK on 4-8-91

CEM DATA REDUCTION SHEET FOR BAG ANALYSIS OR STEADY READINGS

Date 4-4-91 Parameter SO_2, NO_x,* CO_2, O_2, [✓ THC], CO

Operator P. Fitzgerald PN 805644 Location AFTERBURNER OUTLET

Pollutant ppm/% = $\frac{\text{(Chart division - b)}}{\text{m}}$ = $\frac{(\text{CD} - 6.22)}{(.1687)}$

Run No.	Time** (24-H)	Average chart division	Conc.	Comments
ADAM-3	1635-1645	6.8	3.4	BELOW DETECTION LIMIT
	1645-1655	6.5	1.7	↓
	1655-1705	6.5	1.7	
	1705-1715	6.5	1.7	
	1715-1725	6.8	3.4	
	1725-1735	6.8	3.4	

* For NO_x indicate whether NO, NO + NO_2, or NO_2 for specific interval.

** Indicate whether time interval is from beginning of first time to beginning of second time or to end of second time (circle one, or describe alternate).

Calculated by on 4-4-91 Checked by JK on 4-8-91

LABORATORY DATA SHEETS

XI-04-060

INTERNATIONAL TECHNOLOGY CORPORATION

REQUEST FOR ANALYSIS

R/A Control No. 226751
C/C Control No. 211723

PROJECT NAME USATHAMA - Letterkenny
PROJECT NUMBER 816006-002
PROFIT CENTER NUMBER AQS-3671
PROJECT MANAGER C. Bentley
BILL TO AQS - Cinn. (3671)

PURCHASE ORDER NO.

DATE SAMPLES SHIPPED ~~ITAS~~ 4/5/91
LAB DESTINATION ITAS - Cinn.
LABORATORY CONTACT
SEND LAB REPORT TO C. Bentley

DATE REPORT REQUIRED 4/~~24~~30/91
PROJECT CONTACT C. Bentley
PROJECT CONTACT PHONE NO. X 4890

Sample No.	Sample Type	Sample Volume	Preservative	Requested Testing Program	Special Instructions
AOPM-1	Acetone			Acetone & Filters for	
-2	Filter HNO3/H2O2 soln.			Particulate per EPA 5	(Gravimetric)
-3				then	
				digest acetone residue,	(digestion - M 3050 SW846)
BLNKS -	Acc. Filter	=> Analyzed in		filter and HNO3/H2O2 soln.	
	HNO3/H2O2 soln.	same manner as actual samples.		per ITM-001 Multimetals protocol.	
				Combine into single fraction	
Note: Include all Method specific QA/QC				and analyze:	
				{Total Chromium (ICP-6010)	
				Cadmium Zinc}	

Lead by AA (M7421-SW846)

TURNAROUND TIME REQUIRED: (Rush must be approved by the Laboratory Project Manager.)
Normal X Rush ____ (Subject to rush surcharge.)

QC LEVEL: (Levels II and III subject to surcharge; project-specific requirements must be submitted to lab before beginning work.)
I X II ____ III ____ Project Specific ____

POSSIBLE HAZARD IDENTIFICATION: (Please indicate if sample(s) are hazardous materials and/or suspected to contain high levels of hazardous substances.)
Non-hazard ____ Flammable ____ Skin Irritant X (HNO3/H2O2) Highly Toxic ____ Other ____ (Please Specify)

SAMPLE DISPOSAL: (Please indicate disposition of sample following analysis. Lab will charge for packing, shipping, archive and disposal.)
Return to Client ____ Disposal by Lab ____ Archive X (Indicate number of months.) 3 mos.

FOR LAB USE ONLY
Received by ____ Date/Time 4/9/91 09:30 am

WHITE - Original, to accompany samples
YELLOW - Field copy

XI-09-060

INTERNATIONAL TECHNOLOGY CORPORATION

CHAIN-OF-CUSTODY RECORD

R/A Control No. ______

C/C Control No. 211723

PROJECT NAME/NUMBER USATHAMA / 816006-002

LAB DESTINATION ITAS-Cinn.

SAMPLE TEAM MEMBERS C. Buffey / P. Fitzgerald

CARRIER/WAYBILL NO. AQS

Sample Number	Sample Location and Description	Date and Time Collected	Sample Type	Container Type	Condition on Receipt (Name and Date)	Disposal Record No.
AOPM-1	Afterburner Outlet; Multi-metal	4/4	Acetone Rinse Filter	# 15361-A 15361-B	Samples received in [illegible]	
	stack samples.		HNO3/H2O2 Soln.	15362-A	condition without chain-	
					of-custody seals on shipping	
AOPM-2	"	"	"	15363-A 15363-B	container or individual samples	
				15364-A	4/9/91 09:30am	
AOPM-3	"	"	"	15365-A 15365-B		
				15366-A		
Blnks.			Filter Acetone	# 15378 15360-A		
			HNO3/H2O2	15359-A		

Special Instructions: ______

Possible Sample Hazards: ______

SIGNATURES: (Name, Company, Date and Time)

1. Relinquished By: C. Buffey (AQS) 4/8/91

   Received By: Nicholas W. [illegible] ITAS 4/9/91 09:30am

2. Relinquished By: ______

   Received By: ______

3. Relinquished By: ______

   Received by: ______

4. Relinquished By: ______

   Received By: ______

WHITE - To accompany samples
YELLOW - Field copy

IT INTERNATIONAL TECHNOLOGY CORPORATION

ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

ITAQS Cincinnati Date: May 1, 1991

Attn: Mr. Chuck Bruffey

Job Number 21381 P.O. Number 816006-002

This is the Certificate of Analysis for the following samples:

Client Project ID: USATHAMA
Date Received: April 9, 1991
Work Order: X1-04-060
Number of Samples: 4
Sample Type: Multi-Metals Trains

I. Introduction

Four multi-metals trains and blanks arrived at ITAS Cincinnati on April 9, 1991. The samples were sent for analytical work in support of monitoring work on the USATHAMA Project. The samples are labeled as follows:

Run # AOPM-1
Run # AOPM-2
Run # AOPM-3
Run # AOPM-Blank

II. Analytical Results/Methodology

The analytical results for this report are presented by analytical test. Each set of data will include sample identification information, the analytical results, and the appropriate detection limits.

Each train consisted of a filter, acetone rinse and HNO3 impinger. The filter and acetone rinse were analyzed per EPA 5. After EPA 5 analysis they were composited with the HNO3 impinger and analyzed for the metals listed on the next page.

Reviewed and Approved by:

Tim Soward
Tim Soward
Project Manager
104060

II. Analytical Results/Methodology (cont.)

- * Lead by Graphite Furnace Atomic Absorption; EPA Method 7421
- * Cadmium, Chromium and Zinc by Inductively Coupled Plasma Spectroscopy; EPA Method 6010

III. Quality Control

Immediately following the analytical data for the samples can be found the QA/QC information that pertains to these samples. The purpose of this information is to demonstrate that the data enclosed is scientifically valid and defensible. This QA/QC data is used to assess the laboratory's performance during the analysis of the samples it accompanies. All quantitations were performed from within the calibrated range of the analytical instrument.

The lead analyses by Atomic Absorption were done in duplicate. The average is reported.

Client: USATHAMA
Work Order: X1-04-060
10406002

Analytical Results, ug

Client Sample ID	Run # AOPM-1	Run # AOPM-2	
Lab No.	01	02	
Analyte			Detection Limit
Cadmium	10	4.5	1
Chromium	19	20	3
Lead	45	50	4
Zinc	84	120	4

Client Sample ID	Run # AOPM-3	Run # AOPM-4	
Lab No.	03	04	
Analyte		(Blank)	Detection Limit
Cadmium	8.6	ND	1
Chromium	24	3.5	3
Lead	102	1.4	4
Zinc	100	16	4

ND = Not detected above the reported detection limit

Quality Assurance Data

Quality Control
Standard Reference Solution

Analyte	Theoretical Value	Percent Recovery
Cadmium	1	99.4
Chromium	1	98.8
Lead	0.075	102, 96.3
Zinc	1	102

Method 5 Blank Analytical Data

Plant: LETTERKENNY ARMY DEPOT ✓

Density of Acetone 0.7899 g/ml (pa)

Blank Type	Sample identifiable	Liquid level at mark and/or container sealed
Acetone	YES	YES
Filter	YES	YES

Acetone Blank Container No. 15363B | Lab #: X10406004B

Volume of Acetone: 519 ml. (Va) ✓

Date & Time of Wt. 4/22/91 2:15PM | Beaker Gross Wt.: 104947.4 mg. ✓

Date & Time of Wt. 4/23/91 8:45AM | Beaker Gross Wt.: 104947.1 mg. ✓

Average Gross Wt.: 104947.3 mg.

Beaker Tare Wt.: 104934.0 mg. ✓

$$C_a, (mg/g) = \frac{(ma)}{(Va)\ (pa)}$$

Beaker Net Wt.: 13.3 mg. (ma)

Acetone Blank Value: 0.0324 mg/g (Ca)

Blank Value used for Calculations: 0.0100 mg/g

Filter #: 8970049 | Lab #: X10406004A

Date & Time of Wt. 4/22/91 7:30AM | Filter Gross Wt.: 468.6 mg ✓

Date & Time of Wt. 4/22/91 2:15PM | Filter Gross Wt.: 468.7 mg ✓

Average Gross Wt.: 468.7 mg

Filter Tare Wt.: 466.7 mg ✓

Difference: 2.0 mg

Remarks

Signature of Analyst: Melissa A. Ellerson Date: 4-25-91

Signature of Reviewer: Ken Mueller Date: 4/30/91

Method 5 Train Analytical Particulate Data
Acetone Rinses and Filter(s)

Plant:LETTERKENNY Run No.:AOPM-1

Sample LocationAFTERBURNER/OUTLETDensity of Acetone 0.7899 g/ml ✓

Sample type	Sample identifiable	Liquid level at mark and/or container sealed
Acetone	YES	YES
Filter	YES	YES

Acetone Blank Residue Conc. 0.0100 mg/g ✓ Lab #:X10406001B

Acetone Volume: 180 ml. ✓

Date & Time of Wt.4/22/91 2:15PM Beaker Gross Wt.: 98597.8 mg ✓

Date & Time of Wt.4/23/91 8:45AM Beaker Gross Wt.: 98597.4 mg ✓

Average Gross Wt.: 98597.6 mg

Beaker Tare Wt.: 98582.5 mg ✓

Less acetone blank wt.: 1.4 mg

Particulate Wt.: 13.7 mg

Filter # 9170001 Lab #:X10406001A

Date & Time of Wt.4/22/91 7:30AM Filter Gross Wt.: 419.5 mg ✓

Date & Time of Wt.4/22/91 2:15PM Filter Gross Wt.: 419.3 mg ✓

Average Gross Wt.: 419.4 mg

Filter Tare Wt.: 401.0 mg ✓

Weight of Particulate on Filter: 18.4 mg

Weight of Particulate in Acetone Rinse: 13.7 mg

Total Wt. of Particulate:, 32.1 mg

Signature of Analyst: Melissa A. Ellesson Date: 4-25-91

Signature of Reviewer: Ken Mueller Date: 4/30/91

Method 5 Train Analytical Particulate Data
Acetone Rinses and Filter(s)

Plant: LETTERKENNY

Run No.: AOPM-2

Sample Location AFTERBURNER/OUTLET

Density of Acetone 0.7899 g/ml ✓

Sample type	Sample identifiable	Liquid level at mark and/or container sealed
Acetone	YES	YES
Filter	YES	YES

Acetone Blank Residue Conc. 0.0100 mg/g ✓

Lab #: X10406002B

Acetone Volume: 115 ml. ✓

Date & Time of Wt. 4/22/91 2:15PM

Beaker Gross Wt.: 103972.2 mg ✓

Date & Time of Wt. 4/23/91 8:45AM

Beaker Gross Wt.: 103972.0 mg ✓

Average Gross Wt.: 103972.1 mg

Beaker Tare Wt.: 103965.4 mg ✓

Less acetone blank wt.: 0.9 mg

Particulate Wt.: 5.8 mg

Filter # 9170003

Lab #: X10406002A

Date & Time of Wt. 4/22/91 7:30AM

Filter Gross Wt.: 392.1 mg ✓

Date & Time of Wt. 4/22/91 2:15PM

Filter Gross Wt.: 392.4 mg ✓

Average Gross Wt.: 392.3 mg

Filter Tare Wt.: 387.2 mg ✓

Weight of Particulate on Filter: 5.1 mg

Weight of Particulate in Acetone Rinse: 5.8 mg

Total Wt. of Particulate: 10.9 mg

Signature of Analyst: Melissa A Ellerson

Date: 4-25-91

Signature of Reviewer: Ken Mueller

Date: 4/30/91

Method 5 Train Analytical Particulate Data
Acetone Rinses and Filter(s)

Plant: LETTERKENNY Run No.: AOPM-3

Sample Location AFTERBURNER/OUTLET Density of Acetone 0.7899 g/ml ✓

Sample type	Sample identifiable	Liquid level at mark and/or container sealed
Acetone	YES	YES
Filter	YES	YES

Acetone Blank Residue Conc. 0.0100 mg/g ✓ Lab #: X10406003B

Acetone Volume: 105 ml. ✓

Date & Time of Wt. 4/22/91 2:15PM Beaker Gross Wt.: 102438.8 mg ✓

Date & Time of Wt. 4/23/91 8:45AM Beaker Gross Wt.: 102438.4 mg ✓

Average Gross Wt.: 102438.6 mg

Beaker Tare Wt.: 102429.6 mg ✓

Less acetone blank wt.: 0.8 mg

Particulate Wt.: 8.2 mg

Filter # 9170002 Lab #: X10406003A

Date & Time of Wt. 4/22/91 7:30AM Filter Gross Wt.: 402.2 mg ✓

Date & Time of Wt. 4/22/91 2:15PM Filter Gross Wt.: 402.3 mg ✓

Average Gross Wt.: 402.3 mg

Filter Tare Wt.: 400.3 mg ✓

Weight of Particulate on Filter: 2.0 mg

Weight of Particulate in Acetone Rinse: 8.2 mg

Total Wt. of Particulate: 10.2 mg

Signature of Analyst: Cheryl A. Jones Date: 4/30/91

Signature of Reviewer: Date: 4/30/91

X1-04-060

INTERNATIONAL TECHNOLOGY CORPORATION

CHAIN-OF-CUSTODY RECORD

R/A Control No. ______

C/C Control No. ______

PROJECT NAME/NUMBER USATHAMA / 816006-002

LAB DESTINATION ITAS-Cinn.

SAMPLE TEAM MEMBERS C. Buffey / P. Fitzgerald

CARRIER/WAYBILL NO. AQS

Sample Number	Sample Location and Description	Date and Time Collected	Sample Type	Container Type	Condition on Receipt (Name and Date)	Disposal Record No
AOPM-1	Afterburner Outlet; Multi metal	4/4	Acetone Rinse Filter	# 15361-A 15361-B	Samples received in good condition without chain-of-custody seals on shipping containers or individual samples. 4/9/91 09:30am	
	STACK samples.		HNO3/H2O2 Soln.	15362-A		
AOPM-2	"	"	"	15363-A 15363-B		
				15364-A		
AOPM-3	"	"	"	15365-A		
				15365-B		
				15366-A		
Blnks.			Filter Acetone	# 1537B 15360-A		
			HNO3/H2O2	15359-A		

Special Instructions: ______

Possible Sample Hazards: ______

SIGNATURES: (Name, Company, Date and Time)

1. Relinquished By: C. Buffey (AQS) 4/8/91

Received By: Nicholas W. Plummer ITAS 4/9/91 09:30am

2. Relinquished By: ______

Received By: ______

3. Relinquished By: ______

Received by: ______

4. Relinquished By: ______

Received By: ______

WHITE - To accompany samples
YELLOW - Field copy

IT INTERNATIONAL TECHNOLOGY CORPORATION

ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

ITAQS Cincinnati   Date: April 29, 1991

Attn: Mr. Chuck Bruffey

Job Number 21381   P.O. Number 816006-002

This is the Certificate of Analysis for the following samples:

Client Project ID: USATHAMA
Date Received: April 9, 1991
Work Order: X1-04-065
Number of Samples: 12
Sample Type: Solid/Water

I. Introduction

Seven solids and five waters arrived at ITAS Cincinnati on April 9, 1991. The samples were sent for analytical work in support of monitoring work on the USATHAMA Project. The samples are labeled as follows:

Solid # FBM-1	A-1 Ash	Water #2 Lead FBPs
Solid # FBM-2	S-1 Steel Shotblast Media	Water #3 Inlet H20
Solid # FBM-3	#1 Virgin Bed Material	Water #4 FBPs Quench Outlet
Solid # FBM-4	Water #1 Quench Outlet	Water #5 FBPs Quench Outlet

II. Analytical Results/Methodology

The analytical results for this report are presented by analytical test. Each set of data will include sample identification information, the analytical results, and the appropriate detection limits.

The solids were analyzed for the following metals on a TCLP basis.

Reviewed and Approved by:

Tim Soward

Tim Soward
Project Manager
104065

II. Analytical Results/Methodology (cont.)

- Cadmium, Chromium, Lead and Zinc by Inductively Coupled Plasma Spectroscopy; EPA Method 6010

The TCLP leaching was done by EPA Method 1311.

The waters were analyzed for the same metals on a total basis. ICP was also used.

III. Quality Control

Immediately following the analytical data for the samples can be found the QA/QC information that pertains to these samples. The purpose of this information is to demonstrate that the data enclosed is scientifically valid and defensible. This QA/QC data is used to assess the laboratory's performance during the analysis of the samples it accompanies. All quantitations were performed from within the calibrated range of the analytical instrument.

Matrix spikes were performed for each of the TCLP analyses. The recoveries are presented with the sample results.

Client: USATHAMA
Work Order: X1-04-065
10406502

IT ANALYTICAL SERVICES
CINCINNATI, OH

Analytical Results, mg/L

Client Sample ID	Lab No.	Cadmium	Chromium	Lead	Zinc
Solid # FBM-1	01	0.25	0.021	3.4	0.47
MS%		94.2	106	99.5	93.0
Solid # FBM-2	02	0.23	0.052	5.2	0.43
MS%		96.5	109	96.9	96.5
Solid # FBM-3	03	0.41	0.30	7.5	0.30
MS%		90.4	104	94.5	88.7
Solid # FBM-4	04	0.47	0.20	8.2	0.67
MS%		93.1	105	92.6	86.6
A-1 Ash	05	1.1	0.010	44	2.8
MS%		92.4	105	101	89
S-1 Steel Shotblast Media	06	2.7	ND	ND	180
MS%		76.7	102	88.7	(1)
#1 Virgin Bed Material	07	0.006	0.050	ND	0.17
MS%		90.6	103	92.7	84.2
Water #1 Quench Outlet	08	0.007	0.045	0.21	0.18
Water #2 Lead FBPs	09	0.003	0.018	ND	0.15
Water #3 Inlet H2O	10	ND	ND	ND	0.12
Water # 4 FBPs Quench Outlet	11	ND	0.022	ND	0.11
Water # 5 FBPs Quench Outlet	12	0.003	0.020	ND	0.10
Detection Limit		0.002	0.006	0.2	0.008

(1) Inappropriate spike level

Client: USATHAMA
Work Order: X1-04-065
10406504

IT ANALYTICAL SERVICES
CINCINNATI, OH

Quality Assurance Data

Quality Control
Standard Reference Solution

Analyte	Theoretical Value, mg/L	Percent Recovery
Cadmium	1	96.9, 96.3, 94.5, 94.4
Chromium	1	97.9, 97.1, 98.0, 98.0
Lead	2	97.5, 96.5, 99.6, 96.6
Zinc	1	95.1, 93.6, 97.7, 96.9

IT INTERNATIONAL TECHNOLOGY CORPORATION

ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

IT Corporation
1133 21st. Street NW, Suite 500
Washington, DC 20036

Date: May 17, 1991

Attn: Mr. Duane Parker

Job Number 21341

P.O. Number 805625

This is the Certificate of Analysis for the following samples:

Client Project ID: USATHAMA
Date Received: April 9, 1991
Work Order: X1-05-027
Number of Samples: 5
Sample Type: Waste

I. Introduction

Five waste samples arrived at ITAS Cincinnati on April 9, 1991. The samples were sent for analytical work in support of monitoring work on the USATHAMA Project. The samples are labeled as follows:

FBM-1
FBM-2
#1 Virgin Bed Material
FBM-3
FBM-4

II. Analytical Results/Methodology

The analytical results for this report are presented by analytical test. Each set of data will include sample identification information, the analytical results, and the appropriate detection limits.

The analyses requested are listed on the following page.

Reviewed and Approved by:

Timothy Soward

Timothy Soward
Project Manager
105027

II. Analytical Results/Methodology (cont.)

- Cadmium, Chromium, Lead and Zinc by Inductively Coupled Plasma Spectroscopy; EPA Method 6010

III. Quality Control

Immediately following the analytical data for the samples can be found the QA/QC information that pertains to these samples. The purpose of this information is to demonstrate that the data enclosed is scientifically valid and defensible. This QA/QC data is used to assess the laboratory's performance during the analysis of the samples it accompanies. All quantitations were performed from within the calibrated range of the analytical instrument.

Client: USATHAMA
Work Order: X1-05-027
10502703

IT ANALYTICAL SERVICES
CINCINNATI, OH

Analytical Results, ug/g

Client Sample ID	FBM-1	FBM-2	FBM-3	FBM-4	#1 Virgin Bed Material	
Lab No.	01	02	03	04	07	
Analyte						Detection Limit
Cadmium	5.4	6.4	9.2	11	0.28	0.2
Chromium	6.8	5.3	19	37	3.0	0.3
Lead	60	77	200	260	ND	6
Zinc	7.9	9.2	11	18	ND	0.5

ND = Not detected above the reported detection limit

Quality Assurance Data

Quality Control
Standard Reference Solutions

Analyte	Theoretical Value	Percent Recovery
Cadmium	1	95.9
Chromium	1	99.1
Lead	2	99.8
Zinc	1	82.4

IT INTERNATIONAL TECHNOLOGY CORPORATION

ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

IT Corporation
1133 21st. Street NW, Suite 500
Washington, DC 20036

Date: May 17, 1991

Attn: Mr. Duane Parker

Job Number 21421

P.O. Number JTS # 816006

This is the Certificate of Analysis for the following samples:

Client Project ID: USATHAMA Project
Date Received: May 8, 1991
Work Order: X1-05-056
Number of Samples: 3
Sample Type: Solid

I. Introduction

Three solid samples arrived at ITAS Cincinnati on May 8, 1991. The samples were sent for analytical work in support of monitoring work on the USATHAMA Project. The samples were labeled as follows:

Solid # SC-1 Solid # SC-2 Solid # SC-4

II. Analytical Results/Methodology

The analytical results for this report are presented by analytical test. Each set of data will include sample identification information, the analytical results, and the appropriate detection limits.

The analyses requested are listed on the following page.

Reviewed and Approved by:

Tim Soward

Tim Soward
Project Manager
105056

II. Analytical Results/Methodology (cont.)

* Cadmium, Chromium, Lead and Zinc by Inductively Coupled Plasma Spectroscopy; EPA Method 6010

* Total sample weight before analysis

III. Quality Control

Immediately following the analytical data for the samples can be found the QA/QC information that pertains to these samples. The purpose of this information is to demonstrate that the data enclosed is scientifically valid and defensible. This QA/QC data is used to assess the laboratory's performance during the analysis of the samples it accompanies. All quantitations were performed from within the calibrated range of the analytical instrument.

Client: IT USATHAMA
Work Order: X1-05-056
10505602

IT ANALYTICAL SERVICES
CINCINNATI, OH

Analytical Results

Client Sample ID		Solid # SC-1	Solid # SC-2	Solid # SC-4	
Lab No.		01	02	03	
Analyte	Units				Detection Limit
Cadmium	ug/g	600	630	900	0.2
Chromium	ug/g	15,000	21,000	30,000	0.3
Lead	ug/g	86,000	120,000	170,000	6
Zinc	ug/g	790	1,000	2,000	0.5
Total Sample Weight	g	11	0.93	0.26	

Quality Control
Standard Reference Solution

Analyte	Theoretical Value	Percent Recovery
Cadmium	1	101
Chromium	1	104
Lead	2	98.3
Zinc	1	96.4

SAMPLING AND ANALYTICAL PROCEDURES

SAMPLING AND ANALYTICAL PROCEDURES

This Appendix details the sampling and analytical methods used in this test program. These are generic descriptions with modifications detailed as follows:

- Determination of Particulate and Trace Metal Emissions

  The method as written is applicable to the measurement of trace metal emissions including mercury. The additional impinger solution (potassium permanganate) and recovery and analytical procedures specific to mercury analysis will not be used in this test series, since mercury is not a metal analyte of interest. The potassium permanganate impingers will be replaced by an empty impinger followed by an impinger containing silica gel.

- Determination of Total Gaseous Organic Concentration by U.S. EPA Method 25A

  No modifications as written.

Title: 25A
Date: 10/16/90

DETERMINATION OF TOTAL GASEOUS ORGANIC CONCENTRATION BY EPA METHOD 25A

Sampling and analysis procedures for determining total gaseous organic emissions are those described in EPA Method 25A.* Gas flow rates are determined by using EPA Methods 1 and 2 for velocity and temperature, a Fyrite or Orsat analyzer for oxygen and carbon dioxide content, and wet bulb/dry bulb temperature measurements for moisture content. The following is a detailed description of Method 25A equipment and procedures.

Sampling Apparatus

The sampling apparatus is shown in Figure 25A-1. The system is set up and operated in accordance with the guidelines in the operating manual for the total hydrocarbon monitor. In addition to the hydrocarbon analyzer, the sampling system consists of:

<u>Particulate Filter</u> - A short piece of 1/2-in.-i.d. pipe packed with glass wool and attached to the end of the sample probe, if needed, or equivalent.

<u>Sample Probe</u> - Stainless steel tubing inserted into the gas stream being sampled. A three-way ball valve at the outlet of the probe is used to add calibration gas.

<u>Sample Line</u> - 1/4-in.-o.d. heated Teflon line self-limited to maintain a sample temperature between 250° and 300°F.

<u>Sampling Manifold</u> - One stainless steel three-way valve and 1/4-in. stainless steel tubing are used to supply calibration standards and sample gas to the monitor. One three-way valve is used to select calibration injections or to sample stack gas. The whole system is wrapped with heat tape.

---

* 40 CFR 60, Appendix A, July 1990.

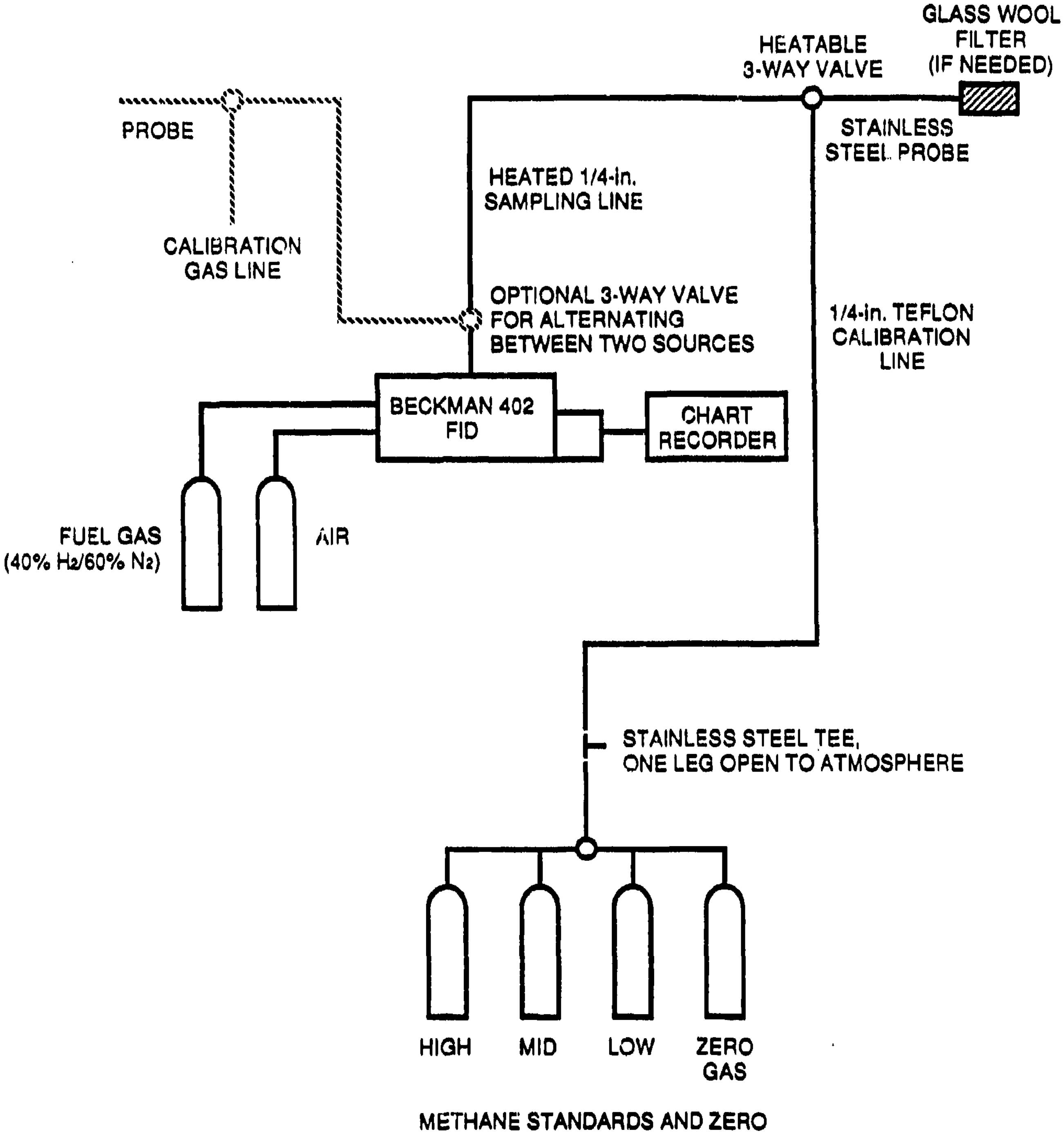


Figure 25A-1. Method 25A sampling system.

Calibration Gases - Methane standards in air and zero nitrogen (less than 0.1 ppm THC) are used to calibrate the monitor.

Fuel and Air - A cylinder of 40 percent hydrogen/60 percent nitrogen and a cylinder of compressed air to provide fuel and an air supply for the analyzer's flame.

Chart Recorder - A Heath strip-chart recorder or equivalent is used to provide a permanent record of hydrocarbon concentration data.

A Beckman 402 total hydrocarbon analyzer that works on the principle of flame ionization is used. All critical sample-handling components of the analyzer are contained in a heat-controlled oven. The oven temperature is maintained at 250°F throughout the test program. The following analyzer specifications were provided by the manufacturer:

Full-scale sensitivity:	Adjustable from 5 ppm methane to 10,000 ppm (%) methane
Response time (0 to 99%):	Less than 1 s for oven temperature of 200°F Less than 1.5 s for oven temperature of 400°F
Electricity stability:	±1 percent of full scale per 24 hours, with ambient temperature change of less than 10°F
Reproducibility:	±1 percent of full scale for successive identical samples
Output:	Selectable from 10 mV, 100 mV, or 1V.

The magnitude of the analyzer response to carbon atoms depends on the chemical environment of this atom in its molecule. Typical ratios of monitor response to methane for carbon atoms in various molecular structures are listed in Table 25A-1.

TABLE 25A-1. MONITOR RESPONSE FOR VARIOUS MOLECULAR STRUCTURES

Molecular structure	Response relative to methane, %
Aliphatic compound	100
Aromatic compound	100
Olefinic compound	95
Acetylenic compound	130
Carbonyl radical	0
Nitrile radical	30

Monitor Setup and Calibration

The monitor setup and check procedures outlined here are performed prior to sampling. The monitor is calibrated by introducing zero and high-level calibration gases to the calibration port of the sampling manifold. The predicted response for low- and mid-level calibration gases is calculated, assuming that the monitor response is linear. The low- and mid-level gases are then introduced into the monitor. If actual responses for the gases differed from the predicted responses by more than 5 percent, the monitoring system is inspected and repaired before sampling begins.

Once the monitor is calibrated, a system integrity check is performed. Zero nitrogen and one of the methane standards are sampled through the sample probes and lines to make sure that the sampling system is not diluting or contaminating the samples. A stainless steel tee with a leg left open to the atmosphere is placed on the end of the probe during this step so that calibration gases being sent from the cylinders do not pressurize the sampling system.

Once the sample lines are checked out, a response-time test is performed. This test consists of introducing zero gas to the probes and switching to high-level calibration gas when the system is stabilized. The response time is the time from the concentration change until the measurement system response, and it is equivalent to 95 percent of the response for the high-level calibration gas. The test is performed three times, and results are averaged.

Sampling Procedures

At the start of the test day, the monitor is calibrated and a system integrity check is performed. Each sample line is also leak-checked by capping the end of the probe and observing the sample flow rotameter level on the hydrocarbon monitor. If no flow is indicated by the rotameter, the leak check is considered acceptable.

Daily calibrations for each range are performed with three calibration standards (low-level, mid-level, and high-level) and zero nitrogen. Each calibration range is checked by linear regression calculations, which indicate linear responses and are used to reduce field data.

When sampling is completed, a calibration drift check is performed on the monitor by introducing the zero and mid-level calibration gas to the monitor. If the calibration drifts for the gases do not exceed 2 percent of span, the pretest calibration curve is used to report sample results. If the calibration drift for either gas exceeds 2 percent, the monitor is recalibrated and both sets of calibration data are used in reporting the results.

DETERMINATION OF PARTICULATE AND METAL EMISSIONS

Sampling for filterable particulate matter and total metals (particulate and gaseous) emissions was conducted in accordance with the Methodology for the Determination of Trace Metal Emissions in Exhaust Gases From Stationary Source Combustion Processes.* This is the same procedure as that in Subsection 3.1 of the Methods Manual for Compliance with BIF Regulations.** The particulate determination in this method is consistent with EPA Method 5.***

Sampling Apparatus

The sampling train used in these tests is assembled by ITAQS personnel and meets all design specifications established by the U.S. EPA. The sampling apparatus consists of:

Nozzle - Borosilicate glass with an accurately measured round opening.

Probe - Borosilicate glass with a heating system capable of maintaining a minimum gas temperature of 250°F at the exit end during sampling.

Pitot Tube - A Type-S pitot tube that meets all geometric standards is used to measure gas velocity during each sampling run.

Temperature Gauge - Type-K thermocouple attached to the pitot tube in an interference-free arrangement with a digital readout to monitor stack gas temperature within 5°F.

Filter Holder - Pyrex glass with a heating system capable of maintaining a filter temperature of 250° ±25°F.

Filter - 87-mm (3-in.)-diameter, Pallflex Type 2500 QAT-UP ultra-pure filter.

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* EPA Draft Protocol, July 1988.

** EPA/530-SW-91-010, December 1990.

*** 40 CFR 60, Appendix A, July 1990.

Draft Gauge - An inclined manometer made by Dwyer with a readability of 0.01 in.H_2O in the 0- to 10-in.H_2O range is used.

Impingers - Five Greenburg-Smith design impingers connected in series with glass ball joints. The first, third, and fifth impingers are modified by removing the tip and extending the tube to within 1.3 cm (0.5 in.) of the bottom of the flask.

Metering System - Vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 2.8°C (5°F), calibrated dry gas meter, and related equipment to maintain an isokinetic sampling rate and to determine sample to volume. The dry gas meter is made by Rockwell, and the fiber vane pump is made by Gast.

Barometer - Aneroid tube type to measure atmospheric pressures to ±2.5 mmHg (±0.1 in.Hg).

Sampling Procedure

Pallflex filters are desiccated for at least 24 hours and weighed to the nearest 0.1 mg on an analytical balance. One hundred mL of 5 percent nitric acid/10 percent hydrogen peroxide solution are placed in each of the first two impingers; the third and fourth impingers contain 100 mL of acidic potassium permanganate solution; and the last impinger contains 200 to 400 g of silica gel.

The train is set up with the probe as shown in Figure PMM-1. The sampling train is leak-checked at the sampling site prior to each test run by plugging the inlet to the nozzle and pulling a 15-in.Hg vacuum, and at the conclusion of the test by plugging the inlet to the nozzle and pulling a vacuum equal to the highest vacuum reached during the test run.

The pitot tube and lines are leak-checked at the test site prior to and at the conclusion of each test run. This check is made by blowing into the impact opening of the pitot tube until 3 or more inches of water is recorded on the manometer and then capping the impact opening and holding it for 15 seconds to ensure that it is leak free. The static-pressure side of the pitot tube is leak-checked by the same procedure, except suction is used to obtain the 3-in.H_2O manometer reading.

Crushed ice is placed around the impingers to keep the temperature of the gas leaving the last impinger at 68°F or less. During sampling, stack gas and sampling

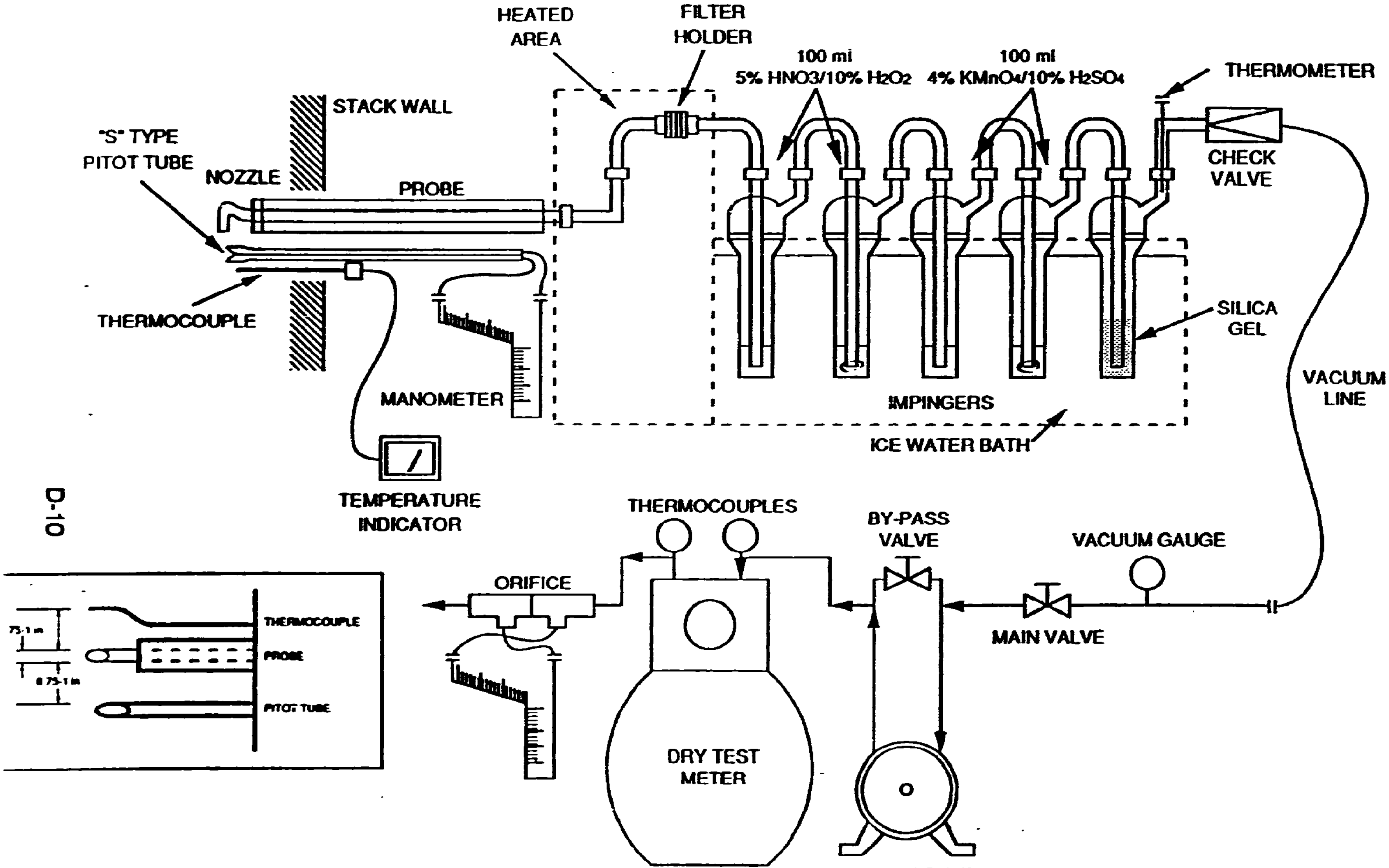

Figure PMM-1. Particulate/metals sampling train.

train data are recorded at each sampling point. Sampling rates are determined with the aid of a programmable calculator, and all sampling data are recorded on the Emission Testing Field Data Sheet.

Recovery Procedures

Upon completion of each sample run, the sampling train is allowed to cool and is then disassembled into sections. The probe and impinger sections are sealed and carefully transported to the cleanup area.

The amount of moisture collected is determined volumetrically using a graduated cylinder or by weighing each impinger before and after the sample run. After being weighed, the silica gel is discarded. Figure PMM-2 is a schematic of the sample recovery performed on the different sample fractions. The samples are recovered as follows:

Container No. 1 - The filter is placed into a petri dish, sealed, and labeled.

Container No. 2 - The filter holder, probe, and nozzle are rinsed with acetone to recover particulate. A nylon brush is used to remove particulate. The rinse is recovered in a glass jar.

Container No. 3 - The nozzle, probe, and filter holder front halves are rinsed with 0.1 N HNO_3 into a leak-free polyethylene container.

The contents of the first two impingers and a 0.1 N HNO_3 rinse of the filter holder backhalf and connecting glassware are placed in the same leak-free polyethylene container. The container is sealed and labeled, and the liquid level is marked.

Container No. 4 - The contents of the third and fourth impingers and an acidified potassium permanganate rinse are placed in an amber glass container. The container is sealed and labeled, and the liquid level is marked.

Blanks of each reagent are taken in the field for preparation and analysis in a manner identical to that for the samples. For each project, the blanks consist of one or more of the following:

1) Field blank - A sampling train is set up, leak-checked, recovered, and analyzed as a sample.

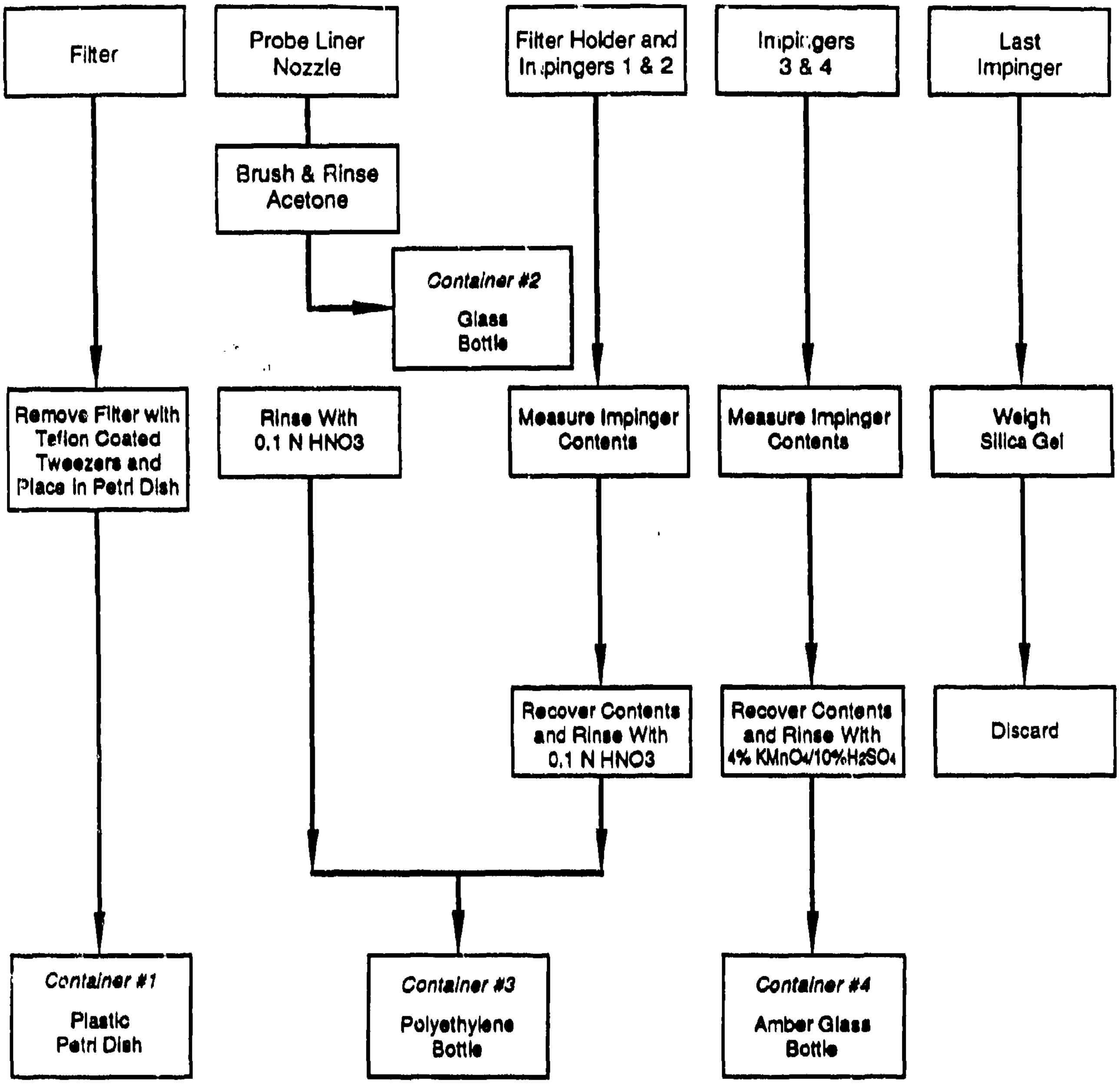

Figure PMM-2. Multimetals train recovery procedures.

2) Reagent blank - A sample of each reagent used is taken and analyzed either separately or by combining them in the same proportion as that used for samples.

3) Blank spike - A set of blank reagents is taken and combined in the same proportion as was used for the samples. Prior to analysis, the blank set is spiked with a known amount of each metal.

A diagram illustrating sample preparation and analysis procedures for each of the sample train components is shown in Figure PMM-3.

Sample Preparation and Analysis, Particulate

Container No. 1 - The filter and any loose particulate matter from this sample are placed into a tared weighing dish, desiccated for 24 hours to a constant weight, and weighed to the nearest 0.1 mg.

Container No. 2 - The acetone washings are transferred to a tared beaker and evaporated to dryness at ambient temperature and pressure, desiccated for 24 hours to a constant weight, and weighed to the nearest 0.1 mg.

Sample Preparation and Analysis, Metals

Container Nos. 1 and 2 - The filter with its filter catch and the acetone residue are divided into portions containing approximately 0.5 g each and placed into the analyst's choice of either individual microwave pressure-relief vessels or Parr® Bombs. Six mL of concentrated nitric acid and 4 mL of concentrated hydrofluoric acid are added to each vessel. For microwave heating, the sample vessels are microwaved for approximately 12 to 15 minutes (in intervals of 1 to 2 minutes) at 600 Watts. For conventional heating, the Parr Bombs are heated at 140°C (285°F) for 6 hours. The samples are then cooled to room temperature and combined with the acid-digested probe rinse.

Container No. 3 - If necessary, the pH of this sample is lowered to 2 with concentrated nitric acid. After pH adjustment, the sample is rinsed into a beaker with water, and the beaker is covered with a ribbed watchglass. The sample volume is reduced to approximately 20 mL by heating on a hot plate at a temperature just below boiling. The sample is then digested as follows:

a) 30 mL of 50 percent nitric acid is added to the sample, and the solution is heated for 30 minutes on a hot plate at a temperature just below boiling.

b) 10 mL of 3 percent hydrogen peroxide is added, and the solution is heated for an additional 10 minutes.

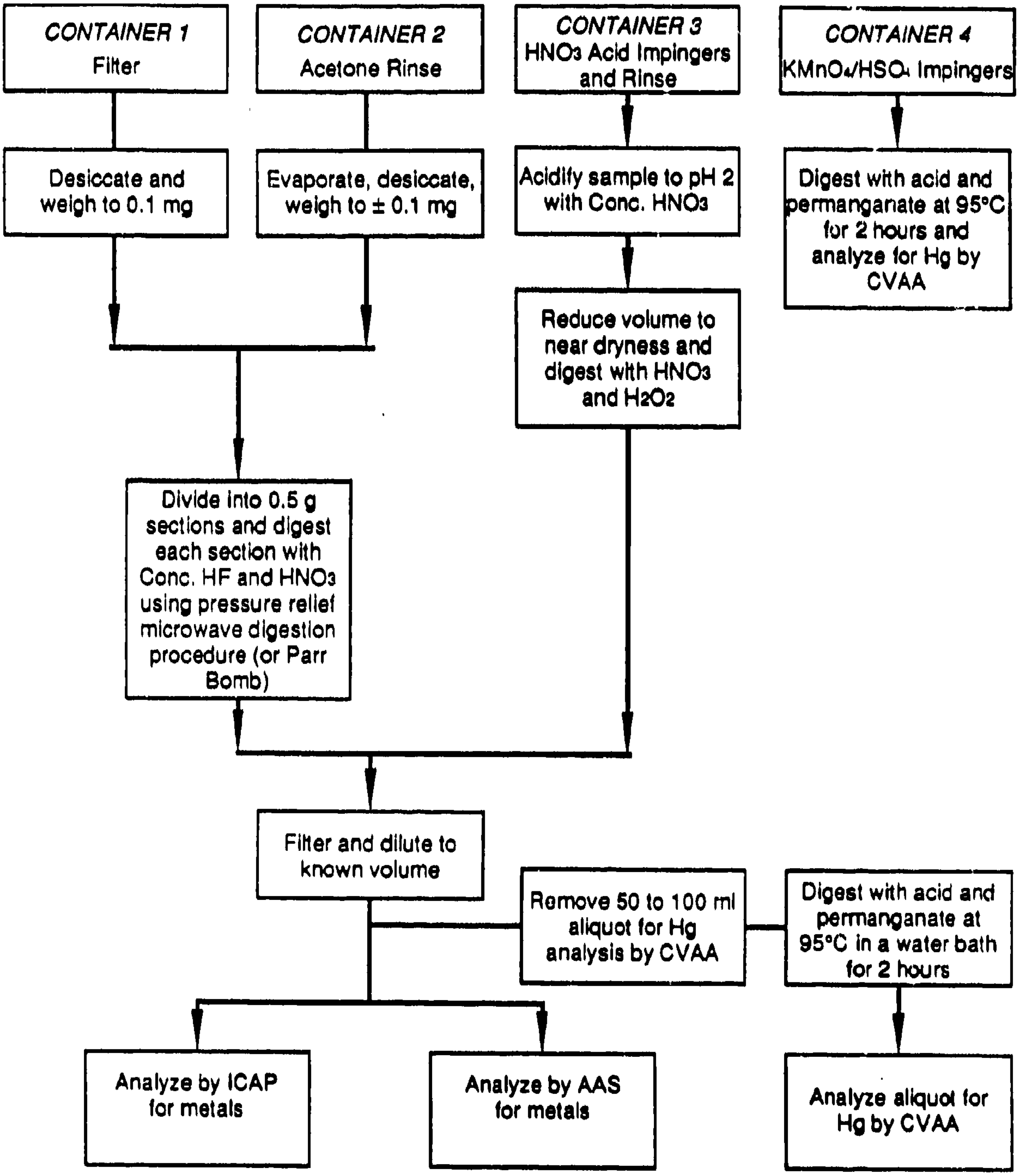

Figure PMM-3. Sample preparation and analysis scheme.

c) 50 mL of hot water is added, and the solution is heated for an additional 20 minutes.

After digestion, the remaining sample is combined with the contents of Container 1. This combined solution of the acid-digested filter, probe, and probe rinse and the impinger contents is filtered by using Whatman 541 filter paper.

The filtered solution is then divided into three fractions. The first fraction is analyzed by inductively coupled argon plasma emission spectroscopy (ICAP) in accordance with EPA Method 200.7 (40 CFR 136, Appendix C) which is the same as Method 6010 from SW 846.* The second fraction is analyzed by graphite furnace atomic absorption spectroscopy (AAS). The third fraction is then digested and analyzed for mercury by cold vapor atomic absorption (CVAA) spectroscopy.

The following list shows the methods normally used for each metal. The listed detection limits are shown in micrograms per sample; actual detection limits will vary depending on blank levels, any dilutions made to account for high levels of metals, or interferences. The detection limit for mercury includes the permanganate fraction.

	Normal procedure			Optional alternate procedure		
Metal	Method	No.*	Nominal detection limit, µg	Method	No.*	Nominal detection limit, µg
Antimony	ICAP	6010	30	AA	7041	2
Arsenic	AA	7060	0.3	-	-	-
Barium	ICAP	6010	0.5	-	-	-
Beryllium	ICAP	6010	0.7	-	-	-
Cadmium	ICAP	6010	1	-	-	-
Chromium	ICAP	6010	3	-	-	-
Copper	-	-	-	ICAP	6010	3
Lead	AA	7421	0.4	ICAP	6010	60
Nickel	-	-	-	ICAP	6010	10
Manganese	-	-	-	ICAP	6010	1
Mercury	AA	7470	0.2	-	-	-
Selenium	-	-	-	AA	7740	0.5
Silver	AA	7761	0.1	-	-	-
Thallium	ICAP	6010	120	AA	7841	0.7
Zinc	-	-	-	ICAP	6010	4

Container No. 4 - A known aliquot of the sample is taken and diluted to approximately 120 mL with mercury-free water. Approximately 15 mL of 50 percent potassium permanganate solution, 5 mL of 50 percent nitric acid, 5 mL of concentrated sulfuric acid, and 9 mL of 5 percent potassium sulfate are added to the sample. The sample is then heated for 2 hours at 95°C in a convection oven or water bath. After cooling, 5 mL of hydroxylamine hydrochloride

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* Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, SW 846, Third Edition, September 1988.

solution is added and mixed with the sample. Then 7 mL of stannous chloride is added and the sample is analyzed for mercury by CVAA spectroscopy.

Normal analytical quality assurance measures include daily full instrument calibration (ICAP is a zero and standard; AAS is a zero and minimum three standards), analysis of a method blank, analysis of a laboratory control sample (LCS, a method blank spiked with a known quantity of each metal), analysis of one sample by ICAP in duplicate, performance of all AAS analyses in duplicate, and performance of a post-digestion spike for each metal analyzed by AAS. For specific projects, a matrix spike may be designated for mercury in the permanganate fraction.

CALIBRATION PROCEDURES AND RESULTS

CALIBRATION PROCEDURES AND RESULTS

All of the equipment used is calibrated in accordance with the procedures outlined in the Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III.* The following pages describe these procedures and include the data sheets.

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*EPA 600/4-77-027b.

Nozzle Diameter

Each nozzle used in these tests is calibrated by making three separate measurements and calculating the average. If a deviation of more than 0.004 inch is found between any two measurements, the nozzle is either discarded or reamed out and remeasured. A micrometer is used for measuring. These calibration data are shown in the following Nozzle Calibration data sheet(s).

NOZZLE CALIBRATION

Date: 4/4/91 Calibrated by: SB/PF

Nozzle identification number	D_1, in.	D_2, in.	D_3, in.	ΔD, in.	D_{avg}
Glass #1	0.255	0.257	0.258	.003	0.255
Glass #2	0.265	0.265	0.265	0	0.265

where:

$D_{1,2,3,}$ = nozzle diameter measured on a different diameter, in. Tolerance = measure within 0.001 in.

ΔD = maximum difference in any two measurements, in. Tolerance = 0.004 in.

D_{avg} = average of D_1, D_2, and D_3.

Figure E-1. Nozzle calibration data.

Pitot Tube Calibration

Each pitot tube used in sampling is constructed by ITAQS and meets all requirements of EPA Method 2, Section 4.1.* Therefore, a baseline coefficient of 0.84 is assigned to each pitot tube. The following pages show the alignment requirements of Method 2 and the Pitot Tube Inspection Data Sheet(s) for each pitot tube used during the test program.

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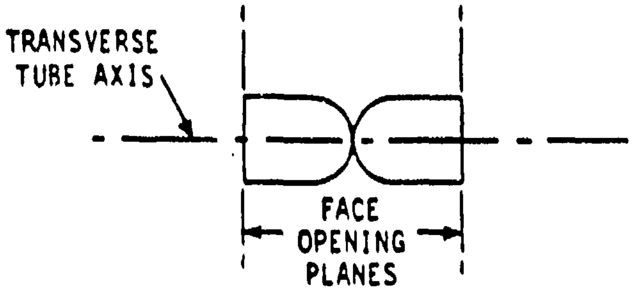
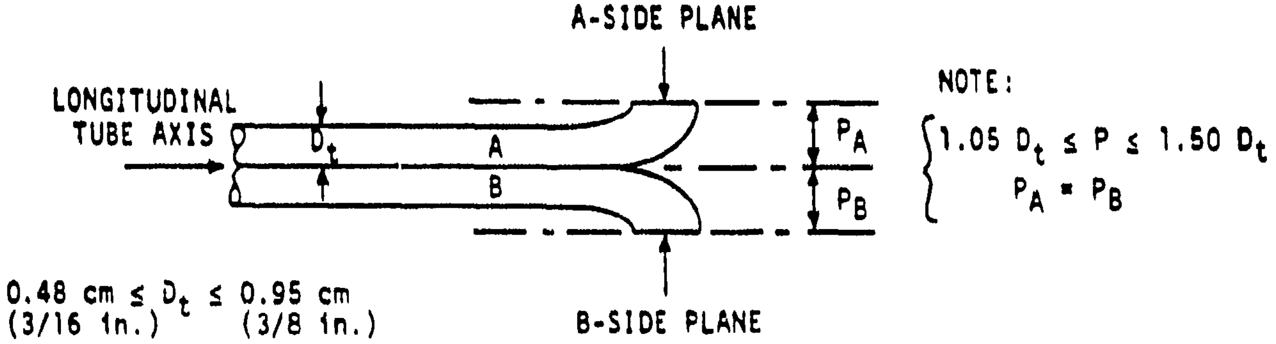
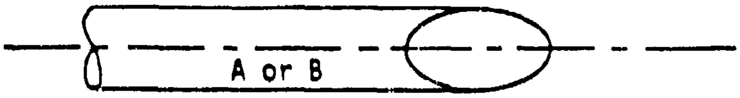
*40 CFR 60, Appendix A, July 1989.



(a) ENDVIEW

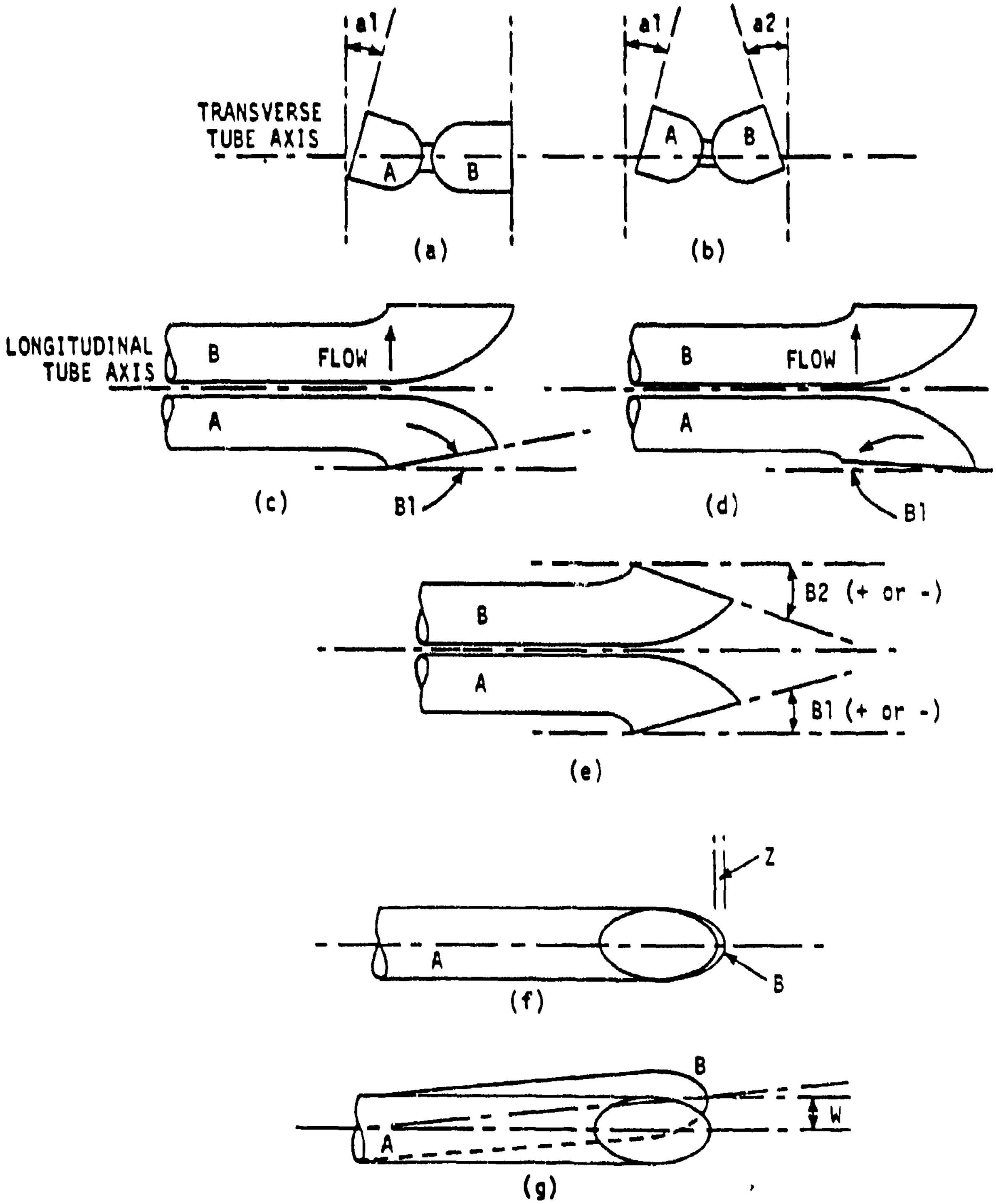


(b)



(c)

Properly constructed Type S pitot tubes shown in: (a) end view, face opening planes perpendicular to transverse axis; (b) top view, face opening planes parallel to longitudinal axis; (c) side view, both legs of equal length and centerlines coincident when viewed from both sides. Baseline coefficient values of 0.84 may be assigned to pitot tubes constructed this way.



Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect Cp as long as a_1 and a_2 are $<10°$, B_1 and B_2 are $<5°$, z is <0.32 (1/8 in.), and w is <0.08 cm (1/32 in.).

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PITOT TUBE INSPECTION DATA SHEET

Pitot Tube No. 5702-2' Date 12-17-90 Inspector J. Wilkins

α_1 degrees	α_2 degrees	β_1 degrees	β_2 degrees
1	1	1	2
<10°	<10°	<5°	<5°

D_t inches	P inches	1.05 D_t inches	1.50 D_t inches
.375	1.012	.394	.563
$0.185 \leq P_t < 0.380$	-	-	-

γ degrees	φ degrees	$P_{\sin(\gamma)}$ inches	$P_{\sin(\varphi)}$ inches
1	0	.017	.00
-	-	<0.125	<0.03125

P_1 inches	P_2 inches	$\|P_1 - P_2\|$ inches	Meet specifications
.506	.506	.00	✓
$1.05 D_t < P_1 < 1.50 D_t$	$1.05 D_t < P_2 < 1.50 D_t$	≤0.010	

Lower line in each table is limits for meeting specifications.

Checked by JM Date 12/17/90

Dry Gas Meter and Orifice Meter

The following page shows the Calibration Setup used for the initial and post-test calibration. A wet-test meter with a 2-cubic-feet-per-minute capacity and ±1 percent accuracy is used. The pump is run for approximately 15 minutes at an orifice manometer setting of 0.5 in.H_2O to heat up the pump and wet the interior surface of the wet-test meter. The information in the following example Calibration Data Sheet is gathered for the initial calibration; the ratio of accuracy of the wet-test meter to the dry-test meter and the $\Delta H@$ are then calculated.

Post-Test Meter Calibration Check

A post-test meter calibration check is made on each meter box used during the test to check its accuracy against the last calibration check. This post-test calibration must be within ±5 percent of the initial calibration. The initial calibration is performed as described in APTD-0576. The post-test calibration is performed by the same method. Three calibration runs are made by using the average orifice setting obtained during each test run and setting the vacuum at the maximum value obtained during each test run. The post-test calibration check indicated that all three runs for each meter box were within the ± 5 percent range allowed by EPA Method 5.*

The Particulate Sampling Meter Box Initial Calibration and Post-Test Calibration data sheets are included in the following pages.

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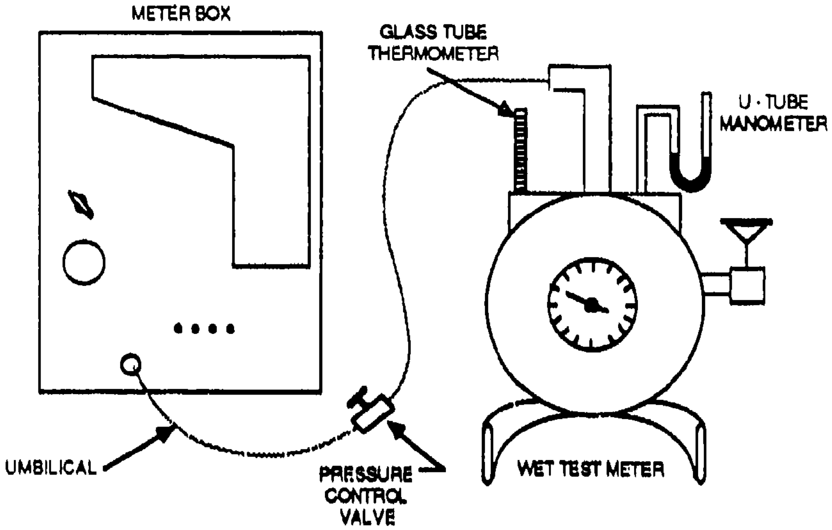
* 40 CFR 60, Appendix A, July 1990.



Calibration setup.

DATE ____________________ METER BOX NO.____________________

BAROMETRIC PRESSURE, P_b = ________ in. Hg. DRY GAS METER NO. ____________________

ORIFICE MANOMETER SETTING ΔH in. H_2O	GAS VOLUME WET TEST METER V_w, ft^3	GAS VOLUME DRY GAS METER V_d, ft_3	WET TEST METER T_w, °F	DRY GAS METER			TIME Ø, min.	Y	ΔH@
				INLET t_{di}, °F	OUTLET t_{do}, °F	AVERAGE t_d, °F			
0.5	5								
1.0	5								
1.5	10								
2.0	10								
3.0	10								
4.0	10								

AVERAGE ____________________

		Y	ΔH@
ΔH	$\frac{\Delta H}{13.6}$	$\frac{V_w P_b (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)(t_w + 460)}$	$\frac{0.0317\,\Delta H}{P_b (t_d + 460)} \left[\frac{(t_w + 460)Ø}{V_w}\right]^2$
0.5	0.0368		
1.0	0.0737		
1.5	0.110		
2.0	0.147		
3.0	0.221		
4.0	0.294		

Y = Ratio of accuracy of wet test meter to dry test meter. Tolerance = ± 0.01

ΔH@ = Orifice of pressure differential that gives 0.75 cfm of air at 70° F and 29.92 inches of mercury, in Hg). Tolerance = ± 0.15.

Calibration data sheet.

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METER BOX INITIAL CALIBRATION

validated 11/8/90

Date:	11/7/90	Meter Box No.:	FT-3
Barometric Pressure, (Pbar):	29.70	Calibrator:	R. Kolde

Run No.	Orifice manometer setting* ΔH in. H2O	Wet test meter volume Vw ft3	Dry gas meter volume Vd ft3	Temperatures: Wet test meter Tw °F	Temperatures: Dry gas meter Inlet Tdi °F	Temperatures: Dry gas meter Outlet Tdo °F	Temperatures: Dry gas meter Average Td °F	Vacuum setting** in. Hg	Duration of run, Ø min.	Duration of run, Ø sec
			142.400	67	80	75				
1	0.50	5.000	147.595	67	80	75	77.5	10	12	27
			147.899	67	80	75				
2	1.00	10.000	158.292	67	80	75	77.5	10	17	50
			158.600	67	80	75				
3	1.50	10.000	168.972	67	81	75	77.8	10	14	34
			169.301	67	81	75				
4	2.00	10.000	179.640	67	82	75	78.3	10	12	41
			179.900	67	82	75				
5	3.00	11.000	191.205	67	84	76	79.3	10	11	20
			191.702	67	84	76				
6	4.00	10.000	201.923	67	84	77	80.3	10	9	0

Run No.	Y	ΔH@
1	0.980	1.71
2	0.979	1.75
3	0.980	1.75
4	0.983	1.77
5	0.988	1.75
6	0.993	1.78
Pretest average	0.984	1.75
Difference*=	0.01	0.07

$$y = \frac{(Vw)(Pbar)(Td+460)}{(Vd)(Pbar+\Delta H/13.6)(Tw+460)}$$

$$\Delta H = \frac{(0.0317)(\Delta H)}{(Pbar)(Td+460)} \times \left|\frac{(Tw+460)\quad(Ø)}{Vw}\right|^{2}$$

Data checked by:
Date: 11/21/90

* Y must not deviate by more than ±0.02Y.
ΔH@ difference ≤0.15 in.H2O = Maximum ΔH@ - Minimum ΔH@

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METER BOX POST-TEST CALIBRATION

[illegible]

Date:	4/8/91	Meter Box No.:	IT-3
Barometric Pressure, (Pbar):	29.34	Initial Y:	0.984 ΔH@: 1.75
Plant:	USATHAMA	Project No.:	805644
Project Manager:	C. BRUFFEY	Calibrator:	d. Keeller

Run No.	Orifice manometer setting* ΔH in. H2O	Wet test meter volume Vw ft3	Dry gas meter volume Vd ft3	Temperatures: Wet test meter Tw °F	Dry gas meter: Inlet Tdi °F	Dry gas meter: Outlet Tdo °F	Dry gas meter: Average Td °F	Vacuum setting** in. Hg	Duration of run, Θ min	sec
			711.855	71	76	73				
1	1.00	10.000	721.560	71	81	77	76.8	3	17	26
			721.360	71	81	77				
2	1.00	10.000	731.685	71	86	79	80.8	3	17	20
			731.685	71	86	79				
3	1.00	10.000	742.835	71	87	82	83.5	3	17	18

Run No.	Y	ΔH@
1	0.978	1.72
2	0.984	1.69
3	0.986	1.68
Post-test average***	0.983	1.70
Difference from Pretest *** =	-0.001	-0.05

$$Y = \frac{(Vw)(Pbar)(Td+460)}{(Vd)(Pbar+\Delta H/13.6)(Tw+460)}$$

$$\Delta H@ = \frac{(0.0317)(\Delta H)}{(Pbar)(Td+460)} \times \left|\frac{(Tw+460)\ (\Theta)}{Vw}\right|^2$$

* To be the average ΔH used during the test series.

** To be the highest vacuum used during the test series.

*** Post-test Y must be within ±0.05 initial Y.

ΔY = (Posttest Y - Initial Y) / Initial Y

Post-test ΔH@ must be within ±0.15 in.H2O of the initial ΔH@.

Data checked by: O Cahill

Date: 4/8/91

Stack Thermocouples

Each thermocouple is calibrated by comparing it with an ASTM-3F thermometer at approximately 32°F, ambient temperature, 100°F, and 500°F. The thermocouple read within 1.5 percent of the reference thermometer throughout the entire range when expressed in degrees Rankine. The thermocouples may be checked at ambient temperature at the test site to verify the calibration. Calibration data are included in the following Thermocouple Calibration Data Sheet(s).

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THERMOCOUPLE CALIBRATION DATA SHEET

Date: 12/26/90 Thermocouple No: 646

Calibrator: B.S Reference: ASTM-3F

Range: 2'

Reference point no.	Source*	Reference thermometer temperature °F	Thermocouple temperature °F	Difference %**
1	2	70	67	.57
2	1	38	38	0
3	3	210	213	.45
4	4	448	451	.33

* Source:
1) Ice bath
2) Ambient
3) Water bath
4) Oil bath

** Percent difference.

$$\frac{\text{Reference temp. °R - thermocouple temp. °R}}{\text{(Reference temp. °R)}} \times 100\%$$

where °R = °F + 460

Each percent difference must be less than or equal to 1.5%.

Checked by ____________ Date 12/26/90

Digital Indicators for Thermocouple Readout

A digital indicator is calibrated by feeding a series of millivolt signals to the input and comparing the indicator reading with the reading the signal should have generated. Error did not exceed 0.5 percent when the temperatures were expressed in degrees Rankine. Calibration data are included in the following Thermocouple Digital Indicator Calibration Data Sheet(s).

THERMOCOUPLE DIGITAL INDICATOR
CALIBRATION DATA SHEET

DATE: 11/6/90 INDICATOR NO: ET-3

OPERATOR: R. Kolde SERIAL NO:

CALIBRATION DEVICE NO: # 3 MANUFACTURER: OMEGA

TEST POINT NO:	MILLIVOLT SIGNAL	EQUIVALENT TEMPERATURE, deg. F	DIGITAL INDICATOR TEMPERATURE READING, deg. F	DIFFERENCE %
1	-0.692	0	-1	-.22
2	1.520	100	100	0
3	3.819	200	200	0
4	6.092	300	300	0
5	8.314	400	399	[illegible]
6	10.560	500	500	0
7	22.251	1000	1000	0
8	29.315	1300	1299	.06
9	36.156	1600	1599	.05
10	42.732	1900	1898	.08

Percent difference must be less than or equal to 0.5%

Percent difference:

(Equivalent temperature, deg. R - Digital Indicator temperature, deg. R)(100%)

(Equivalent temperature, deg. R)

Where, deg. R = deg. F + 460

Dry Gas Thermocouples and Impinger Thermocouples

The dry gas thermocouples are calibrated by comparing them with an ASTM-3F thermometer at approximately 32°F, ambient temperature, and a higher temperature between approximately 100° and 200°F. The thermocouples agreed within 5°F of the reference thermometer. The impinger thermocouples are checked in a similar manner at approximately 32°F and ambient temperature, and they agreed within 2°F. The thermocouples may be checked at ambient temperature prior to the test series to verify calibration. Calibration data are included in the following Dry Gas Thermometer and Impinger Thermocouple Calibration Data Sheet(s).

[illegible] GAS THERMOCOUPLE
CALIBRATION DATA SHEET

Date: 11/6/90
Calibrator: R.Kolde
Thermocouple No: FT-3
Reference: ASTM-3F Thermometer

INLET

Reference point No.	Source'	Reference thermometer temperature deg. F	Thermocouple temperature deg. F	Difference deg. F''
1	1	65	65	0
2	2	33	34	1
3	3	200	200	0

OUTLET

Reference point No.	Source'	Reference thermometer temperature deg. F	Thermocouple temperature deg. F	Difference deg. F''
1	1	65	65	0
2	2	33	34	1
3	3	200	200	0

'Source: 1. Ambient
2. Ice bath
3. Water bath

''[illegible] deg. F [illegible] points

IMPINGER THERMOCOUPLE CALIBRATION DATA SHEET

Date: 12/14/90 Thermocouple No: I-13

Calibrator: T. Yarbough Reference: ASTM-3F

Reference point no.	Source*	Reference thermometer temperature °F	Thermocouple temperature °F	Difference °F**
1	1	70	71	1
2	2	34	34	0

* Source: 1) Ambient
2) Ice bath

** Difference must be less than 2°F at both points.

Checked by Date 12/14/90

Trip Balance

The trip balance is calibrated by comparing it with Class-S standard weights, and it agreed within 0.5 g. Calibration data are shown in the following Trip Balance Calibration Data Sheet(s).

IT INTERNATIONAL TECHNOLOGY CORPORATION

TRIP BALANCE CALIBRATION DATA SHEET

Balance No.	Date	Calibrator	Mass determined for					
			5 g	Error	50 g	Error	100 g	Error
419	12/14/90	BJ Graves	5.3	0.3	50.3	0.3	100.2	0.2
420	12/14/90	BJ Graves	5.0	0.0	50.0	0.0	100.1	0.1
421	12/14/90	BJ Graves	5.1	0.1	50.1	0.1	100.1	0.1
422	12/14/90	BJ Graves	5.1	0.1	50.1	0.1	100.1	0.1
418	12/14/90	BJ Graves	5.0	0.0	50.1	0.1	100.0	0.0
199	12/14/90	BJ Graves	5.0	0.0	50.0	0.0	100.0	0.0
Mettler	12/14/90	BJ Graves	5.0	0.0	50.0	0.0	100.0	0.0

Error must not exceed 0.5 grams at each point.

Checked by ____________ Date 12/14/90

Barometer

The field barometer is calibrated to within 0.1 in.Hg of an NBS-traceable mercury-in-glass barometer before the test series. It is checked against the reference barometer after each test series to determine if it reads within 0.2 in.Hg. The barometer read within the allowable limits each time. Calibration data are included in the following Barometer Calibration Log(s).

BAROMETER CALIBRATION LOG

	BAROMETER NO.	408	[illegible]	~~[illegible]~~ 415	411	~~[illegible]~~ 415	406	408
	Client	Dupont	[illegible]	Dupont	Kimmins	[illegible]		MSD
	Project No.	332037		332013		332055-01		803811-035-02
PRETEST	BAROMETER READING	29.54	[illegible]	29.15 ~~29.~~	29.10	29.60	29.09	29.60
	REFERENCE BAROMETER READING	29.54	[illegible]	29.13	29.12	29.60	29.09	29.60
	DIFFERENCE*	.000	[illegible]	.02	.02	.00	.00	.00
	DATE	3/26/91	[illegible]	3/27/91	3/27/91	4/16/91	3/27/91	4/16/91
	CALIBRATOR	MK	[illegible]	MK	MK	MK	BJ	MK
POST-TEST	BAROMETER READING	29.60	29.60	29.60		[illegible]	29.71	
	REFERENCE BAROMETER READING	29.60	29.58	29.60		[illegible]	29.70	
	DIFFERENCE**	.00	.02	.00		.00	0.01	
	DATE	4/16	4/16/91	4/16		[illegible]	4/16/91	
	CALIBRATOR	MK	[illegible]	MK		[illegible]	[illegible]	

*Barometer is adjusted so that difference does not exceed 0.05 in. Hg.
**Barometer is not adjusted. If difference exceed 0.10 in. Hg, inform project manager immediately.

APPENDIX C-1

SUMMARY OF OBSERVATIONS
FBSS RUNS ON APRIL 4, 1991

Test Paint Characteristics

Description:

Manufacturer: Pratt and Lambert, Wichita, KS
Product: No. 742-324
Type: Enamel - Alkyd - Gloss
Color: Yellow 13655
Spec: TT-E-489G Am-1 Type I Class A
Lot No.: G808010
Manufactured: September 12, 1988
Density: 9.9 lbs./gal.

Composition:

	Composition from the Manufacturer* wt %		Analysis**
Component	Total Concentration	Concentration in Non-volatiles	Results, wt %
Volatiles	37.6	---	---
Non-volatiles	62.4	100	56.2
Lead	18.34	29.4	19.21
Chromium	3.01	4.8	3.73
Cadmium	None	None	< 2 pp m
Zinc (from drier [16%])	---	0.1	0.12

* Composition reported by the manufacturer from batch information. Telephone report from Mr. Gene Saghi, Technical Director, (Phone: 316-733-1361).

** Analyses performed by Martel Laboratory Services, Inc., Baltimore, MD. Results are on a dry basis except non-volatiles.

Calculated density of the non-volatiles: 1.95 gm/cm^3

MARTEL

Martel Lab Number: 10530

Log Identification: W-9303

Samples received by Martel.
Project Identification: Military Paint

International Technology Corporation
1133 21st Street NW
Washington, DC 20036
Attention: Dr. Elbert Herrick

June 13, 1991

Client Identification: IT

Analytical Parameter	Method	Result	Units
Log Identification: W-9303			
Date Received: 05/17/91			
Sample ID: 1. Military Paint			
Solids (Total)	EPA 160.3	56.2	%
Lead	EPA 239.1	19.21	%
Chromium	EPA 200.7	3.73	%
Cadmium	EPA 200.7	<2	mg/kg
Zinc	EPA 200.7	0.12	%

All procedures used are in accordance with the following methods:
EPA-600/4-79-020, "Methods for Chemical Analysis of Water and Wastes".
SW-846, "Test Methods for Evaluating Solid Waste", 1986.
Results report on a dry basis except total solids. Replicate analysis confirms the results.

QC Approval

Date

Eileen A. Killoran
Laboratory Approval

6-13-91
Date

MART [illegible]

Analytical Information
Dates, Times, Analysts
(dates may refer to date begun or date approved)

Log Number	Test Code	Date Performed	Time Performed	Analyst Initials
** Sample ID: 1. Military Paint				
9303	TS	06/05/91	10:00	NMN
9303	PB	06/05/91	16:00	BAB
9303	CR	06/05/91	16:00	BAB
9303	CD	06/05/91	16:00	BAB
9303	ZN	06/05/91	09:30	BAB

INTERNATIONAL TECHNOLOGY CORPORATION

ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

ITAQS Cincinnati

Date: April 29, 1991

Attn: Mr. Chuck Bruffey

Job Number 21381

P.O. Number 816006-002

This is the Certificate of Analysis for the following samples:

Client Project ID:	USATHAMA
Date Received:	April 9, 1991
Work Order:	X1-04-065
Number of Samples:	12
Sample Type:	Solid/Water

I. Introduction

Seven solids and five waters arrived at ITAS Cincinnati on April 9, 1991. The samples were sent for analytical work in support of monitoring work on the USATHAMA Project. The samples are labeled as follows:

- Solid # FBM-1
- Solid # FBM-2
- Solid # FBM-3
- Solid # FBM-4
- A-1 Ash
- S-1 Steel Shotblast Media
- #1 Virgin Bed Material
- Water #1 Quench Outlet
- Water #2 Lead [illegible]
- Water #3 Inlet H2O
- Water #4 FBPs Quench Out
- Water #5 FBPs Quench Outlet

II. Analytical Results/Methodology

The analytical results for this report are presented by analytical test. Each set of data will include sample identification information, the analytical results, and the appropriate detection limits.

The solids were analysed for the following metals on a TCLP basis.

Reviewed and Approved by:

Tim Soward

Tim Soward
Project Manager
104065

II. Analytical Results/Methodology (cont.)

- * Cadmium, Chromium, Lead and Zinc by Inductively Coupled Plasma Spectroscopy; EPA Method 6010

The TCLP leaching was done by EPA Method 1311.

The waters were analyzed for the same metals on a total basis. ICP was also used.

III. Quality Control

Immediately following the analytical data for the samples can be found the QA/QC information that pertains to these samples. The purpose of this information is to demonstrate that the data enclosed is scientifically valid and defensible. This QA/QC data is used to assess the laboratory's performance during the analysis of the samples it accompanies. All quantitations were performed from within the calibrated range of the analytical instrument.

Matrix spikes were performed for each of the TCLP analyses. The recoveries are presented with the sample results.

Client: USATHAMA
Work Order: X1-04-065
10406502

IT ANALYTICAL SERVICES
CINCINNATI, OH

Analytical Results, mg/L

Client Sample ID	Lab No.	Cadmium	Chromium	Lead	Zinc
Solid # FBM-1	01	0.25	0.021	3.4	0.47
MS%		94.2	106	99.5	93.0
Solid # FBM-2	02	0.23	0.052	5.2	0.43
MS%		96.5	109	96.9	96.5
Solid # FBM-3	03	0.41	0.30	7.5	0.30
MS%		90.4	104	94.5	88.7
Solid # FBM-4	04	0.47	0.20	8.2	0.67
MS%		93.1	105	92.6	86.6
A-1 Ash	05	1.1	0.010	44	2.8
MS%		92.4	105	101	89
S-1 Steel Shotblast Media	06	2.7	ND	ND	180
MS%		76.7	102	88.7	(1)
#1 Virgin Bed Material	07	0.006	0.050	ND	0.17
MS%		90.6	103	92.7	84.2
Water #1 Quench Outlet	08	0.007	0.045	0.21	0.18
Water #2 Lead FBPs	09	0.003	0.018	ND	0.15
Water #3 Inlet H2O	10	ND	ND	ND	0.12
Water # 4 FBPs Quench Outlet	11	ND	0.022	ND	0.11
Water # 5 FBPs Quench Outlet	12	0.003	0.020	ND	0.10
Detection Limit		0.002	0.00[illegible]	0.[illegible]	

(1) Inappropriate spike level

Quality Assurance Data

Quality Control
Standard Reference Solution

Analyte	Theoretical Value, mg/L	Percent Recovery
Cadmium	1	96.9, 96.3, 94.5, 94.4
Chromium	1	97.9, 97.1, 98.0, 98.0
Lead	2	97.5, 96.5, 99.6, 96.6
Zinc	1	95.1, 93.6, 97.7, 96.9

INTERNATIONAL TECHNOLOGY CORPORATION

ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

IT Corporation
1133 21st. Street NW, Suite 500
Washington, DC 20036

Date: May 17, 1991

Attn: Mr. Duane Parker

Job Number 21341

P.O. Number 805625

This is the Certificate of Analysis for the following samples:

Client Project ID: USATHAMA
Date Received: April 9, 1991
Work Order: X1-05-027
Number of Samples: 5
Sample Type: Waste

I. Introduction

Five waste samples arrived at ITAS Cincinnati on April 9, 1991. The samples were sent for analytical work in support of monitoring work on the USATHAMA Project. The samples are labeled as follows:

FBM-1
FBM-2
FBM-3
FBM-4
#1 Virgin Bed Material

II. Analytical Results/Methodology

The analytical results for this report are presented by analytical test. Each set of data will include sample identification information, the analytical results, and the appropriate detection limits.

The analyses requested are listed on the following page.

Reviewed and Approved by:

Timothy Soward

Timothy Soward
Project Manager
105027

American Council of Independent Laboratories
International Association of Environmental Testing Laboratories
American Association for Laboratory Accreditation

IT Analytical Services • 11499 Chester Road • Cincinnati, OH 45246 • 513-782-4600

Client: USATHAMA
Work Order: X1-05-027
10502703

IT ANALYTICAL SERVICES
CINCINNATI, OH

Analytical Results, ug/g

Client Sample ID	FBM-1	FBM-2	FBM-3	FBM-4	#1 Virgin Bed Material	
Lab No.	01	02	03	04	07	
Analyte						Detection Limit
Cadmium	5.4	6.4	9.2	11	0.28	0.2
Chromium	6.8	5.3	19	37	3.0	0.3
Lead	60	77	200	260	ND	6
Zinc	7.9	9.2	11	18	ND	0.5

ND = Not detected above the reported detection limit

Quality Assurance Data

Quality Control
Standard Reference Solutions

Analyte	Theoretical Value	Percent Recovery
Cadmium	1	95.9
Chromium	1	99.1
Lead	2	99.8
Zinc	1	82.4

II. Analytical Results/Methodology (cont.)

- Cadmium, Chromium, Lead and Zinc by Inductively Coupled Plasma Spectroscopy; EPA Method 6010

III. Quality Control

Immediately following the analytical data for the samples can be found the QA/QC information that pertains to these samples. The purpose of this information is to demonstrate that the data enclosed is scientifically valid and defensible. This QA/QC data is used to assess the laboratory's performance during the analysis of the samples it accompanies. All quantitations were performed from within the calibrated range of the analytical instrument.

IT INTERNATIONAL TECHNOLOGY CORPORATION

ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

IT Corporation
1133 21st. Street NW, Suite 500
Washington, DC 20036

Date: May 17, 1991

Attn: Mr. Duane Parker

Job Number 21421

P.O. Number JTS # 816006

This is the Certificate of Analysis for the following samples:

Client Project ID: USATHAMA Project
Date Received: May 8, 1991
Work Order: X1-05-056
Number of Samples: 3
Sample Type: Solid

I. Introduction

Three solid samples arrived at ITAS Cincinnati on May 8, 1991. The samples were sent for analytical work in support of monitoring work on the USATHAMA Project. The samples were labeled as follows:

Solid # SC-1 Solid # SC-2 Solid # SC-4

II. Analytical Results/Methodology

The analytical results for this report are presented by analytical test. Each set of data will include sample identification information, the analytical results, and the appropriate detection limits.

The analyses requested are listed on the following page.

Reviewed and Approved by:

Tim Soward

Tim Soward
Project Manager
105056

II. Analytical Results/Methodology (cont.)

- Cadmium, Chromium, Lead and Zinc by Inductively Coupled Plasma Spectroscopy; EPA Method 6010
- Total sample weight before analysis

III. Quality Control

Immediately following the analytical data for the samples can be found the QA/QC information that pertains to these samples. The purpose of this information is to demonstrate that the data enclosed is scientifically valid and defensible. This QA/QC data is used to assess the laboratory's performance during the analysis of the samples it accompanies. All quantitations were performed from within the calibrated range of the analytical instrument.

Client: IT USATHAMA
Work Order: X1-05-056
10505602

IT ANALYTICAL SERVICES
CINCINNATI, OH

Analytical Results

Client Sample ID		Solid # SC-1	Solid # SC-2	Solid # SC-4	
Lab No.		01	02	03	
Analyte	Units				Detection Limit
Cadmium	ug/g	600	630	900	0.2
Chromium	ug/g	15,000	21,000	30,000	0.3
Lead	ug/g	86,000	120,000	170,000	6
Zinc	ug/g	790	1,000	2,000	0.5
Total Sample Weight	g	11	0.93	0.26	

Quality Control
Standard Reference Solution

Analyte	Theoretical Value	Percent Recovery
Cadmium	1	101
Chromium	1	104
Lead	2	98.3
Zinc	1	96.4

Table 2-2
Summary of Flue Gas Conditions at the Afternburner Outlet
April 4, 1991

		Volumetric Flow Rate				Composition %	
Run No.	Time (24-h)	acfm[a]	dscfm[b]	Temperature °F	Moisture %	O_2	CO_2
AOPM-1	1324-1424	360	271	270	19.1	19.0	1.0
AOPM-2	1509-1609	425	253	261	19.3	19.0	1.0
AOPM-3	1635-1735	426	250	271	19.4	19.0	1.0

[a] afcm = Actual cubic feet per minute

[b] dscfm = Dry standard cubic feet per minute. Standard conditons are 68°F, 29.92 in Hg, and zero percent moisture.

Table 2-5
Summary of Particulate and Metals Emissions at the Afterburner Outlet
April 4, 1991

		Particulate Emissions			Metals Emissions							
		Concentration			Concentration, ug/m^3				Mass Emission rate, lb/h			
Test No.	Time (24-h)	gr/dscf	mg/m^3	Mass Emission rate, lb/h	Cd	Cr	Pb	Zn	Cd	Cr	Pb	Zn
ADPM-1	1324-1424	0.015	34.6	0.035	10.8	20.5	48.6	90.6	1.1E-05	2.1E-06	4.9E-05	9.2E-05
ADPM-2	1509-1609	0.0049	11.1	0.011	4.6	20.4	51.0	122	4.3E-06	1.9E-05	4.8E-05	1.2E-04
ADPM-3	1635-1735	0.0047	10.9	0.010	9.2	25.5	109	106	8.6E-06	2.4E-05	1.0E-04	9.9E-05

mccrone associates

CONSULTING: ULTRAMICROANALYSIS • MICROSCOPY • SMALL PARTICLE PROBLEMS • SOLID-STATE CHEMISTRY

THE McCRONE GROUP
1956 35th ANNIVERSARY 1991

7 June 1991

Dr. Duane Parker
Senior Chemist
IT Corporation
11499 Chester Road
Cincinnati, OH 45246

Dear Dr. Parker:

This report summarizes the results of our electron microprobe analysis of the two samples we received in May. This work will be billed under your purchase order number 41683.

The first sample arrived on 8 May 1991. It was a small quantity of deposits in a glass bottle. The second sample arrived two weeks later and was labelled "Test Panel Fluidized Bed Paint, Stripping Oven Letterkenny Army Depot, Cadmium Plating Effects".

SAMPLES

The samples were examined both visually and with a stereomicroscope. The first sample had a lot of metallic and a few non-metallic particles of various sizes. Figure 1 is a photomicrograph of all the particles. As you can see, most of them are yellow metallic fragments (scrapings). We selected a few metallic particles for analysis and also placed a sample of the bulk of the particles on a beryllium substrate for electron microprobe analysis.

The second sample was a corroded metal plate which had areas of dark brown and gray discoloration. We scraped a small quantity of the deposits from both area and mounted them on the substrate for analysis.

ANALYSIS

Electron microprobe analysis of the particles from the first sample identified the metallic particles as cadmium metallic. Cadmium oxide was present only as a thin yellow stain on the surface. Besides cadmium particles there were a number of stainless steel and occasional iron oxide particles. A number of iron oxide and some of the cadmium particles were corroded heavily with chlorine. The chlorine level in the particles was variable, ranging from pure metallic particles to low chlorine compounds to pure iron chloride particles. Chlorine seemed to be associated mostly with iron and chromium. Table II summarizes the results of our analysis of the samples of small particles.

The scrapings from the second sample, the corroded panel, were also analyzed. The scrapings were again identified as a corrosion products of iron, chromium and cadmium. Very few metallic particles were identified in this sample. The scrapings consists of cadmium oxide, cadmium chloride, iron oxide and iron chloride particles. Again, the analysis of the scraping from the second sample (Test Panel) are shown in Table II. X-ray micrographs of the small particles from Sample 1 are shown in Figures 2 through 6. From the pictures you can see that chlorine is associated mostly with the iron while the cadmium is mostly metallic.

The results were given to you by telephone immediately following our analysis. Thank you for consulting McCrone Associates, Inc. If you have any questions concerning this analysis, please do not hesitate to contact me.

Sincerely,

John Gavrilovic

John Gavrilovic, Ph.D.
Senior Research Associate

JG:tbc
Enclosure
Ref: MA20915; P.O. #41683

TABLE I
Samples for Analysis
IT Corporation, MA20915

LABEL	DESCRIPTION
Lead PN 3769-7 Sample No. SC-3 Scrapings from one Cd plate Steel panle #4, Test Run #3, on 4/4/91, scraped on 4/25/91	Glass jar with small particles, mix of metallic particles, rust and nonmetallic
Test Panel, Fluidized Bed Paint, Stripping Oven Letterkenney Army Depot, Cadmium Plating Effects	Heavily corroded metal panel in a plastic bag. Red and gray corrosion deposits.

TABLE II
Electron Microprobe Analysis of Two Samples
IT Corporation, MA20915

SAMPLE	ELEMENTS % BY WEIGHT								
	Cd	**Pb**	**Fe**	**Cr**	**Cl**	**S**	**Al**	**Si**	**C + O**
Yellow scrapings Sample No. SC-3	62.8	---	7.7	1.2	10.3	1.7	7.3	1.1	bal
Single metal particle Sample No. SC-3	99.0	---	---	---	---	---	---	---	bal
Letterkenney A.D. Surface Deposits	9.0	6.9	1.0	3.5	4.7	---	37.5	---	bal
Letterkenney A.D. Dark Deposits	4.1	---	48.1	0.2	12.0	---	---	1.5	bal

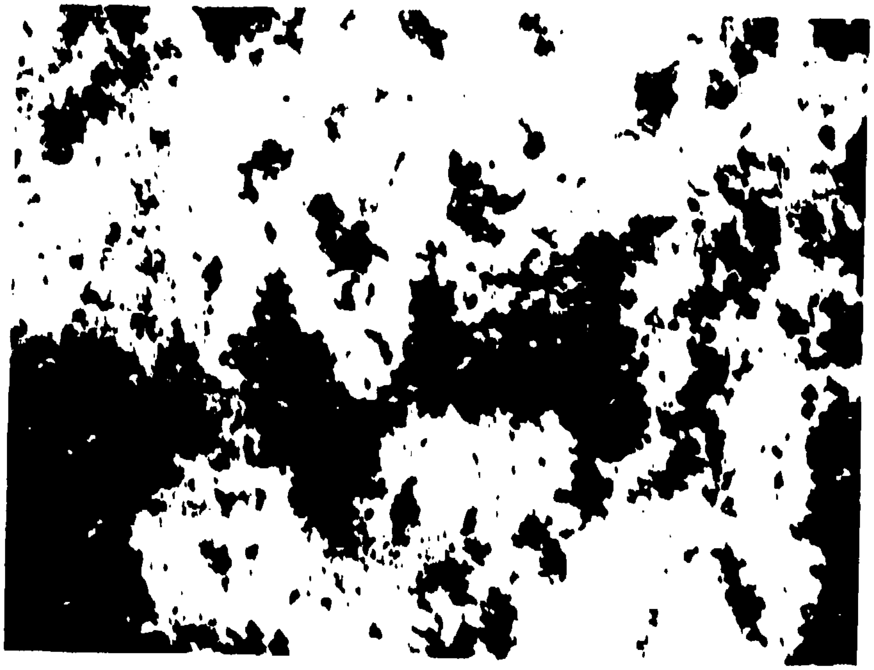


FIGURE 1
Photomicrograph of small particles scraped from one cadmium plated steel panel #4. Magnification 23X.

FIGURE 2.
Scanning electron micrograph of the small particles shown in Figure 1. Magnification 500X.

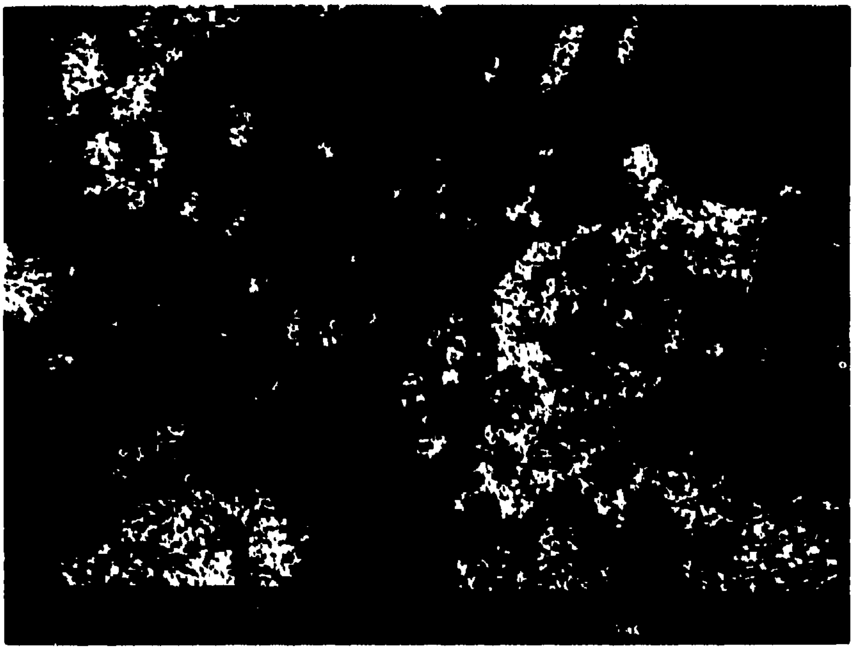


FIGURE 3.
Cadmium distribution micrograph of the particle shown in Figure 2.

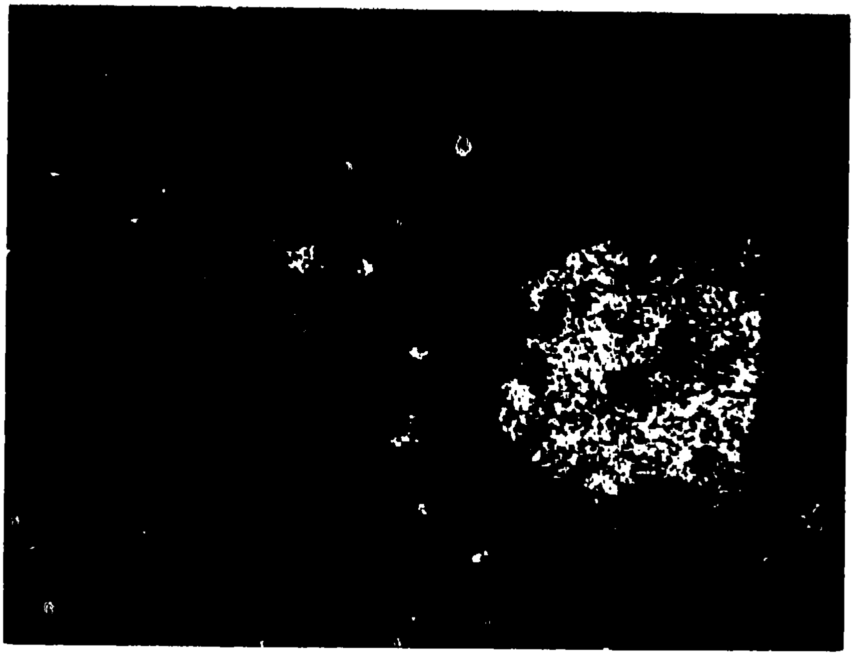


FIGURE 4
Iron distribution micrograph for the particle shown in Figure 2.

FIGURE 5.
Chlorine distribution micrograph for the particle shown in Figure 2.

FIGURE 6.
Oxygen distribution micrograph for the particle shown in Figure 2.

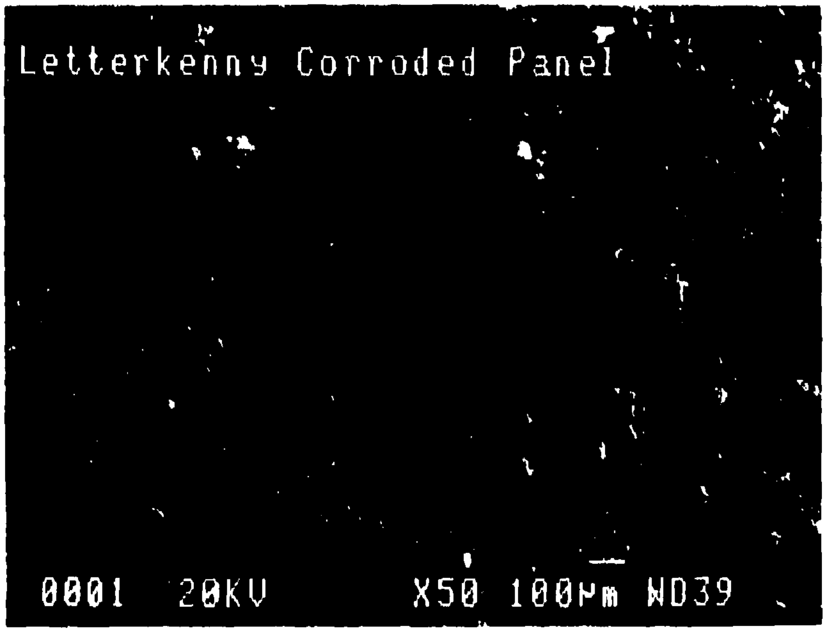
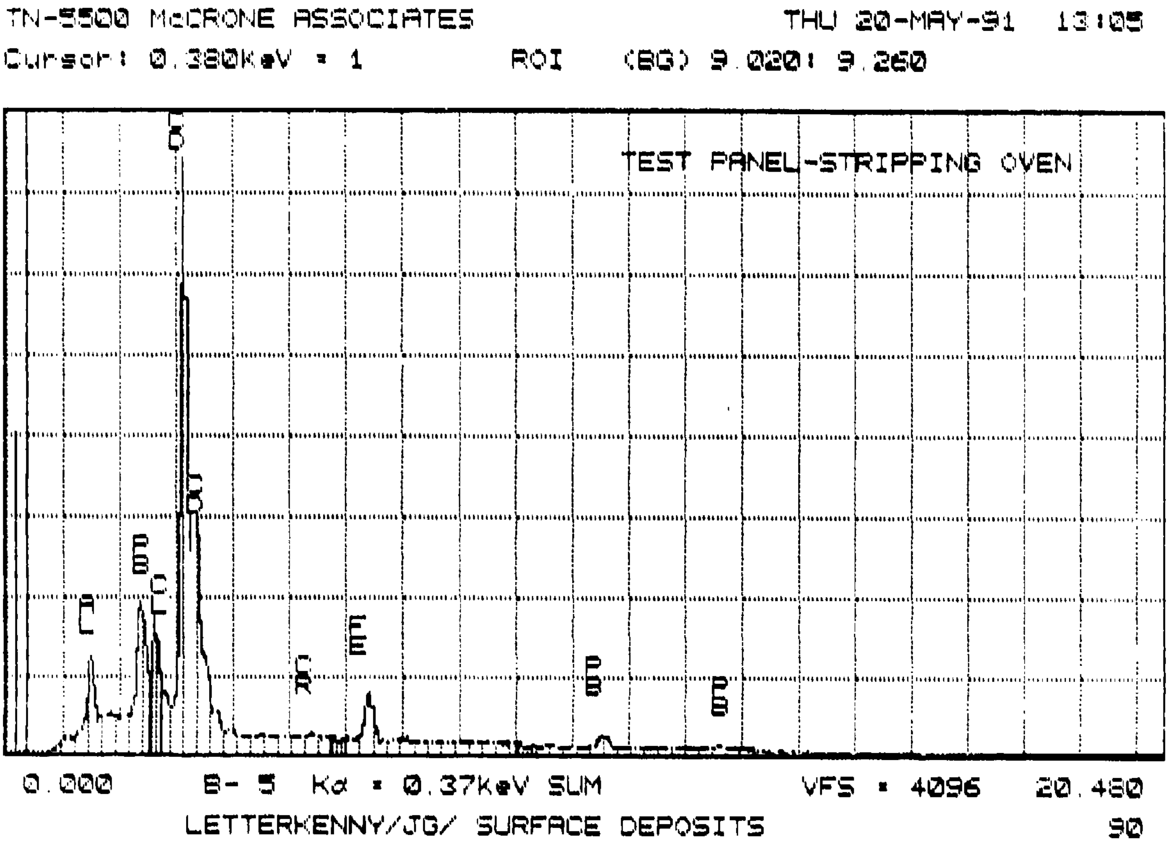


FIGURE 7
Scanning electron micrograph of the surface
of the corroded test panel. Magnification 50X.



TN-5500 McCRONE ASSOCIATES THU 20-MAY-91 13:05

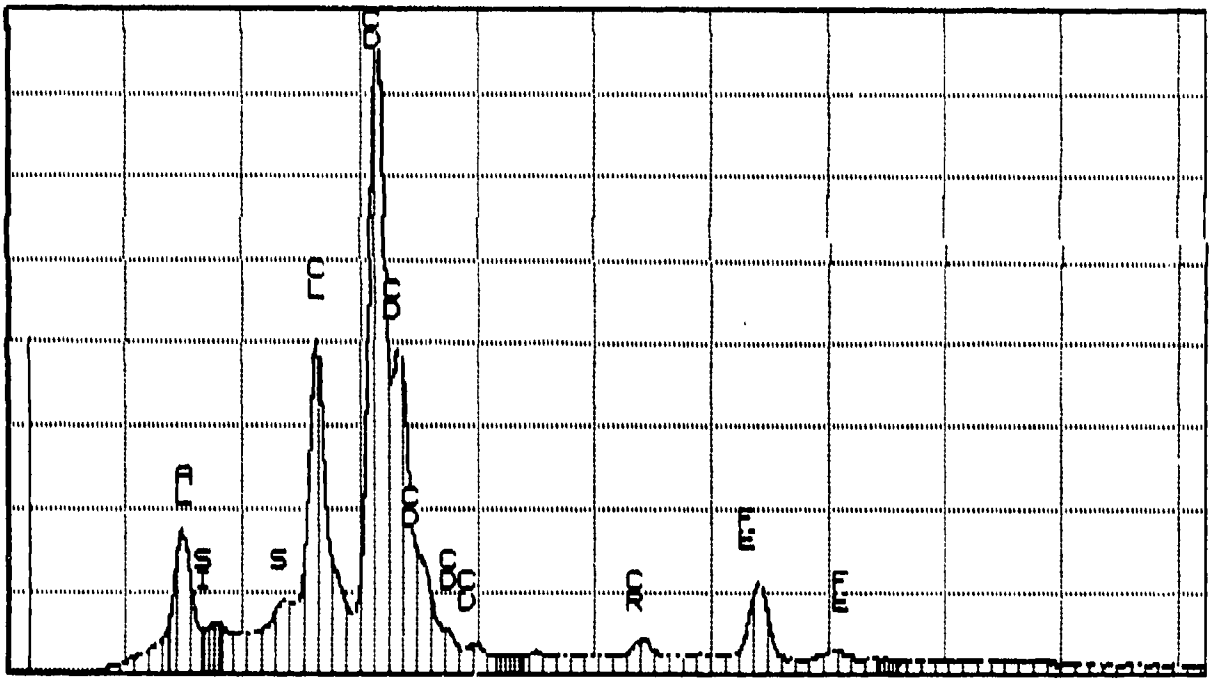
Cursor: 0.380KeV = 1 ROI (BG) 9.020: 9.260

0.000 B- 5 Kα = 0.37KeV SUM VFS = 4096 20.480

LETTERKENNY/JG/ SURFACE DEPOSITS 90

McCRONE ASSOCIATES THU 23-MAY-91 14:12

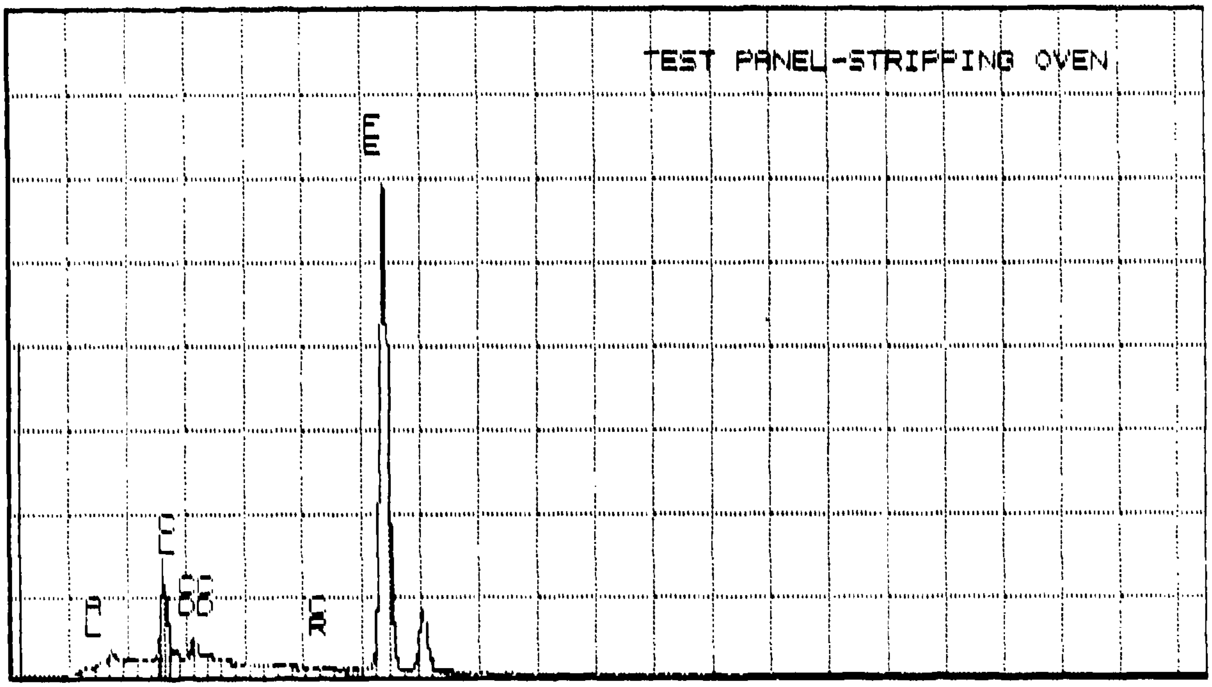
Cursor: 0.000keV = 0 ROI (BG) 7.420: 7.600



0.000 B- 5 VFS = 2048 10.240

90 IT/JG/ YELLOW SCRAPINGS

TN-5500 McCRONE ASSOCIATES THU 20-MAY-91 13:10
Cursor: 0.000keV = 0 ROI (BG) 9.020: 9.260



0.000 B- 5 VFS = 4096 20.480
LETTERKENNY/JG/ SURFACE DEPOSITS-DARK AREAS 90

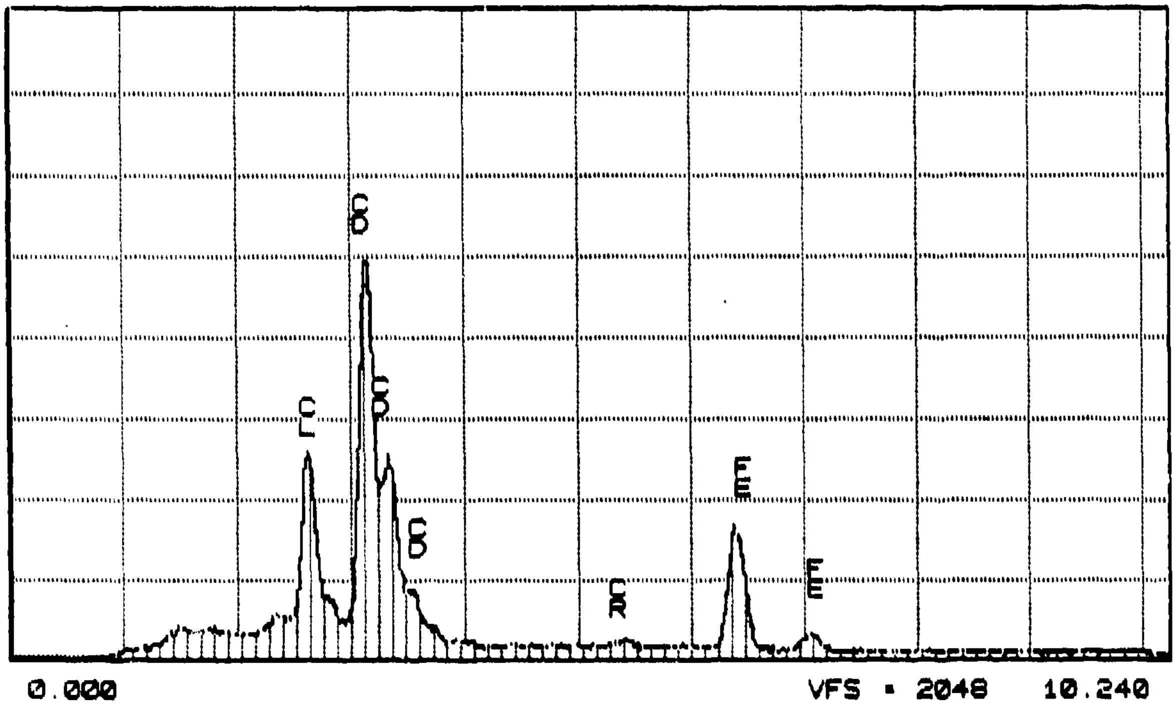
```
SEMI-QUANTITATIVE ANALYSIS: LETTERKENNY/JG/ SURFACE DEPOSITS
EL     NORM. K-RATIO

CD-L 0.06012 +- 0.00741
PB-M 0.04180 +- 0.00681
AL-K 0.21072 +- 0.00859
FE-K 0.00696 +- 0.00238
CR-K 0.02659 +- 0.00405
CL-K 0.02971 +- 0.00310
O -K 0.00000 +- 0.00000

ZAF CORRECTION        20.00 KV        35.00 Degs

No. of Iterations  0
----      K       [Z]     [A]     [F]    [ZAF]  ATOM.%   WT.%
CD-L  0.060  1.203  1.079  0.999  1.296.  1.97    8.98
PB-M  0.042  1.341  1.072  1.000  1.438   0.82    6.92
AL-K  0.211  1.004  1.544  0.997  1.546  34.23   37.53   *
FE-K  0.007  1.094  1.037  0.998  1.131   0.40    0.91
CR-K  0.027  1.092  1.059  0.997  1.153   1.67    3.53
CL-K  0.030  1.012  1.369  0.995  1.378   3.32    4.72
O -K  0.063  0.935  6.308  1.000  5.897  57.58   37.41 D *
 * - High Absorbance

STOICH RESULTS
CD    8.98
PBO   7.46
AL2O3  70.88
FEO   1.17
CRO3   6.80
CL   4.72

SSQ:
```

```
SEMI-QUANTITATIVE ANALYSIS: IT/JG/ YELLOW SCRAPINGS
EL    NORM. K-RATIO

CD-L 0.58866 +- 0.00377
FE-K 0.07805 +- 0.00133
CR-K 0.01134 +- 0.00044
CL-K 0.10384 +- 0.00096
S -K 0.01649 +- 0.00037
AL-K 0.04601 +- 0.00067
SI-K 0.00814 +- 0.00026
O -K 0.00000 +- 0.00000

ZAF CORRECTION       20.00 KV       55.00 Degs

No. of Iterations  4
----      K       [Z]     [A]     [F]    [ZAF]   ATOM.%  WT.%
CD-L  0.589  1.084  1.043  0.999  1.129  30.00  62.79
FE-K  0.078  0.973  1.000  1.000  1.051   7.40   7.74
CR-K  0.011  0.976  1.138  0.992  1.101   1.21   1.18
CL-K  0.104  0.915  1.197  0.963  1.055  15.81  10.34
S  -K  0.016  0.887  1.280  0.972  1.103   2.87   1.72
AL-K  0.046  0.912  1.862  0.995  1.689  14.54   7.34  *
SI-K  0.008  0.881  1.646  0.991  1.437   2.11   1.11  *
O -K  0.005  0.847 18.581  1.000 15.734  26.04   7.79 D *
 * - High Absorbance

STOICH RESULTS
CD  62.79
FE   7.74
CR   1.18
CL  10.34
S    1.72
AL2O3  13.86
SIO2   2.37

SSQ:
```

```
SEMI-QUANTITATIVE ANALYSIS: IT/JG/ SAMPLE No. SC-3.-SINGLE PARTICLE
EL    NORM. K-RATIO

CD-L 0.99999 +- 0.05148
CL-K-0.00000 +- 0.00000

ZAF CORRECTION        20.00 KV       55.00 Degs

No. of Iterations  0
----     K      [Z]     [A]     [F]    [ZAF]  ATOM.%  WT.%
CD-L  1.000  1.000  1.000  1.000  1.000 100.00 100.00
CL-K  0.000  0.845  1.199  0.937  0.950   0.00    0.00 G
 * - High Absorbance

SSQ: SET SSQ

SSQ:
```

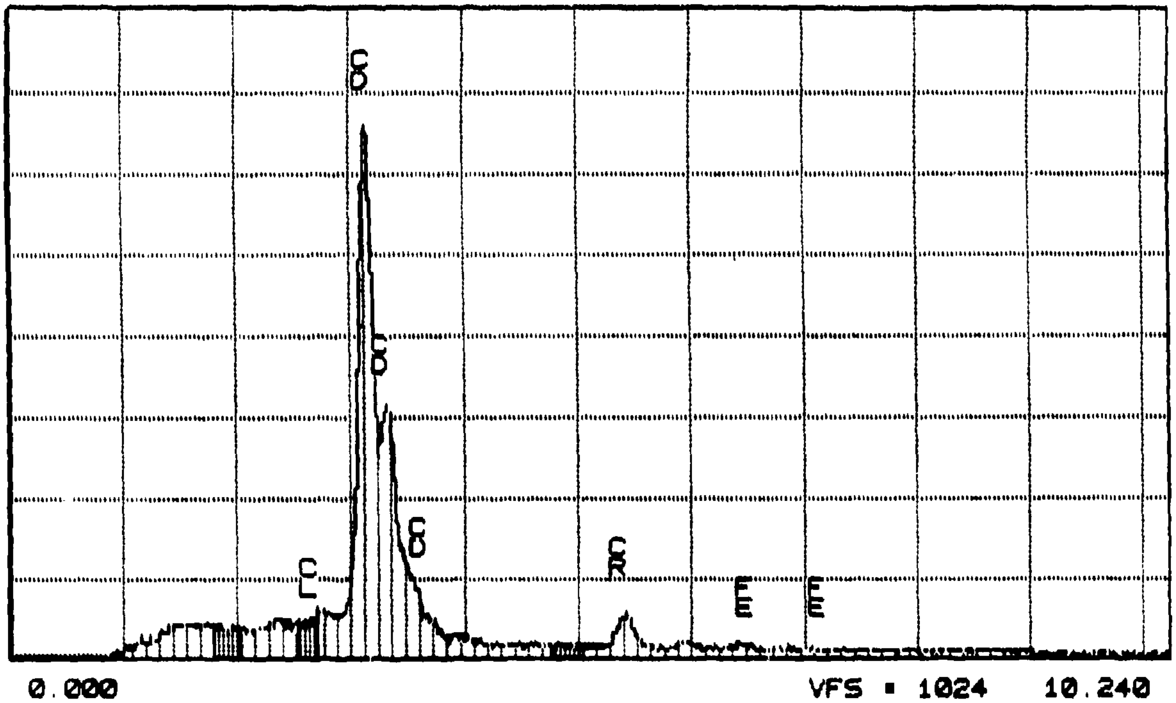
McCRONE ASSOCIATES WED 15-MAY-91 12:37

Cursor: 0.000keV = 0 ROI (0) 0.000: 0.000

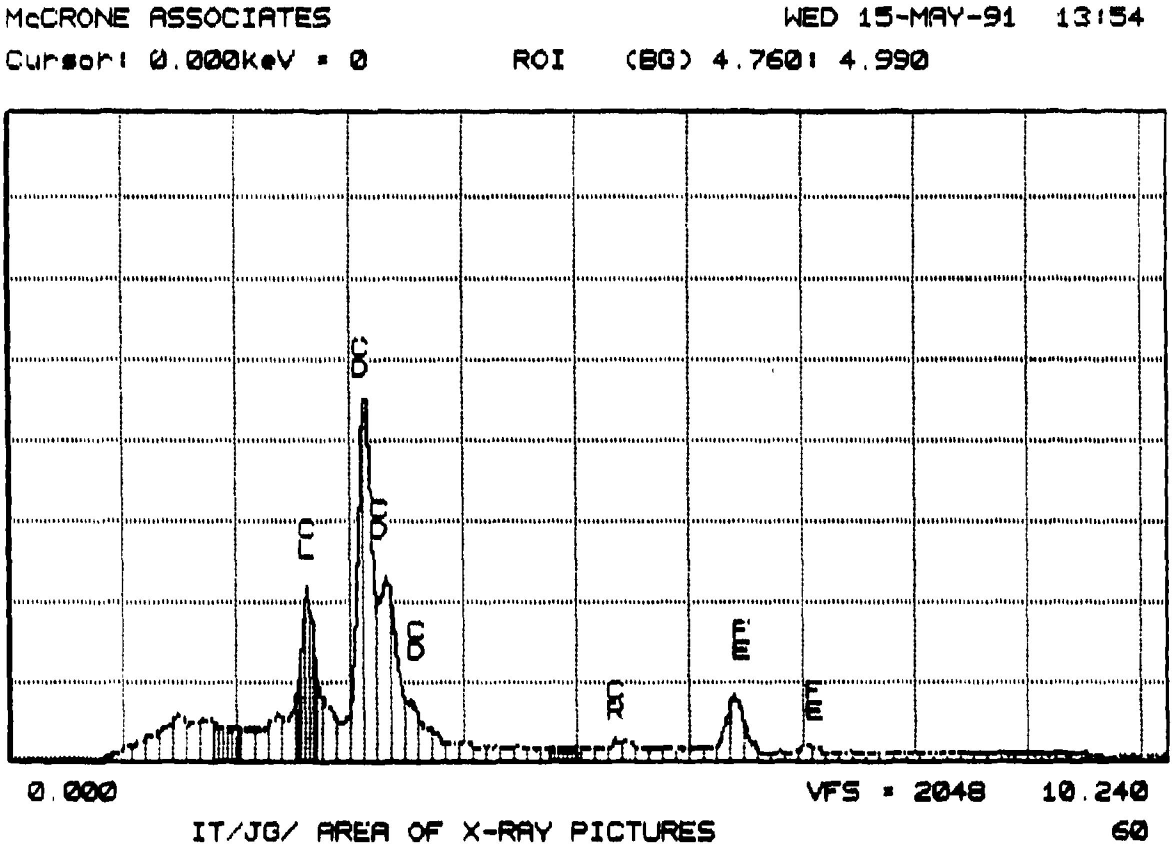


90 IT/JG/ SAMPLE No. SC-3.

McCRONE ASSOCIATES WED 15-MAY-91 12:48
Cursor: 0.000KeV = 0 ROI (BG) 4.760: 4.990



23 1T/JG/ SAMPLE No. SC-3.-SINGLE PARTICLE



McCRONE ASSOCIATES WED 15-MAY-91 13:54

Cursor: 0.000keV = 0 ROI (BG) 4.760: 4.990

IT/JG/ AREA OF X-RAY PICTURES 60

APPENDIX C-2

LIST OF ACRONYMS AND ABBREVIATIONS

A	Temperature Indicated by Afterburner Thermocouple
CFM	Cubic Feet Per Minute
CFR	Code of Federal Regulations
CS	Caustic Soda Process
DESCOM	U.S. Army Depot Support Command
DP	Duane Parker (IT)
DR	Dennis Reed (LEAD)
EBT	Exhaust Blower
EPA	Environmental Protection Agency
°F	Degrees Fahrenheit
FBC	Fluid Bed Cooler/Quench Fluidizer Bed
FBM	Fluidizer Bed Media
FBPS	Fluidized Bed Paint Removal Process, Fluidized Bed Paint Stripper System
FCT	Afterburner Fire Chamber
ft^2	Square Feet
ft^3	Cubic Feet
Gal.	Gallons
gm	Grams
gph	Gallons per Hour
gpm	Gallons per Minute
HEPA	High Efficicnecy Particulate Absorber
ITAQS	IT Air Quality Services
ITAS	IT Analytical Services
ITEP	IT Environmental Programs, Inc.
IWTP	Industrial Water Treatment Plant
JM	John Murphy (IT)
kW	Kilowatt
lbs.	Pounds
LEAD	Letterkenny Army Depot

MCL	Maximum Contaminant Levels
mg/hr	Milligrams per Hour
mg/L	Miligrams per Liter
mg/M3	Miligrams per Cubic Meter
MP	Michael Paul (Procedyne)
MSB	Molten Salt Bath
NaOH	Caustic Soda
ND	Non-detectable
OSHA	Occupational Safety and Health Act
PM	Paul Mraz (IT)
ppm	Parts per Million
PSI	Pounds per Square Inch
PSIG	Pounds per Square Inch Gauge
R	Rockwell Hardness
RJ	Ronald Jackson (USATHAMA)
RCRA	Resource Conservation and Recovery Act
RRAD	Red River Army Depot
S	Temperature Measured in the Exhaust Stack at Sample Point
SCFH	Standard Cubic Feet per Hour
SCFM	Standard Cubic Feet per Minute
TCE	Trichloroethane
THC	Total Hydrocarbons
TCLP	Toxicity Characteristic Leaching Procedure
ug/gm	Micrograms per Gram
ug/M3	Micrograms per Cubic Meter
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
VOC	Volatile Organic Constituent/Compound
Wt. %	Weight Percent