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# EFFECTIVE DISPOSAL OF FUEL CELL POLYURETHANE FOAM

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The objective of this effort was to determine an effective means to dispose of fuel cell polyurethane foam. The foam fills the fuel cells of certain Air Force aircraft to suppress explosions, attenuate fuel sloshing, and serve as a barrier to foreign object debris. Waste foam is generated by two processes. Foam contaminated with fuel and purge fluid is removed from fuel cells for periodic replacement. Scrap foam is left over when foam is cut to fit the interior of fuel cells. The traditional method of foam disposal is to bury it in a landfill. Foam is not very amenable to landfilling due to its high void ratio (greater than 95 percent voids).

This study proceeded in three phases. The first phase was to determine if waste foam is a hazardous waste. In Phase II, we performed a comprehensive literature review to identify possible disposal methods, and tested the most promising methods in the laboratory. Finally, we performed a full-scale test of the best disposal method. (Keywords:

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19. ABSTRACT

Clean scrap foam is not a hazardous waste. Contaminated foam is not a hazardous waste under the Resource Conservation and Recovery Act. This determination is subject to rapidly changing regulations and interpretations of those regulations. Some states (California, New Jersey, and South Carolina) have ruled that wastes containing waste petroleum products are classified as hazardous wastes. Regardless of the waste classification, the most effective disposal method is to incinerate the foam in a two-chamber incinerator. Full-scale tests determined that particulate emissions averaged 0.098 gr/dscf (0.19 lb/100 lb charged) and $NO_x$ emissions averaged 0.0869 gr/dscf (70 ppm). Foam burns readily and has a high combustibility rating (13,000 BTU/lb). Foam loading rates must be carefully regulated to prevent overcharging of the incinerator.

Cost-effectiveness of an onbase incinerator will depend on the size of the waste stream. Robins AFB GA generates in excess of 15,000 cubic yards of foam annually. Robins is the only base where an onbase incinerator dedicated to foam disposal would even be remotely cost effective. Other bases could contract for foam disposal off base, or could assess the possibility of operating an incinerator to destroy all combustible or hazardous wastes including foam. Local or state classification of waste foam may dictate special handling procedures or incinerator emissions control equipment.

# PREFACE

This report was prepared by the New Mexico Engineering Research Institute (NMERI), University of New Mexico, Albuquerque, New Mexico, for the Air Force Engineering and Services Center (AFESC), Air Force Engineering and Services Laboratory, Tyndall Air Force Base, Florida, under Contracts No. F2601-81-C-0013 and No. F29601-84-C-0080. This report summarizes work done between June 1984 and April 1986. The AFESC/RDVW Project Officer was Capt E. Heyse.

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This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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# SECTION I
# INTRODUCTION

## OBJECTIVE

The objective of this effort was to determine if contaminated fuel cell polyurethane foam is a hazardous waste, to survey and evaluate possible methods/processes of waste disposal for scrap (uncontaminated) and contaminated foam, and to conduct a full-scale test of the recommended disposal method/process.

## BACKGROUND

The Air Force installs five types of flexible polyurethane foams in fuel cells (three types of fuel cells referred to here are integral, bladder, and external pod) of C-130, F-15, F-4, A-10, and helicopter aircraft. The foams differ in the type of polyol they contain (polyester or polyether) and in pore size. The various types are distinguishable by color. Foams are used in aircraft fuel cells to suppress explosions, arrest flames, attenuate fuel sloshing, and as a barrier to foreign objects (Reference 1). Antistatic formulations are designed to dissipate static electrical charges. The open-cell (reticulated) foams reduce the volume available to fuel by 2.5 to 3.0 percent.

The original Type I foam (orange) is a polyester-based, coarse-pore polymer, first installed in 1966. In 1970, lower-density Type II (yellow, coarse-pore) and Type III (red, fine-pore) polyester polyurethane foams were developed. In 1974, Type IV (dark blue, coarse-pore) and Type V (light blue, fine-pore) polyether polyurethane foams were introduced. The polyether formations are stated to offer better hydrolytic stability and increased service life compared to polyester polyurethanes. Hydrolytic stability is of great importance for materials used in fuel cells, where conditions of high heat and humidity often exist. The introduction of a new foam has usually resulted in replacement of the older foam type and, thus, an increase in the amount of waste generated. New types of foam are under development. Table 1 contains a short list of typical or nominal properties for fuel cell polyurethane foams. A more detailed compilation of foam properties is presented in Section II of this report (References 2 and 3).

TABLE 1. TYPES OF POLYURETHANE FUEL CELL FOAM.[a]

| Type | Polyol | Color | Density, lb/ft$^3$ | Pore size, pores/inch |
|---|---|---|---|---|
| I | Polyester | Orange | 1.8 | 10 |
| II | Polyester | Yellow | 1.3 | 15 |
| III | Polyester | Red | 1.3 | 25 |
| IV | Polyether | Dark blue | 1.3 | 15 |
| V | Polyether | Light blue | 1.3 | 25 |

[a] All foams are manufactured by SCOTFOAM Corporation, Eddystone, Pennsylvania, who supplied this information.

Waste foam can either be clean scrap or contaminated with jet fuel and purge fluid. Clean foam scrap is generated when the foam is cut to fit the interior of fuel cells. Contaminated foam results from regular aircraft maintenance. Foam deteriorates in the fuel cells and must be replaced every 3 to 5 years. Installing the newer types of foams will also generate contaminated foam.

The foam is purchased in sheets, some common sizes being 8 by 40 by 84 inches and 12 by 44 by 110 inches. Cutting is done in various locations, sometimes by contractors. Every Air Force base which installs or replaces foam may do some cutting; however, the foam is usually available already cut in kit form from a designated major foam-cutting facility, such as Warner-Robins Air Logistics Center (ALC). The cutting process results in 30 to 35 percent scrap.

The waste foam generated during aircraft maintenance is removed according to the following procedure. Before removing foam from a fuel cell, the cell is purged with purge fluid (a high flashpoint paraffin). This raises the flashpoint of the fluid within the cell. This operation results in a sizable fraction of the turbine fuel being replaced with purge fluid. The foam waste resulting from replacement is contaminated with both jet fuel and purge fluid.

The presence of hydrocarbon fluids causes the contaminated foams to be potentially classifiable as a hazardous waste. Also, because of their bulk, both contaminated and uncontaminated foams present a solid waste disposal problem. Currently, Sacramento ALC classifies and handles its contaminated foam as a hazardous waste, while Warner-Robins ALC and Ogden ALC classify and handle it as nonhazardous. These latter two ALCs dispose of both contaminated and uncontaminated foam wastes in local sanitary landfills. Due to expected increases in foam wastes and to environmental regulations, landfilling is now or will soon be impractical or unacceptable. New methods of disposal must be found (Reference 4).

## SCOPE/APPROACH

The scope and technical requirements of this task involved contacting several bases to determine the extent of the waste problem, classifying the waste, conducting a survey to locate all possible disposal/recycling methods that could alleviate/solve this problem, and testing a practical solution.

Samples of contaminated foam were taken from aircraft fuel cells at Warner-Robins ALC at Robins Air Force Base (AFB), Georgia; Ogden ALC at Hill AFB, Utah; and Sacramento ALC at McClellan AFB, California (Reference 5). Personnel were contacted at three Tactical Air Command (TAC) bases: Myrtle Beach AFB, South Carolina; Luke AFB, Arizona; George AFB, California; and one Military Airlift Command (MAC) base, Little Rock AFB, Arkansas (Reference 6). All applicable federal, state, and local regulations were reviewed, and laboratory testing was conducted on the samples to determine if waste foam should be classified as a hazardous waste.

A technology survey and literature review were conducted to identify potential disposal and resource recovery methods that could apply to the waste problem (Reference 7). Methods which would alleviate the waste problem were evaluated. Incineration was chosen as the preferred disposal method.

Full-scale tests were conducted to determine the feasibility of incinerating the waste foam. These tests proved favorable. Specifications for incineration systems were formulated for each installation studied.

# SECTION II

# INITIAL SURVEY AND HAZARDOUS WASTE CLASSIFICATION

## ONSITE INSPECTIONS OF WASTE GENERATION

This section contains information obtained by the authors, both firsthand and from Air Force base personnel, during visits to Warner-Robins ALC, Ogden ALC, and Sacramento ALC.

### Warner Robins Air Logistics Center

Warner-Robins ALC, located at Robins AFB in Warner Robins, Georgia, was visited 9 July 1984. This ALC is responsible for maintenance of C-141, C-130, F-15, and helicopter aircraft. Foam is installed in all but the C-141 aircraft; however, very few helicopters have undergone foam installations at Warner Robins, and no such installations were in progress during the visit. According to Warner Robins ALC personnel, installations and/or replacement of foam in C-130 and F-15 aircraft are also being performed at San Antonio ALC; Hayes Aircraft Company, Birmingham, Alabama (installation only); Aero Corporation in Lake City, Florida; and in Korea, Italy, and Japan (Yokota AFB).

#### C-130 Aircraft

C-130 aircraft contain both integral (wing) tanks and external pod tanks. The tank capacity varies depending on the specific model (C-130-A, -B, -E, -H, -N, -P; Reference 8). According to ALC personnel, the average C-130 aircraft has 1500 pieces of cut foam, totaling about 1600 $ft^3$. The foam volume increases to 1800 $ft^3$ when extra tanks (right and left exterior) are installed. Because of its large fuel tank volume, maintenance of the C-130 is the largest single source of both new and used fuel cell foam waste in the Air Force. According to Warner Robins personnel, about half of the Air Force's C-130 aircraft were fitted with foam, and work was in progress to fit those remaining. As shown in Table 2, a complete change of foam in a C-130 aircraft with auxiliary tanks results in the generation of 2044 pounds of waste foam (net weight) which could contain as much as 1926 pounds (296 gallons) of fluid, as approximated from the JP-4 fuel retention of 2.5 percent for Type IV foam (Table 2). This figure is based on JP-4 rather than on purge fluid,

TABLE 2. FUEL/FOAM VOLUMES AND WEIGHTS FOR C-130 AIRCRAFT.[a]

| Tank[b] | Total volume without foam, gallons | Air space with foam, gallons | Maximum fuel capacity with foam, gallons (pounds) | Fuel displaced/ retained by foam (2.5% maximum), gallons (pounds) | Foam, pounds |
|---|---|---|---|---|---|
| 1 | 1392 | 41 | 1320 (8580) | 30 (195) | 206 |
| 2 | 1278 | 37 | 1213 (7885) | 27 (176) | 189 |
| 3 | 1278 | 37 | 1213 (7885) | 27 (176) | 189 |
| 4 | 1392 | 41 | 1320 (8580) | 30 (195) | 206 |
| L.Aux. | 938 | 27 | 890 (5785) | 20 (130) | 139 |
| R.Aux. | 938 | 27 | 890 (5785) | 20 (130) | 139 |
| L.Ext. | 1442 | 41 | 1369 (8899) | 31 (202) | 213 |
| R.Ext. | 1442 | 41 | 1369 (8899) | 31 (202) | 213 |
| R.Fus. | 1856 | 55 | 1760 (11440) | 40 (260) | 275 |
| L.Fus. | 1856 | 55 | 1760 (11440) | 40 (260) | 275 |
| Total | 13812 | 402 | 13104 (85178) | 296 (1926) | 2044 |

[a] Technical Order 1C-130(H)H-2-6, "Fuel Systems Maintenance Manual."

[b] The specific tanks used depend on model.

although it is likely that purge fluid is retained to the same extent. The actual amount of fluid retained in contaminated foam depends greatly on how the foam is handled during and following removal from a fuel cell. Fluid retention in the foam samples actually obtained at the three ALCs is discussed later in this section.

At present, the C-130 uses dark blue foam everywhere except at fuel entry points, where yellow foam is used. The foam is held in place only by contact with other pieces of foam, tank walls, and baffles within the tanks. With the exception of component voids for clearance with pumps, fuel level probes, and fuel inlets, the foam fills the entire interior of the tank. Sealants are present but these do not appear to contact with the foam, though they do contact the fuel. At Warner-Robins ALC, during the sample collection, a number of C-130 aircraft were undergoing foam replacement outside of hangers while parked on the flightline. New foam was brought to this area in cardboard boxes. The foam inside the boxes came wrapped in black polyethylene. According to maintenance personnel, polyethylene wrapping of new foam is necessary to prevent rapid degradation by sunlight. The used foam is placed in clear, pink polyethylene bags (said to have antistatic properties to prevent ignition of foam) before being placed in a 20-yd$^3$ capacity dumpster. Two to three dumpsters full of contaminated foam waste from C-130 aircraft leave the flight line each week for disposal.

### F-15 Aircraft

The F-15 uses much less foam than the C-130. The F-15 had been using red foam in the fuselage tanks and light blue foam in the wing tanks, but there has been a change to yellow foam in the fuselage tanks. At Warner-Robins ALC, the replacement of red foam by yellow is being performed in a hanger rather than outside, in contrast to the C-130 aircraft operation. The F-15 contains foam which is glued in place with 3M fuel-resistant coating (flash point 60°F) containing methyl isobutyl ketone and ethanol. A solvent is used to remove the cement during foam removal; however, there are complaints that even with a solvent, foam removal is very difficult and shredding often occurs. Occasionally cement adheres to the discarded foam. The contaminated foam is bagged and placed in a dumpster for disposal.

### Foam-Cutting Operation

Warner-Robins ALC operates a massive foam-cutting operation, both to supply its own needs (primarily for C-130 aircraft) and to supply other installation facilities with foam kits. At the time of the visit, the cutting was in operation three shifts, 6 days a week; however, plans were being made at that time to go to a 7-day schedule to meet the foam requirements, with 20 additional workers to be added to the facility.

The foam is marked, using templates as guides, and individual pieces are cut using shop equipment (usually band saws) or hand-held knives. Some comments were made about static electricity accumulation during the cutting operations. Each piece is individually numbered for installation in the appropriate position in a fuel cell. The shop foreman estimates a 35 percent scrap loss in the cutting operation. The scrap is placed in black polyethylene bags (for ease of handling) and placed in a 40-yd$^3$ dumpster for disposal.

## Generation and Disposal of Waste Foam

The Civil Engineering Department at Warner-Robins ALC reported the waste quantities given in Table 3 for the month of May 1984. All foam is taken to the Houston County landfill for disposal. A trip to the landfill showed that foam constituted a major part of the waste at the site. Although the foam had been placed in polyethylene bags for disposal (both new scrap and used contaminated foam), few of the bags were intact at the landfill site. This apparently was caused by the use of heavy machinery for waste burial.

TABLE 3. WASTE FOAM GENERATED AT WARNER-ROBINS ALC IN MAY 1984.

| Building no. | Source | Comments | Total volume |
|---|---|---|---|
| 310 | Scrap from cutting | 53 pickups of a 40-yd$^3$ container | 2120 yd$^3$ |
| 110 | Used C-130 foam | 12 pickups of a 20-yd$^3$ container | 240 yd$^3$ |
| 149 | Used F-15 foam | 12 pickups of an 8-yd$^3$ container | 96 yd$^3$ |
| 137 | Used foam, uncertain source | 8 pickups of an 8-yd$^3$ container | 64 yd$^3$ |

[a] Average weight per load, 800 pounds; disposal cost, $8000 not including landfill fee.

The county landfill is rapidly running out of space, and a new location must be found. Robins AFB is a heavy user of the landfill. In particular, the polyurethane foam is a severe problem since it tends to float to the surface and blow about. No dump fires have been reported.

## Ogden Air Logistics Center

Ogden ALC at Hill AFB, Ogden, Utah, was visited on 8 July 1984, resulting in the following observations.

## F-4 Aircraft

F-4 aircraft are the only aircraft serviced by Ogden ALC that have polyurethane fuel cell foam. No new F-4 aircraft are being produced, so all waste foam is generated from the replacement of old, deteriorated orange (Type I) foam with yellow (Type II) foam. Each F-4 aircraft has seven neoprene bladder-type fuel cells with approximately 17-36 pieces of cut foam required per cell, depending on the particular cell. Following purging of the fuel cells with purge fluid (now Isopro® 5, earlier Phillips 1010), the foam is replaced while the aircraft are in the service hanger. New yellow foam is contained in polyethylene bags before installation; however, orange foam is simply discarded in a dumpster without being bagged. Foam that can be reused is housed in a ventilated building in cardboard boxes until it can be placed back into the fuel cells. The concentration of potentially explosive fumes in the building is monitored.

## Foam-Cutting Operation

A minimal amount of foam is being cut by the Carpenter Shop at Ogden ALC for installation in F-4 aircraft. Ogden has also recently contracted with an outside firm to do some foam cutting. The foam is being cut at Ogden with standard carpentry tools on an as-needed basis. Foam for about 40 fuel cells (about 6 aircraft) had been cut during the 3 months before our visit to the base. At the time of the visit, there were orders for cutting foam for an additional 20 fuel cells (about 3 aircraft). Each cell requires the cutting of approximately four 40- by 84- by 8-inch sheets of foam. The foam sheets on hand were obtained from Rogers Foam Corporation,* who purchase foam from SCOTFOAM. Carpenter Shop personnel estimate a loss of 30 percent as scrap. Therefore, approximately 23 $yd^3$ of new scrap were generated by foam cutting at Ogden during a 3-month period. No new orange (Type I) foam has been used at Ogden ALC for several years.

## Waste Foam Disposal

Waste foam disposal at Ogden ALC occurs irregularly, depending on what aircraft are in for servicing. An 8 $yd^3$ dumpster is emptied about

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*Rogers Foam Corporation, Sommerville, Massachusetts.

three times each month. During the visit to Ogden ALC, only unpackaged used orange foam, most of it badly deteriorated, was observed in the container. The foam is disposed of at the Davis County landfill. A visit to the landfill revealed only one piece of polyurethane foam (evidently for a fuel cell since it contained markings similar to those observed on other cut pieces at the various ALCs). The piece was dark blue foam (Type IV) and seemed to be newly cut.

No disposal problems were reported with Ogden ALC waste at the Davis County landfill. The County is negotiating with Hill AFB to supply steam heat to that base using a proposed $53 million waste-fired steam generator, which will burn waste from all sources.

### Sacramento Air Logistics Center

Sacramento ALC, located at McClellan AFB, was visited on 20 July 1984. Sacramento ALC supports F-4 and A-10 aircraft, with an emphasis on the latter. Some helicopters and C-130 aircraft are serviced occasionally. All of these aircraft use fuel cell polyurethane foam. No foam cutting is performed at Sacramento ALC.

### A-10 Aircraft

In 1982 Technical Order 900 was issued calling for removal of all old red (Type III) foam from A-10 aircraft and replacement with light blue (Type V) foam. The A-10 aircraft contains 250 ft$^3$ of foam. At the time of the visit, 144 aircraft had been converted, with 120 aircraft remaining for conversion. Fairchild Industries, Inc., Crestview, Florida, makes the foam kits for the A-10 aircraft. Each A-10 requires 17 different kits. Unlike the situation observed at other bases, foam removal at Sacramento ALC is performed with stringent clothing requirements, including the wearing of respirator masks, body suits, and gloves to handle all contaminated foam. Used purge fluid is aerated to eliminate low flashpoint materials (JP-4) and is reused. The flashpoint on purge fluid is not supposed to be allowed to drop below 120°F and is closely monitored at Sacramento; however, closed-cup flashpoints on fluid drained directly from foam in purged A-10 tanks (aircraft No. 77/203) during the visit to Sacramento ALC were determined to be 93°F (left main tank), 113°F (right main tank), 113°F (left wing tank), and 97°F (right wing tank). These values are well below the minimum value of 140°F set for classification of a liquid as "flammable" for transportation purposes or the designation of a waste as "ignitable" under EPA guidelines. According to base personnel, at one time Sacramento ALC was using a mixture of JP-5 and Phillips 1010 purge fluid. If light blue (Type V) foam of acceptable quality is removed during maintenance of an aircraft, it is dried in special enclosed drying sheds and then stored in wooden boxes in a large storage building for later reuse. A large number of such boxes were on hand during the visit. In some cases, dried foam was retained at Sacramento ALC for long periods of time. Foam from a helicopter had been stored for several months prior to that ALC visit.

### Waste Foam Disposal

All contaminated fuel cell foam scheduled for disposal at Sacramento ALC is handled as a hazardous waste; however, reusable foam is not handled as hazardous waste. Waste foam is immediately placed in a 55-gallon steel drum upon removal from a fuel cell. Unlike the situation observed at the other ALCs, Sacramento ALC personnel transfer foam rapidly to closed containers (drums). The foam is not allowed to remain exposed to the air for any significant length of time. The purpose of this procedure may be to minimize hydrocarbon emissions, which are strictly regulated in California (Reference 9). The material is not bagged before placement in the drum. Each A-10 aircraft foam conversion generates thirty 55-gallon drums of waste. The individual drums are labeled as containing hazardous waste and are held in a well-marked hazardous waste storage area for disposal by a contractor. All drums contained red (Type III) foam on 20 July 1984.

A Manifest Log for A-10 waste foam was obtained for 10 May 1982 through 31 March 1983 and for 9 January 1984 through 19 June 1984. The log for the intervening time period was not immediately available. The data showed that eighty 55-gallon drums of waste foam were transported from Sacramento ALC approximately every 2 weeks during the first period cited. Transportation was somewhat more irregular during the second period cited with a shipment of 80 drums departing about every 2.3 weeks.

Safety Specialists, Inc., Santa Clara, California, a previous contractor for the disposal of foam from Sacramento ALC, had transported the drums and their contents as a "combustible solid," as designated by Sacramento ALC. At first, foam waste shipments had been made with a designation of "flammable liquid" and later as "combustible liquid"; however, the classification "combustible solid" was eventually considered to be more appropriate for the waste foam. The contents of foam and liquid were compacted in the drum, using a specially designed compactor capable of applying a pressure of 36,000 lb/in.$^2$. This reduced the volume and lowered the costs involved in disposal at the Class 1 hazardous waste site, Kettleman Hills, near Coalinga, California. The contents of additional drums were added to the container until it was highly compacted. A load of 80 drums could be compacted to give a total volume equivalent to about 6-10 drums (an average reduction in volume of 90 percent). Safety Specialists, Inc. found approximately 1 gallon of free liquid in the bottom of each drum picked up from Sacramento ALC. The liquid apparently drained from the foam. This was not observed at either Ogden ALC or at Warner Robins ALC, evidently because the foam at these ALCs was allowed to sit for some time before being placed in containers.

The present waste disposal contractor, IT Corporation, no longer accepts any hazardous waste in metal drums at any of its disposal sites. This is a company policy rather than a state regulation. The foam is removed from the drums at Sacramento ALC and placed in a truck-mounted bin which IT uses for transportation of hazardous waste. Usually 55-drum lots are collected. The purging fluid, which has naturally drained from the contaminated foam and collected in the drum, is poured into a separate container for disposal by subcontractor, Casmalia Resources. Casmalia solidifies the fluid by addition of vermiculite and then landfills it. California state law prohibits landfilling any liquid wastes. According to IT, only 1-2 gallons of fluid are collected during each 55-drum lot pickup. The foam is placed in a Class 1 site operated by IT Corporation near Benicia, California. No compaction is carried out before disposal; however, the entire site is continuously compacted using heavy equipment. It estimates an 80 percent compaction for the site contents as a whole and a remaining lifetime of 30-50 years for the site.

## Total Waste Foam Generated

It is difficult to precisely calculate the amount of foam generated each year by each ALC visited, since most figures give the volume of the container used rather than the mass of foam. If, however, one assumes a void space of 50 percent in each load (a very conservative estimate), the following figures can be derived from the data collected. The volumes of both new scrap and used contaminated foam disposed of each year by the three ALCs are as follows:

| | | |
|---|---|---|
| Warner-Robins, ALC | 15,120 yd$^3$ | (530,000 lb) |
| Ogden, ALC | 144 yd$^3$ | (5,000 lb) |
| Sacramento, ALC | 659 yd$^3$ | (23,000 lb) |
| Total | 15,923 yd$^3$ | (558,000 lb) |

## Additional Observations

During visits to each of the ALCs, comments were heard from base personnel about static electricity generation or fire problems. Some stated that the foam prevented such problems; others stated that the problems were caused by foam. In no case did anyone commenting on the problem have firsthand knowledge of an incident involving fire and polyurethane foam. In many cases, personnel pointed out pieces of used foam with discolorations on the surface caused by an unobserved spontaneous explosion or fire within the tank of an aircraft. In an advertising brochure, SCOTFOAM, the manufacturer of polyurethane foams, shows a photograph of a piece of foam said to show a discoloration owing to an explosion suppression. Some base personnel stated that the discolorations were burn marks showing that the foam had suppressed an in-tank explosion or fire. Others stated that the explosion or fire had been caused by static electricity generated by friction of fuel with the foam. Evidence exists that static charge generation can occur during filling, owing to fuel impingement upon foam surfaces; however, the phenomena cited by base personnel (mechanics, foremen, etc.) involved spontaneous ignitions that had apparently not occurred during filling. In no instance was documentation or concrete evidence provided for the occurrences cited, other than discolorations on random samples of used foam. It was not obvious that the discolorations observed were burn marks.

Personnel at SCOTFOAM do cite several documented cases where fires occurred in C-130 or A-10 aircraft during fuel-filling or fuel-switching operations. The only documented explosion occurring during a flight involved impingement of fuel in a partially foam-filled fuel cell during an assault landing.

## Additional Bases Contacted

A survey of typical TAC and MAC bases was conducted. One MAC base (Little Rock AFB) and three TAC bases (Myrtle Beach AFB, Luke AFB, and George AFB) were contacted.

Each base had a different waste foam management procedure. The amount of waste foam generated by these TAC and MAC bases is small, and removal does not occur on a regular basis. This is probably true of other non-ALC bases. Aircraft are only serviced at TAC and MAC bases when they need immediate repairs and cannot fly to an ALC. However, the environmental aspects of foam disposal are of serious concern at Myrtle Beach AFB.

Foam disposal could become a serious problem at Myrtle Beach AFB. A request has been made to the South Carolina Department of Health and Environmental Control (DHEC) to permit foam disposal in a landfill after the fluids have been removed. According to the Chief of the base Environmental Contracts Office, wastes containing petroleum products are now considered hazardous in South Carolina. Environmental personnel are now working with DHEC to determine whether waste foam should be classified as hazardous.

## Foam Sample Collection and Transportation

Table 4 lists samples of contaminated foam collected at the three ALCs. Samples of contaminated yellow and light blue foam were unavailable. Samples of new foam scrap were also collected, although new orange foam could only be obtained directly from SCOTFOAM. The contaminated material was shipped in sealed metal quart cans, each containing approximately 70-130 grams of foam. The material was shipped as a flammable solid, according to DOT Regulations (Reference 10).

TABLE 4. SAMPLES COLLECTED.

| Label | Color | Type | Source |
|---|---|---|---|
| | | | WARNER-ROBINS ALC |
| WR1 | Dark blue | IV | C-130, No. 63-0771, installed April 1983, tank 1 |
| WR2 | Dark blue | IV | C-130, No. 63-0771, installed April 1983, tank 1 |
| WR3 | Dark blue | IV | C-130, No. 63-0771, installed April 1983, tank 4 |
| WR4 | Dark blue | IV | C-130, No. 63-0771, installed April 1983, tank 4 |
| WR5 | Dark blue | IV | Unknown C-130, taken from flight line dumpster |
| WR6 | Red | III | F-15, foam 3 years old, badly deteriorated |
| WR7 | Red | III | F-15, newer piece, less deterioration |
| | | | OGDEN ALC |
| HA | Orange | I | Taken from dumpster |
| HB | Orange | I | Taken from dumpster, greater deterioration |
| HC | Orange | I | Taken from dumpster |
| HD | Orange | I | Taken from dumpster |
| HE | Orange | I | Taken from dumpster |
| HF | Orange | I | Taken from dumpster, greater deterioration |
| HG | Orange | I | Taken from dumpster |
| HH | Orange | I | Taken from dumpster |
| HI | Orange | I | Taken from dumpster |
| HJ | Orange | I | Taken from dumpster |
| HK | Orange | I | Taken from dumpster |
| HL | Orange | I | Taken from dumpster |
| HM | Orange | I | Taken from dumpster |
| | | | SACRAMENTO ALC |
| 1 | Red | III | Drum 1, somewhat deteriorated |
| 2 | Red | III | Drum 1, somewhat deteriorated |
| 3 | Red | III | Drum 2, better condition |
| 4 | Red | III | Drum 2, better condition |
| 5 | Red | III | Drum 3, drier, no deterioration |
| 6 | Red | III | Drum 3, drier, no deterioration |
| MA | Red | III | From random drum |
| MB | Red | III | From random drum |
| MC | Red | III | From random drum |
| MD | Red | III | From random drum |
| ME | Red | III | From random drum |
| MF | Red | III | From random drum |

## ANALYSES OF WASTE FOAM

Test procedures to determine if a solid waste is hazardous, according to the definition of Section 3001 of the Resource Conservation and Recovery Act (RCRA, PL 94-580) are specified (Reference 10) by the United States Environmental Protection Agency (EPA). These methods are approved for obtaining data to satisfy the requirement of 40 CFR, Part 261 (Reference 11), Identification and Listing of Hazardous Waste.

### Physical Properties

#### Uncontaminated Foam

The specified physical properties of the uncontaminated foams are presented in Table 5.

#### Contaminated Foam

Appearance. Contaminated or fuel-soaked foams were often badly degraded and had sometimes completely disintegrated. Used foams showed significant color changes when compared to new foams. Both very old red and very old orange foams were found to be a dark reddish brown and could be distinguished only by differences in pore size. The contaminated foams had a persistent hydrocarbon odor. At one ALC, a foam sample which had been allowed to sit in an open room for several months still had a strong odor.

Tests performed on new foams showed that they deteriorate rapidly under sunlight, discoloring and becoming fragmented. These tests indicated that the polyether types of new foam degrade more rapidly in the sunlight than do the polyester types.

Liquid Content. Since the liquid contaminants in the polyurethane foams are volatile, the contents of fluid can be approximated from the loss of volatiles. The data shown in Table 6 were obtained upon drying contaminated foam samples to constant weight (3 weeks) under ambient conditions outdoors. The data show a wide variation in volatile losses. This is precisely what is expected since the fluid content should depend greatly on the

TABLE 5. FOAM PHYSICAL PROPERTIES PER MIL-B-83054B (USAF). (References 2 and 3)

| Property | Type I | Type II | Type III | Type IV | Type V |
|---|---|---|---|---|---|
| Color | Orange | Yellow | Red | Dark blue | Light blue |
| *Polyol type* | *Polyester* | *Polyester* | Polyester | Polyether | Polyether |
| Density range, lb/ft$^3$ ft | 1.70-2.00 | 1.20-1.45 | 1.20-1.45 | 1.20-1.45 | 1.20-1.45 |
| Porosity, pores/inch | 7-15 | 8-18 | 20-30 | 8-18 | 20-30 |
| Air pressure drop, inches of water[a] | 0.190-0.285 | 0.140-0.230 | 0.250-0.330 | 0.140-0.230 | 0.250-0.333 |
| Minimum tensil strength, lb/in.$^2$[b] | 15 | 15 | 15 | 10 | 15 |
| Tensile strength minimum at 200 percent elongation, lb/in.$^2$[b] | 10 | 10 | 10 | -- | -- |
| Minimum ultimate elongation, percent[b] | 220 | 220 | 220 | 100 | 100 |
| Minimum tear resistance, lb/in.$^2$[c] | 5 | 5 | 5 | 3 | 3 |

[a] Cylindrical specimen, 10 inches in diameter, 1 inch thick.

[b] ASTM D1564-71 (Suffix T), 5.5 by 1 by 0.5 inches.

[c] ASTM D1564-71 (Suffix G), 6 by 1 by 1 inches.

TABLE 5. FOAM PHYSICAL PROPERTIES PER MIL-B-83054B (USAF) (CONTINUED).

| Property | Type I | Type II | Type III | Type IV | Type V |
|---|---|---|---|---|---|
| Color | Orange | Yellow | Red | Dark blue | Light blue |
| Polyol type | Polyester | Polyester | Polyester | Polyether | Polyether |
| Maximum constant deflection compression set, percent[d] | 30 | 35 | 35 | 30 | 30 |
| Minimum compression load deflection (lb/in.$^2$) at | | | | | |
| 25 percent deflection[e] | 0.40 | 0.30 | 0.30 | 0.35 | 0.35 |
| 65 percent deflection[f] | 0.60 | 0.50 | 0.50 | 0.60 | 0.60 |
| Maximum JP-4 fuel displacement, volume, percent | 3.0 | 2.5 | 2.5 | 2.5 | 0.5 |
| Maximum JP-4 fuel retention, volume, percent | 2.5 | 2.5 | 4.5 | 2.5 | 4.5 |
| Maximum flammability, in./min[f] | 10 | 15 | 15 | 15 | 15 |
| Extractable materials maximum weight, percent[g] | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |

[d] ASTM D1564-71 (Method B), 4 by 4 by 3 inches.

[e] ASTM D1564-71 (Suffix D), 4 by 4 by 3 inches.

[f] ASTM D-1692-76, 6 by 2 by 0.5 inches.

[g] Types I, II test fluid (TT-S-735).

TABLE 5. FOAM PHYSICAL PROPERTIES PER MIL-B-83054B (USAF) (CONCLUDED).

| Property | Type I | Type II | Type III | Type IV | Type V |
|---|---|---|---|---|---|
| Color | Orange | Yellow | Red | Dark blue | Light blue |
| Polyol type | Polyester | Polyester | Polyester | Polyether | Polyether |
| Volume increase after fluid age, volume, percent | | | | | |
| Type I fluid[g] | 0-5 | 0-5 | 0-5 | 0-15 | 0-15 |
| Type II fluid[g] | 0-12 | 0-12 | 0-12 | 0-37 | 0-37 |
| JP-4 fuel | 0-10 | 0-10 | 0-10 | 0-25 | 0-25 |
| Maximum entrained solid contamination, mg/ft$^3$ | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 |
| Maximum tensile loss on steam autoclave exposure, percent[h] | 40 | 40 | 40 | 30 | 30 |

[g] Types I, II test fluid (TT-S-735).

[h] 121.1°C; Types I, II, III foam, 5 hours; Types IV, V, 10 hours.

TABLE 6. LOSS OF VOLATILES FROM CONTAMINATED FOAMS.

| Sample | Initial mass, g | Final mass, g | Percent loss |
|---|---|---|---|
| MB | 74.38 | 71.52 | 3.85 |
| MA | 78.08 | 62.83 | 19.53 |
| HC | 71.23 | 71.05 | 0.25 |
| HA | 120.65 | 107.48 | 10.92 |
| WR5 | 126.62 | 113.58 | 10.30 |
| WR3 | 101.52 | 76.35 | 24.79 |
| WRZ | | | 6.66 |
| MD | | | 10.11 |
| WR7 | | | 4.44 |
| HB | | | 5.74 |

amount of time which expires before containerization and upon the manner of handling the samples. Note that sample WR3 (Table 6) was collected directly from a fuel cell and placed in containers immediately. On the other hand, WR5, a similar sample from the same type of aircraft and same ALC, was collected from a dumpster. The differences observed for HC and HA or for MB and MA cannot be readily explained. However, fluid contents will vary widely for the contaminated foams.

Ignitability. Test samples of contaminated foams were found to burn readily, although not violently. The foam decomposes to a combustible, flammable viscous liquid as it burns. Significant amounts of soot and smoke are released during combustion. The EPA does not have a procedure to determine the flashpoint of a solid. Flashpoint is a consideration for a liquid waste. As of 14 June 1985, EPA suggests that the paint filter test be used to determine whether or not a waste contains free liquid (Reference 12). The test involves placing a 100-gram sample of the waste on a 60-mesh paint filter for 5 minutes. Any liquid passing through the filter by the force of gravity alone is considered free liquid. Contaminated foam was not subjected to the paint filter test during the 1984 laboratory tests. However, if foam is removed by current maintenance procedures at Ogden ALC and Warner-Robins ALC, it is unlikely that any free liquid would be recovered by the paint filter test. It is possible that free liquid would be found in samples from Sacramento ALC, which handles waste foam in a different manner.

Extraction Procedure Toxicity Tests. The Extraction Procedure (EP) is designed to simulate the leaching a waste will undergo if disposed of in a sanitary landfill. In this laboratory test, a representative sample of the waste is extracted with distilled water maintained at a pH of 5, using acetic acid. The extract obtained from the EP is then analyzed to determine if any of the thresholds established for eight elements (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver), four specified pesticides, and two specified herbicides have been exceeded. If the EP extract contains any one of the above substances in an amount equal to or exceeding the levels specified in 40 CFR 261.24, the waste possesses the characteristic of EP toxicity. On 6 June 1986, EPA announced proposed changes to the EP Toxicity Test. A new test, known as the Toxicity Characteristic Leaching Procedure (TCLP), monitors a number of additional organic chemicals. Two chemicals included in these additions are benzene and toluene (Reference 13).

Since no known route exists for the introduction of pesticides or herbicides in fuel cell polyurethane foam samples, no analyses were performed for these substances. A total of six samples were extracted using the EP procedure, and the extract was tested for eight different metal ions. Elemental analyses were performed using an inductively coupled plasma (ICP) spectrometer (Laboratory One) and an emission spectrometer (Laboratory Two). Extracts from three different samples were tested in each laboratory. Analyses on two samples were repeated using atomic absorption (AA) spectrometry. In one case, an exceedingly large (10.1 ppm) quantity of silver was found (sample WR4). Repeated analysis on the identical extract gave a result of <0.02 ppm for the silver content. It is suspected that the particular portion of the extract used in the first test had been contaminated with silver chloride from a damaged combination pH electrode. In the second case, ICP gave an analysis of 1.0 ppm for selenium in sample WR6. Since there is only one usable emission line for a selenium in ICP, and that line is susceptible to overlap by an iron line, selenium results are often high. AA spectrometry does not suffer from this problem, and the AA result on the identical solution showed less than 0.01 ppm Se. The results of the EP toxicity tests are given in Table 7. The limits of detection on these elements is 0.01 ppm or better. The repeatability

TABLE 7. EXTRACTION PROCEDURE METAL ANALYSES, ppm.

Laboratory One

| Sample | HM | 5 | WR6 | EPA limits |
|---|---|---|---|---|
| As | <0.002 | 0.9 | 1.02 | 5.0 |
| Ba | <0.005 | <0.005 | <0.005 | 100.0 |
| Cd | <0.002 | <0.002 | <0.002 | 1.0 |
| Cr | <0.005 | <0.005 | <0.005 | 5.0 |
| Pb | 0.112 | 0.065 | 0.318 | 5.0 |
| Hg | <0.002 | <0.002 | <0.002 | 0.2 |
| Se | <0.002 | 0.9 | [a]<0.001 | 1.0 |
| Ag | <0.003 | <0.003 | <0.003 | 5.0 |

Laboratory Two

| Sample | 1 | WR4 | HF | EPA limits |
|---|---|---|---|---|
| As | <0.0001 | <0.0001 | <0.0001 | 5.0 |
| Ba | <0.0001 | <0.0001 | <0.0001 | 100.0 |
| Cd | 0.055 | 0.053 | 0.235 | 1.0 |
| Cr | <0.0001 | <0.0001 | <0.0001 | 5.0 |
| Pb | 0.038 | 0.023 | 0.246 | 5.0 |
| Hg | 0.045 | 0.046 | 0.068 | 0.2 |
| Se | 0.190 | 0.174 | 0.202 | 1.0 |
| Ag | <0.0001 | [a]<0.02 | <0.0001 | 5.0 |

[a] By atomic absorption.

is approximately 5 percent. The proposed threshold limits for benzene and toluene under the TCLP are 0.07 mg/L and 14.4 mg/L, respectively. A modified TCLP Test was performed at the AFESC on samples of contaminated foam collected from an F-15 fuel cell from Warner-Robins ALC in July 1986. Leachate contained 0.033 mg/L benzene and 0.0165 mg/L toluene. These results indicate contaminated foam is not a hazardous waste under the proposed new regulations. However, the amount of benzene found is sufficiently close to the maximum allowed to warrent concern. Additional samples should be collected and analyzed.

## Gas Chromatography--Mass Spectrometry (GC/MS) Tests

In GC/MS (Reference 14), gas chromatography is first used to separate components and then mass spectrometry (Reference 15) is used to determine the structure of the compound. GC/MS was determined for neat liquid pressed from seven different foam samples (samples designated 2, 3, HL, WR1, 6, HI, and WR2). The neat liquid is not "free-liquid" (Reference 12) since it was recovered under pressure. The liquids removed from the first two samples listed were combined to give sufficient material for testing. Attempts to obtain adequate GC/MS analyses on hexane extracts of the foam were unsuccessful, apparently owing to the resulting samples being too dilute. The results were as expected, with lighter aromatic compounds (benzene, toluene) being easily identified. High molecular weight compounds could not be unambiguously identified. The gas chromatograms show that a complex mixture of compounds is present in the fluid, an expected result.

## Chemistry of Polyurethane Foam and Contaminating Fluids

### Polyurethane Foam

Most polyurethanes are formed by the reaction of diols containing a central chain that is either a polyether (SCOTFOAM hybrid foams Types IV and V use an acrylonitrile-styrene containing polyoxyalkylene polyether) or a polyester (Types I, II, and III foams), with aromatic diisocyanates (References 16 and 17). Typical isocyanates are 2,4-toluene diisocyanate, 4,4-benzidene diisocyanate, and 1,5-naphthalene diisocyanate. SCOTFOAM employs an 80:20 mixture of the 2:4 and 2:6 isomers of toluene diisocyanate for their Types IV and V foams. Although isocyanates are highly toxic, they are no longer chemically active in the fully cured polymer, nor can they be released in significant amounts under any reasonable condition. The polymerization reaction is

OCN-[diisocyanate]-NCO + HO-[polyether or polyester]
---> polyether or polyester type polyurethane

The portion of the molecule in brackets is variable to give a variety of polyurethane polymers. Normally, the reaction is carried out in two steps. Initially the diisocyanate is reacted with a smaller amount of diol to yield prepolymer with isocyanate end groups. The prepolymer is then reacted with diol, diamine, diacid, or amino alcohol chain extenders to give the final polymer. SCOTFOAM employs tertiary amine and organometallic catalysts. Blowing is achieved by reaction of the isocyanate functional group with water to give carbon dioxide gas (a technique employed by SCOTFOAM) or by addition of a fluorocarbon blowing agent. Dyes are added to the fuel cell polyurethane foams. Most foam material is made in a continuous process as slab stock which is cut up to be sold to fabricators.

## Purge Fluids and Fuels

A complete list of the fluids which come into contact with the polyurethane foams and their additives is presented in Table 8. This table also lists those chemical constituents which are environmentally significant. This table was compiled from Material Safety Data Sheets obtained from the manufacturers and from military specifications.

Purge fluids (Reference 18) are high-flashpoint (200°F), low-volatility C13-C17 isoparaffins used to purge fuel cells before maintenance or foam removal. Antioxidants and electrical conductivity additives may be added. On occasion, JP-5 has been used as a purge fluid.

JP-4 is the standard United States Air Force (USAF) turbine engine fuel; however, JP-5 and aviation gasoline (AVGAS) are used as alternate or emergency fuels (Technical Order 1C-130A-2-1). JP-4 (Reference 19) is a volatile (vapor pressure 2-3 lb/in.$^2$), low flashpoint (-20°F approximately), widecut, gasoline-type turbine fuel. JP-5 (Reference 19) is a high-flashpoint (140°F minimum), kerosene-type fuel employed primarily in Navy aircraft. Both contain as a maximum 25 percent aromatics and 5 percent olefins. Aviation gasoline (Reference 20) comes in three octane or performance grades--80/87 (low lead, red in color), 100/130 (standard USAF AVGAS, blue), and 115/145 (the former standard AVGAS, purple). All three grades contain tetraethyllead and ethylene dibromide.

TABLE 8. CONTAMINATING FLUIDS.

**PURGE FLUID**

MIL-F-38299B

| | | |
|---|---|---|
| Soltrol 220 | Philips Petroleum | C13-C20 isoparaffins<br>2000 ppm aromatics |
| Purging Fluid | Continental Chemical | Petroleum oil |

Note: Reports of 1010, Isopro 5, Telura 5, and Bray purging fluids being used have been received. Some of these may be Soltrol 220 or Continental purging fluid, relabeled by the distributor.

**FUEL**

| | | |
|---|---|---|
| JP-4 | MIL-T-5624L | Maximum 25 percent aromatics<br>Maximum 5 percent olefins |

**EMERGENCY AND ALTERNATE FUELS**

| | | |
|---|---|---|
| JP-5 | MIL-T-5624L | Maximum 25 percent aromatics<br>Maximum 5 percent olefins |
| Gasoline, aviation | 80/87 Octane MIL-G-5572 | Tetraethyllead, ethylene dibromide |
| Gasoline, aviation | 100/130 Octane MIL-G-5572 | Tetraethyllead, ethylene dibromide |
| Gasoline, aviation | 115/145 Octane MIL-G-5572 | Tetraethyllead, ethylene dibromide |

**FUEL ADDITIVES**

Antioxidants--Used in JP-5 and some JP-4 at 17.2 to 24.0 mg/l. In addition, antioxidants are required at 50-150 ppm in icing inhibitors.

2,4-di-tert-butylphenol
6-tert-butyl-2,4-dimethylphenol
2,3,6-trimethylphenol
2,4,5-triisopropylphenol
2,6-di-tert-butyl-4-methylphenol
2,6-di-tert-butylphenol
2,4,6-trimethylphenol
2,4,6-triisopropylphenol

**Nonspecific**

2,6-dialkylphenols
2,4,6-trialkylphenols
tri-tert-butyl-dimethylphenols
tert-butyl-dimethylphenols
dimethylphenols
2,3,5-trialkylphenols
tert-butylphenols
tert-butyl-methylphenols
tert-butyl-ethylphenols
isopropylphenols

TABLE 8. CONTAMINATING FLUIDS (CONTINUED).

| | | |
|---|---|---|
| | **ICING INHIBITORS** | |
| JP-4 additive MIL-I-27686E (0.10 to 0.15 percent by volume) | | Ethylene glycol monomethyl ether (2-ethoxy-ethanol)<br>50-150 ppm alkylphenol antioxidant |
| JP-5 additive MIL-I-85470 (AS) (0.15 to 0.20 percent by volume) | | diethylene glycol monomethyl ether |
| | **STATIC DISSIPATOR ADDITIVE** [electrical conductivity additive used in JP-4 only (1 ppm or less)] | |
| ASA-3 | Royal Lubricants | 50 percent xylene<br>0.4 to 0.5 percent Cr |
| Stadis® 450 | DuPont | Proprietory sulfur-nitrogen compound<br>100 ppm toluene<br>400 ppm isopropyl alcohol |
| | **METAL DEACTIVATOR** | |
| (May be present at a maximum concentration of 5.8 mg/l in JP-4, JP-5) | | N,N'-disalicylidene-1,2-propanediamine<br>N,N'-disalicylidene-1,2-cyclohexanediamine |
| | **CORROSION INHIBITOR--MIL-I-25017** (used in JP-4 and JP-5 at 9 to 54 mg/l.) | |
| Tolad® 256[a] | Tretolite Division | Carboxylic acids in kerosene propanediamine |
| Tolad® 249 | Tretolite Division | Carboxylic acids in aromatic hydrocarbons, 25 ppm light aromatic naphtha |
| DCI-4A | DuPont | Carboxylic acids in xylene |
| DCI-6A | DuPont | Carboxylic acids in xylene |
| Nalco® [illegible]5 | Nalco Chemical Co. | Fatty acids/hydrocarbon solvent |
| Nalco® 5403 | Nalco Chemical Co. | Polycarboxylic acids aromatic solvent |
| HITEC® E-515 | Edwin Cooper, Inc. | Petroleum distillate |

[a] No longer in production.

TABLE 8. CONTAMINATING FLUIDS (CONCLUDED).

| | CORROSION INHIBITOR--MIL-I-25017 (CONCLUDED) | |
|---|---|---|
| HITEC® E-580 | Edwin Cooper, Inc. | |
| UNICOR® J | UOP Process Division | High molecular weight organic acid/ aromatic solvent |
| LUBRIZOL® 541 | Lubrizol Corp. | 37 percent xylene (1 percent benzene) |
| P 3305 | Unichema Chemie B.V. | Dimer acid kerosene |
| PRI-19[a] | Apollo Technologies | 50-60 percent petroleum distillates |
| ARCO® 4410 | Arco Performance Chemicals | |
| MOBILAD® F-80 | Mobile Chemical Co. | Fatty acids<br>solvent naphtha (45 percent) |

[a] No longer in production.

A large number of additives are used in the various fuels. Antioxidants--substituted phenols or diamines--are used in JP-5 and may be found in JP-4 and AVGAS. Two types of icing inhibitors are in use. Ethylene glycol monomethyl ether (References 21-22) is used in JP-5. A static dissipator additive is added to JP-4 to increase the conductivity. Two types are in use, one containing chromium and the other a proprietary sulfur-nitrogen compound. Metal deactivators, disalicylidenediamine chelating agents, may be added to both JP-4 and JP-5. A large number of materials have been approved (Reference 11) as corrosion inhibitors (Reference 23). Finally, dyes (blue: 1,4-dialkylaminoanthraquinone; and red: an alkyl derivative of azobenzene-4-azo-2-napthol) are added to AVGAS.

## REGULATIONS AND CLASSIFICATION OF FOAM WASTE

The regulations concerning the classification of wastes are complex and open to different interpretations, as is discussed further on in this section. The applicable regulations have been reviewed by an attorney and a letter concerning that review is referenced in the text of this report. The conclusions presented here have also been given legal review.

### Federal

The Resource Conservation and Recovery Act (RCRA) of 1984 mandates hazardous waste management. Section 3001 of Subtitle C, Hazardous Waste Management, calls for the development of criteria for the identification and listing of hazardous waste. Part 261 of Title 40 of the Code of Federal Regulations carries out this requirement. Subpart C of 40 CFR 261 lists four characteristics of hazardous waste to be used to determine if a waste is hazardous--ignitability, corrosivity, reactivity, and toxicity. In addition, Subpart D contains lists of materials declared to be hazardous wastes by the EPA. If a material is recycled, used as a fuel, or used in some other useful function, it normally will not be classified a hazardous waste, regardless of its characteristics (though it could still be a hazardous material). Here, fuel cell polyurethane foam is considered a waste. If at some future time it can be turned into a resource, many of the considerations herein would then be disregarded. In the following discussion, only selected portions of 40 CFR 261 relevant to waste foam are presented.

## Ignitability

A solid waste exhibits ignitability (40 CFR 261.21, paraphrased) if it

(a) Is a liquid and has a flashpoint less than 140°F,

(b) Is not a liquid, and under standard temperature and pressure, can cause fire through friction, absorption of moisture, or spontaneous chemical changes, and, when ignited, burns so vigorously and persistently that it creates a hazard,

(c) Is an ignitable compressive gas,

(d) Is an oxidizer.

Since polyurethane foam, even when saturated with purge fluid, is not a liquid, a gas, or an oxidizer (hydrocarbons are reducing agents), items (a), (c), and (d) do not apply. Further, the initial samples that were collected at Warner-Robins ALC and Ogden ALC contained no free liquid. New samples were taken from Warner-Robins ALC in June 1986. These samples passed the proposed paint filter test.

The significant word in (b) is "and." The waste must ignite from friction or other causes and burn vigorously. While contaminated polyurethane foam does burn readily, qualitative judgment is required to decide whether the combustion is sufficiently vigorous to cause a hazard; and the EPA does not provide criteria for making such a judgment. Of greater importance, however, is that there is no evidence of ignition through friction, spontaneous changes, or reaction with water. Although some statements have been made that fuel cell foam can build up static electricity, not at any Air Force base visited had personnel either seen or heard of static buildup in waste-contaminated foam or of a fire owing to such a phenomenon. In fact, the authors have heard of no reports of fires in discarded fuel cell polyurethane foams from any cause. Thus, the foam as normally collected does not have the characteristics of ignitability; however, if free liquid is present in the contaminated foam when tested by the paint filter test, and the flashpoint of this liquid is below 140°F, the foam could be a hazardous waste.

### Corrosivity

A solid waste exhibits the characteristic of corrosivity (40 CFR 261.22, paraphrased) if it

(a) Is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5.

(b) Is a liquid and corrodes steel.

Fuel cell polyurethane foam is not aqueous, nor is it a liquid, and it does not corrode steel, as shown by its behavior in fuel tanks. Thus, it does not have the properties of corrosivity.

### Reactivity

A solid waste exhibits the characteristic of reactivity (40 CFR 261.23, paraphrased) if it

(a) Is normally unstable and readily undergoes violent change,

(b) Reacts violently with water,

(c) Forms explosive mixtures with water,

(d) Generates toxic gases in water,

(e) Is a cyanide or a sulfide, or

(f) Is capable of detonation (under a variety of defined conditions).

Polyurethane foam meets none of these criteria. Thus, this material does not exhibit reactivity.

### Extraction Procedure Toxicity

A solid waste exhibits the characteristics of EP toxicity (40 CFR 261.24, paraphrased) if the EP extract contains metal concentrations equal to or greater than the concentrations shown below:

| | | | |
|---|---|---|---|
| As | 5.0 ppm | Pb | 5.0 ppm |
| Ba | 100.0 ppm | Hg | 0.2 ppm |
| Cd | 1.0 ppm | Se | 1.0 ppm |
| Cr | 5.0 ppm | Ag | 5.0 ppm |

Since all of the EP extracts tested have values below these limits (Table 7), the foam cannot be classified as a hazardous waste under this portion of the RCRA regulations.

Proposed regulations, which would include more chemicals (including benzene and toluene) in the EP Toxicity Test, should not change this classification (Reference 13).

### Listed Wastes

Subpart D of 40 CFR 261 contains lists of wastes which have been declared hazardous. Section 261.31 contains a list of hazardous wastes from nonspecific sources (the F-list). Some of the compounds, e.g., xylene and toluene, may be found in contaminated fuel cell polyurethane foam; however, this list defines these materials as spent solvents, and the trace amounts found in the foam cannot be considered as such. The EPA has stated in writing, in fact, that this list does not apply to mixtures containing these chemicals. In a letter dated July 21, 1981, Mr. John P Lehman, Director, Hazardous and Industrial Waste Division, United States Environmental Protection Agency, states:

> ...[I]t is our interpretation that the regulations are intended to apply to spent solvents identifiable as any technical grades of the chemical that are produced or marketed and not to mixtures otherwise containing the chemical.

Section 261.32 contains a list of hazardous wastes from specific sources (the K-list). Fuel cell foam is not contained in this list. The list of discarded commercial chemical products, off-specification species, container residues, and spill residues given in 40 CFR 261.33 (the P-list of acute hazardous wastes and the U-list of toxic wastes) requires a more careful examination. Although a number of these chemicals may be found in small amounts in the foam, they certainly are not commercial products, manufacturing chemical intermediates, off-specification commercial products, or manufacturing chemical intermediates as required by this subsection. In fact, attention is called to the following comment in 40 CFR 261.33,as amended by 46 FR 27476, May 20, 1981:

> [Comment: The phrase "commercial chemical product or manufacturing chemical intermediate having the generic name listed in..." refers to a chemical substance which is manufactured or formulated for commercial or manufacturing use which consists of the commercially pure grade of the chemical, any technical grades of the chemical that are produced or marketed, and all formulations in which the chemical is the sole active ingredient. It does not refer to a material, such as manufacturing process waste, that contains any of the substances listed in paragraphs (e) or (f). Where a manufacturing process waste is deemed to be a hazardous waste because it contains a substance listed in paragraphs (e) or (f), waste will be listed in either 261.31 or 261.32 or will be identified as a hazardous waste by the characteristics set forth in Subpart C of this Part.]

This passage states that mixtures containing substances in the 40 CFR 231.33 P- and U-lists are not hazardous wastes for this reason alone. They must also exhibit the characteristics of a hazardous waste or be listed in the F- or K-lists.

Finally, one must consider Appendix VIII, Hazardous Constituents. A careful reading of 40 CFR 261 shows that this list is meant to be a guide in determining which materials should be listed. Appendix VIII is not meant to have independent regulatory status. This is the interpretation of a majority of environmental authorities consulted, including federal and state environmental officials (private conversations), environmental lawyers, and hazardous waste managers. Note, however, that this interpretation is apparently not universal. One published paper states that "Appendix VIII was originally accepted by the regulated community as having no independent regulatory status. The Agency is assuming, however, that it indeed has full regulatory status..." (Reference 24). The article cited was not written by any member of a regulatory agency.

## State

The state of Georgia has accepted 40 CFR 261 as defining hazardous wastes (Reference 25). The Utah Hazardous Waste Management Regulations merely restate the federal regulations. Thus, regulations of neither of these states cause any change in the conclusions reached from the federal regulations. On the other hand, the California Administrative Code, Title 22, Division 4, Environmental Health, has taken an entirely different approach. Under Article 9, Section 66680 of the California regulations:

> A waste that consists of or contains a material cited in the List of Chemical Names or the List of Common Names presented in this Article shall be considered a hazardous waste and shall be handled and disposed of according to the requirements set forth in this Chapter unless it is shown to the satisfaction of the Department that the waste does not meet the definition of hazardous waste presented in Article 1 of this Chapter.

California includes gasoline (Number 355), toluene (Number 738), xylene (Number 776), and fuel waste on the Common Names list. Waste foam which contains any of these materials is a hazardous waste under the California regulations, unless it can be shown not to meet their definition. An examination of other criteria which California uses for a hazardous waste indicates that it would be difficult to have contaminated foam waste declared nonhazardous. Thus, contaminated fuel cell polyurethane foam waste is a hazardous waste under California regulations. New Jersey and South Carolina are the only other states that currently have laws defining petroleum-product-contaminated wastes as hazardous. Contaminated foam is a hazardous waste in these two states.

## Local

One must consider two types of local regulations--city/county and airbase. Counties in Utah and Georgia operate under the corresponding state laws which have already been reviewed. Each of the county landfills has regulations concerning their use; however, these do not include defining hazardous wastes though they may concern inappropriate wastes or wastes which are incompatible with a landfill disposal.

Robins AFB has a hazardous waste management plan, but contaminated foam is not considered to be a hazardous waste. Hill AFB has issued a Hazardous Waste Management Plan (Reference 26) which defines a hazardous material as being one which may

> 1. Cause or significantly contribute to, an increase in mortality, or an increase in serious, irreversible, or incapacitating reversible illness; or
>
> 2. Pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed.

The Plan also presents a list of predetermined hazardous wastes which is essentially a major portion of the list given in 40 CFR 261.31. Neither of these criteria indicates that used polyurethane foam is classifiable as a hazardous waste under the definitions presented in the Ogden ALC Hazardous Waste Management Plan.

Like the California regulations, the Sacramento ALC Management of Hazardous Waste regulations (Reference 27) define as hazardous anything containing fuel wastes or gasoline.

## SUMMARY

Neither new or used fuel cell polyurethane foam, as normally collected, is classifiable as a hazardous waste at Warner-Robins ALC or at Ogden ALC under applicable federal, state, or local regulations. This conclusion may not be true if collection results in free liquid in addition to foam--a condition which was not observed at these two ALCs. This situation could, and is likely to, change. The trend in environmental legislation is toward stricter, more comprehensive, and more inclusive regulations. Specific areas of stricter regulation possible in the immediate future include the following:

1. The EPA may rule, instead of merely suggesting, that free liquids be separated from mixed wastes by the paint filter and subjected to flashpoint evaluation.

2. The proposed TCLP may set unachievable thresholds for benzene and toluene.

3. More states could declare petroleum-containing wastes to be hazardous.

4. Because of the volume of material and the chemicals contained, contaminated (and possibly uncontaminated) fuel cell foam is a likely candidate for a specified hazardous waste stream.

Contaminated fuel cell foam is classified as a hazardous waste under California law and under Sacramento ALC regulations. It would probably be difficult to have the waste declared nonhazardous at this location. New foam scrap would probably not be classified as hazardous in California. Contaminated foam is also a hazardous waste in New Jersey and South Carolina.

Disposal of both new and used fuel cell polyurethane foam is being performed in accordance with applicable laws and regulations at Warner-Robins ALC, Ogden ALC, and Sacramento ALC. Note, however, that while the waste may not be hazardous at Warner-Robins or at Ogden, it is likely incompatible with landfill disposal owing to its bulk and the possibility of ground subsidence. Also, large landfill cleanup costs would occur if the waste were ever classified as hazardous.

# SECTION III

# REVIEW OF DISPOSAL AND RESOURCE RECOVERY PROCESSES

In this section, information gathered from literature and patent searches, waste equipment manufacturers, and waste recovery companies is briefly reviewed. A detailed process evaluation for each base considered is included at the end of this section.

## SURVEY OF DISPOSAL AND RESOURCE RECOVERY ALTERNATIVES

A literature and patent search was conducted, using both manual and computerized methods, to explore various sources. This search revealed a large amount of work that has been accomplished on disposal and recycling methods for scrap polyurethane foams. A number of processes use heat, steam, chemicals, or other means to degrade foam, convert it into its original components, or reduce the volume.

Several manufacturers of industrial waste handling equipment and researchers developing new methods of disposing/recycling wastes were contacted. Information on the state-of-the-art of foam recycling/disposal was obtained from individuals familiar with the foam disposal problem.

Laboratory tests were conducted at NMERI to evaluate the different methods of recycling/disposal. The results are included as Appendix C to this report.

### Hydrolysis

In this class of processes, waste foam is heated under pressure in a steam or water-saturated environment (References 28-36). The foams degrade from solids to sticky liquids, which contain polyols (used in the original manufacturing process) and amines (which can be chemically converted to isocyanates--another original component of the foam).

The Ford Motor Company Polymer Science Department, Dearborn, Michigan, has patented several chemical processes that involve hydrolysis (References 31, 35-39). An author of one of these processes, which is used to recycle seat-cushion scrap, was contacted. His company does not recommend this type of process for general use.

Laboratory hydrolysis tests were conducted on the foam. A steam autoclave was used to test samples of both dry and water-immersed foam in a high-temperature and pressure, steam-saturated environment. Steam hydrolysis readily degraded the polyester foam. Polyether foams are specifically formulated to improve hydrolytic stability and do not hydrolyze as rapidly (Reference 42).

### Pyrolysis

Pyrolysis uses heat to decompose wastes in a generally oxygen-free or an oxygen-deficient atmosphere. During this process, depolymerization (breaking of the linkages between monomers) and fragmentation (breaking of the chains themselves) occur. The final product is a complex mixture which is greatly reduced in volume (References 43-48).

Tests were conducted to evaluate this process. The foam was placed in a high-temperature environment (equivalent to the decomposition temperature given in the patent literature). The foam did not degrade and only slight charring occurred.

### Glycolysis

Glycolysis is essentially hydrolysis with a glycol substituted for water. The foam is permitted to react with the glycol at high temperatures and pressures to produce a polyol mixture contaminated with byproducts. Other processes similar to glycolysis include hydroglycolysis, steam hydrolysis/alcoholysis, and alcoholysis (References 31, 37-41). These processes are performed similarly and give similar products.

The Upjohn Company, a chemical manufacturer, has patented several processes for polyurethane foam recycling. Of the two Upjohn employees contacted, one was a patent author for a process (Reference 49) developed at the D. S. Gilmore Laboratory in New Haven, Connecticut. This technology was developed to aid large foam manufacturers to recycle their scrap to reduce operating costs. Upjohn expressed doubt that the process could be adopted for use by foam consumers.

## Biodegradation

According to some sources, polyurethane is somewhat biodegradable (Reference 50). Bacteria would have to be specially developed and bred to decompose polyurethane foam. No bacteria are currently available to handle this problem. Biodegradation also requires excessive time and space.

Two series of laboratory biodegradation tests were performed on the foam. General, nonspecific as well as specifically formulated bacteria were tested. After several weeks, no significant weight or volume changes were observed.

## Photolysis

Polyurethane foam can be slowly degraded by ultraviolet light (Reference 51); however, there would be some danger in the use of high energy radiation. Lower energy radiation (visible light and infrared, for example) would be less successful in decomposing the foam. The products should be similar to those obtained from pyrolysis, since both heat and radiation cause chain breakage and depolymerization.

The effects of ultraviolet and infrared light on foams were studied in two separate series of tests. The polyether foams were affected more than the polyesters in the ultraviolet tests. No noticeable effect was observed during the infrared tests.

## Chemical Degradation

Foam degradation can be accomplished by heating polyurethanes in the presence of carboxylic acids (Reference 52), primary amines (References 51, 53-57), and acids/solvents (Reference 58). The products created by these processes are mixtures of a number of undesirable compounds.

Two solvent recovery equipment manufacturers, Recyclene Products (San Jose, California) and Finish Engineering (Erie, Pennsylvania) proposed that the foam could be degraded in a pressurized, heated chamber filled with a chemical agent that could aid in the degradation process. The foam would be converted into its original components, and the chemical agent could be used over and over again. After evaluating this possibility, it was decided that this method would be too impractical to pursue.

Several acids, bases, and chemical solvents were tested to determine the ability they possessed to chemically degrade the foam. No permanent significant changes occurred during these tests. Even if the foam could be chemically degraded, the product that would be produced would be more undesirable than the original foam waste.

### Baling and Shredding

If scrap foam continues to be landfilled, it could be reduced in volume by compacting, baling, shredding, or grinding. Seven manufacturers of this type of equipment were contacted. It would be difficult to shred or grind the pliable foam; and the problem of managing the waste at the landfill site could be increased, especially under windy conditions. Compacting or baling the foam would significantly reduce its volume, but the foam would still have to be landfilled.

### Recycling/Rebonding

A large amount of scrap polyurethane foam is currently shredded or chopped and used as a filler in new foam formulations for carpet underlay padding (rebonding). Shredded foam is also used in stuffing furniture and for children's toys. The manufacturer of the fuel cell foam, SCOTFOAM (Eddystone, Pennsylvania), shreds their scrap and sells it to rebonders.

Fifty-one plastic or foam recycling/rebonding companies were contacted and questioned about purchasing scrap foam. Only four companies expressed interest, and these placed unreasonable acceptance and shipping restrictions on the scrap foam.

### Incineration

Incineration of the foam was considered. A two-chambered, afterburner-equipped unit, operating at high temperatures, could possibly reduce the volume/weight of the foam dramatically without any environmental problems.

Twenty commercial incinerator manufacturers were contacted and only 10 were interested in the foam disposal problem (Appendix D). After an initial field test of the foam at the New Mexico State Hospital Incinerator Facility (Las Vegas, New Mexico) proved favorable, larger field demonstrations were planned. These tests are discussed in Section IV.

## PROCESS EVALUATION

Only the processes deemed feasible--landfilling, incineration, and selling the foam to recyclers/rebonders--have been evaluated. The other processes discussed in the first part of this section were omitted because of their impracticality or problems caused by hazardous products. The cost factors are presented only for Warner-Robins ALC, the largest producer of scrap foam. Since incineration has been chosen as the preferred disposal method, its discussion is more detailed.

The processes in this evaluation are judged by the following factors (Reference 59).

### Environmental Factors

The federal, state, and local environmental laws/regulations that would affect the operation of the process being studied are first discussed. Then, specific problems such as emissions, residues, and byproducts produced by a process are evaluated. The expected public opinion as well as the outlook for the future for each process is also mentioned.

### Economic Factors

The current and future amounts of waste foam generated by a process are discussed. The possibilities of using the existing base facilities to reduce the costs of a process and the ease of incorporating a process into the existing base routine are also evaluated. Finally, the costs of the process are estimated (Warner-Robins ALC--incineration process only).

### Landfilling

Waste foam is now landfilled at all the ALCs and Air Force bases that were surveyed. Warner-Robins ALC, Ogden ALC, and Sacramento ALC were visited to review this method of disposal.

#### Environmental Factors

All federal, state, and local regulations have been reviewed for the three ALCs. Regulations allow the foam to be landfilled in nonhazardous waste sites in Utah and Georgia. In California, however, contaminated foam wastes are deposited in a Class 1 hazardous waste landfill. Contaminated foam could be classified as hazardous in Utah and Georgia in the future. Unless otherwise specified, any waste material containing petroleum products is considered a hazardous waste in California, South Carolina, and New Jersey. Such regulations can be expected for other states in the future.

Several environmental problems are created by landfilling waste foam. An extensive period of time is required for degradation of polyurethane, which for all practical purposes could be considered nonbiodegradable in landfills. Owing to the sheer bulk of landfilled foam, subsidence could be a serious problem in the future. Of greater concern is the possibility of the foam being declared a hazardous waste in the future; in which case, site cleanup could be required.

Landfilling almost certainly produces emissions due to purge fluid and other contaminants, which are expected to occur at relatively low levels. The high-volume and low-density properties of foam make it a difficult material to landfill. It fills the site rapidly and is often blown about by the wind. The tendency for windblown foam was apparent at the Houston county landfill, where the waste from Warner-Robins ALC is taken. The foam also tends to "float" to the top of the landfill when buried.

Problems are occurring at the landfill sites used for foam disposal in California. The Class 1 hazardous waste disposal site at Benicia, California, where foam waste from Sacramento ALC is now disposed, is reported to be leaking (Reference 60). The same is true for the Kettleman Hills Class 1 site, where Sacramento ALC waste foam has been deposited in the past (Reference 61).

Landfills are unsightly and undesirable by the public. Landfilling is considered to be an unsafe method for disposing of industrial waste. This is particularly true when those wastes may be declared hazardous in the future. This negative opinion will continue to grow as landfills are filled and new landfills are needed.

Landfilling is being phased out as a method of disposal for industrial wastes. As current landfills are filled, it will be more difficult to obtain approval for new sites. As of August 1985, this was a serious problem at the Houston county landfill and no new site had yet been located. Old landfills are also causing problems. Groundwater and soil contamination and other environmental problems have caused the initiation of large landfill cleanup programs (Reference 62).

## Economic Factors

The amount of waste foam being placed in landfills each year at the three ALCs is as follows:

| | | |
|---|---|---|
| Total foam waste | 427,000 ft$^3$ | (558,000 lb) |
| Warner-Robins ALC | | |
| Total foam wastes | 405,000 ft$^3$ | (530,000 lb) |
| Contaminated foam | 65,000 ft$^3$ | (85,000 lb) |
| Uncontaminated foam | 340,000 ft$^3$ | (445,000 lb) |
| Ogden ALC | | |
| Total foam wastes | 4,000 ft$^3$ | (5,000 lb) |
| Contaminated foam | 3,300 ft$^3$ | (4,200 lb) |
| Uncontaminated foam | 700 ft$^3$ | (800 lb) |
| Sacramento ALC | | |
| Total foam wastes | 18,000 ft$^3$ | (23,000 lb) |
| Contaminated foam | 18,000 ft$^3$ | (23,000 lb) |
| Uncontaminated foam | 0 ft$^3$ | |

The amount of foam waste that will be generated in the future cannot be predicted exactly. Plans have been made, however, to install foam in all C-130 aircraft in use today. Each C-130 requires between 1600 and 1800 $ft^3$ of foam (depending on the aircraft production series), and there is approximately 35 percent waste in the foam-cutting operation (Reference 5). Since only half of the approximately 300 C-130 aircraft have been fitted at this time, about 76,000 $ft^3$ of uncontaminated foam waste will be produced as a result of this one operation alone. The A-10, F-15, F-4, and helicopter aircraft will continue to be refitted with replacement foam required as a result of normal degradation. The A-7 is also being fitted with fuel cell foam. New fuel cell foams with a better antistatic formulation are being developed. These new foams could replace much of the fuel cell foam in use today. Such a replacement will generate a large amount of additional waste, both removed contaminated foam and new scrap foam.

Warner-Robins ALC spent over $98,000 in fiscal year 1984 for foam disposal. This figure includes transportation and landfill charges. These costs are expected to increase. The volume of the waste could be decreased by shredding, baling, or compaction. Volume reduction would reduce the cost of transportation to the landfill; however, it would also increase processing costs.

## Incineration

Incineration is a possibly environmentally safe disposal method in which a large volume/weight reduction and good emission characteristics are possible.

### Environmental Factors

All federal, state, and local air quality regulations have been evaluated and are discussed in Section IV of this report. Permitting requirements for installing an onbase unit are discussed in Section V. Emissions are the main concern of the public and of the federal and state environmental control agencies who deal with incinerators. This problem is largely avoided by the use of a two-chambered (or afterburner-equipped) incinerator. Gases emitted by burning the foam would be passed into a separate chamber, where they would be reburned. Emission studies of the products given off in foam incineration are discussed in Section IV of this report.

Little residue remains when polyurethane foam is incinerated. A volume reduction of better than 99 percent is possible. The small amount of ash left over is expected to be nonhazardous and could be safely landfilled. A complete analysis of this ash residue is included in Appendix B.

Historically, the general public has disliked combustion as a method for waste disposal. In the past, combustion disposal methods often produced gaseous emissions and left behind undesirable solid products. More advanced incineration technology can be clean and efficient.

### Economic Factors

Incineration costs could be reduced through the use of contractors hired to run an incinerator facility. Contractors could use either their own or an Air Force supplied incinerator. Transportation of waste to the incinerator would be supplied by the contractor or by base personnel, whichever is more cost-effective.

The following is an individualized evaluation of the economics of incinerating foam.

### Warner-Robins ALC

The large amount of waste foam generated at Warner Robins makes onbase incineration a feasible option. Contracted incineration is likely to be difficult to find and would create logistical difficulties unless the contractor were located nearby. An onbase incinerator could be dedicated to combustion waste foam, or could be used to burn all solid combustible wastes including foam. Design of an incinerator to burn all combustible solid wastes would have required an extensive waste survey which was outside the scope of this effort. The following evaluation is for an incinerator dedicated to foam combustion only.

The estimated base price of an incinerator ranges from $12,000 to $300,000, depending on the manufacturer, model, and size of the unit purchased. This initial cost to the Air Force would not include installation and shipping costs, which could be equal to the price of the incinerator. There should be very little maintenance on a nonhazardous waste incinerator; however, replacement could occur as often as every 8 to 10 years.

An incinerator with a capacity of about 1200 lb/hr of type "0" waste, (common trash that is highly combustible), (400 lb/hr of foam) would be the minimum size needed for foam disposal at Warner-Robins. With an operation time of 1456 hours a year (four 6-hour days and one 4-hour day each work week), incineration of 582,000 pounds of foam is possible. This time allotment would allow startup and shutdown periods, time for ash removal, and time for making minor repairs. The incinerator would be powered by natural gas, propane, or fuel oil. Electric power would be required to operate such support equipment as burner ignitors and monitoring gages. This unit would require about 1.9 million BTU/hr to operate. The fuel bill would be approximately $14,000 per year, according to current natural gas prices. A foam storage bin with a ram-loading system would be the preferable accessories for the incinerator.

If Air Force personnel were assigned to operate an incinerator, the base maintenance department would have to accommodate additional personnel manhours. Training sessions would also be necessary to ensure the proper and safe operation of the facility. Personnel would have to be assigned to monitor and load the incinerator. This could be handled by one person; however, a second person could be used to transport foam, fill in for vacation time and sick leave, and perform simple maintenance.

Maintenance costs for an incinerator of the size needed for Warner-Robins ALC would be minimal. Incinerators are designed and built to be operated outdoors with minimal shelter.

No emission control devices should be necessary for the operation of an afterburner-equipped incinerator that is properly sized and operated. This will be discussed more in detail in the next section of this report.

The estimated yearly costs with no contractor operation and no emission control equipment at Warner-Robins ALC are presented below. These costs were calculated for the smallest acceptable incinerator, and a 50 percent cost overrun factor was included. The installation and capital equipment costs are conservatively prorated over 4 years. The prorated installation costs will be smaller than those estimated, since installation cost for a replacement unit would be smaller than that for the initial unit.

| | Cost/year |
|---|---|
| Capital equipment ($300,000 initial cost) | $ 75,000 |
| Installation ($120,000 initial cost) | 30,000 |
| Fuel costs | 14,000 |
| Maintenance | 5,000 |
| Operating personnel (2) | 30,000 |
| | $154,000 |

### Ogden ALC and Bases Where Foam is not Hazardous

This base generates a small (5,000 lb/yr) amount of waste that is produced very sporadically. This would also be typical of any TAC or MAC base that is not a major aircraft service center. The foam is not a hazardous waste in Utah. This is also true of the majority of the TAC and MAC bases. At these installations, the purchase of a dedicated incinerator for foam disposal cannot be justified. Bases should evaluate the feasibility of purchasing an incinerator to dispose of nonhazardous combustible solid wastes. Foam could be incinerated along with other wastes. The foam could also be shipped to an outside waste contractor who would be required to incinerate the foam. Local companies that operate industrial kilns or incinerators may be available around some bases, and these could be contracted to incinerate the waste foam.

If the foam is ever redefined as a hazardous waste solely due to its ignitability or corrosivity characteristics, it could be possible to still allow the foam to be incinerated in a nonhazardous waste incinerator, according to 240 CFR 264.340. However, if the levels of benzene or toluene ever cause the foam to be redefined as a hazardous waste, the disposal of the foam should be handled by a hazardous waste contractor. A hazardous waste incinerator should be used.

## Sacramento ALC and Bases Where Foam is Hazardous

The amount of waste foam generated at this facility (23,000 lb/yr) could warrant the purchase of a small incinerator, were the foam not considered a hazardous waste under California environmental laws. This would also be true of any Air Force base located in a state where the foam is considered a hazardous waste (South Carolina, New Jersey). The cost of a hazardous waste incinerator dedicated to foam destruction would be prohibitive. In addition to the excessively high capital outlay needed, such an incinerator may have to pass stringent emission tests before it could be licensed and permanently installed. Base personnel at Sacramento ALC who now handle the foam are required to wear full safety gear and handle foam as a dangerous waste. This could create difficulties if base personnel were required to operate the incinerator facility. However, if significant quantities of other hazardous, combustible, solid wastes were generated on these bases, an onbase hazardous waste incinerator may become economically feasible.

The difficulties imposed by California and other state environmental laws where the foam is considered a hazardous waste might justify the hiring of a hazardous waste contractor to transport and incinerate the foam. This would be an expensive procedure but probably no more so than is the present use of a hazardous waste landfill. Moreover, incineration avoids the possibility of liability which could result from leaking sites.

## Recycling/Rebonding

Recycling is an economical and environmentally sound disposal method, but it may not be practical for the Air Force. The major problems are the uncertain market, the small demand for certain types of foams, the need to segregate foam types when shipping, the possible liability for foam use, and the lack of a market for contaminated foams. In addition, the Federal Government could be a barrier to the sale if there were any possibility that the foam seller could be held liable for foam use.

## Environmental Factors

Environmental problems posed by disposal of new foam by this method would be virtually nonexistent. There would be no residues, emissions, or byproducts if the foam were sold as scrap. The recycling/rebonding company would be responsible for any waste products that would be produced from processing the foam. Public opinion should be very favorable. One should note, however, that the foam seller may still be liable for the use of the foam. The use of the foam for an unsafe product or the involvement of the foam in an accident such as a fire could pose legal problems for the foam seller.

The potential for this method of disposal is uncertain. The foam seller would be dependent on the scrap polyurethane market. Prices could change sporadically and unexpectedly, and the market could disappear at times. When the contract to buy foam expired, rebidding would be necessary and foam could accumulate. Companies are very specific as to what type of foam they will accept. None of the potential buyers contacted expressed interest in the contaminated foam. Laboratory tests show that washing this foam with detergent and water will not remove sufficient contaminates to permit its reuse as uncontaminated material.

## Economic Factors

The only ALC facility studied that would significantly benefit from selling foam would be Warner-Robins ALC. Eighty-three percent of the total foam waste generated at Warner-Robins ALC is clean scrap foam. The majority of waste generated at the other ALCs (and apparently most TAC and MAC bases) is contaminated foam. The problem of disposing of contaminated foam would still remain and would still have to be resolved.

It would not be difficult to incorporate the selling of foam into the base operating routine. The only base facilities used would be those now in use for loading and storage of foam for landfill disposal. Most of the process, including packaging, loading, and shipping, could be handled by contractors. Waste foam could be placed into the waste containers already in use, and the contractors would be responsible for preparation and shipping.

Since the foam is being sold, the initial savings could be substantial. These savings would vary, depending on the price obtained and the amount of responsibility the seller would be required to assume for handling and shipping costs. No formal bids have been established with the recycling and rebonding companies. These bids would have to be determined by direct negotiations involving the Air Force. Preliminary price estimates show that the foam would sell for $0.05 to $0.25 per pound ($22,000 to $100,000 per year for Warner-Robins uncontaminated foam). The price would depend on the quality, type, and amount of the foam sold.

Operation and maintenance costs would depend on the amount of responsibility the local base would have to assume. If the base were required to prepare and ship the foam, this requirement could substantially increase costs. The purchase and installation of a baler could add $60,000 or more to the capital equipment outlay. Some important safety and personnel problems are involved in the operation of a baler.

## SUMMARY

Possible methods of polyurethane foam waste disposal were surveyed and evaluated. Pyrolysis, glycolysis, hydrolysis, chemical degradation, and related processes are likely to produce products which would be harder to eliminate than the original foam waste. Photolysis and biodegradation are very slow and would require excessive financial investment. None of these processes would fit well into normal base routine.

There are only three feasible disposal processes for fuel cell foam: (1) landfilling, (2) selling the uncontaminated foam to rebonding/recycling companies, and (3) incineration.

Landfilling could be continued. This process is relatively low-cost at most bases (Sacramento ALC is an exception), and it fits well into base routine. The major problems with landfilling are that it is environmentally unsound and leaves the waste foam generator open to the possibility of future liability. These potential problems are particularly severe at Warner Robins ALC. It is unlikely that landfilling can be continued indefinitely for even small waste foam generators owing to expected changes in regulations.

Land-filling will be a problem in those states (California, New Jersey, South Carolina) which could, or do, declare contaminated fuel cell foam to be a hazardous waste. The number of such states will almost certainly increase. Landfilling may continue to be a viable disposal method for bases which produce only small amounts of waste foam, such as Ogden ALC and most TAC and MAC bases. If landfilling continued, baling could be useful at Warner-Robins ALC. Volume reduction is unlikely to be useful at other bases because of the small volume of waste or, in the case of Sacramento ALC, the present disposal procedure. The cost for continuation of landfilling at Warner-Robins ALC will be about $100,000 per year. This figure includes transportation and landfill charges. With the purchase and operation of a baler, the cost would be about $125,000 per year. This cost includes the initial purchase of a baler and personnel costs to operate it.

Selling scrap foam to recycling/rebonding companies is environmentally sound and potentially highly cost-effective. This procedure should be considered as an auxiliary method of disposal for uncontaminated foam. Other methods must be available to dispose of contaminated foam and to dispose of foam when the market disappears, as it is almost certain to do at times. If Warner-Robins ALC were to dispose of all uncontaminated foam in this manner, as much as $100,000 per year could be realized from the savings in landfill disposal costs, if there were no transportation or equipment costs. In that case, the process would almost pay for itself. It is likely, however, that significant costs will be required in manpower, baling equipment, and transportation. Relatively large and probably incalculable administrative costs would also be incurred. There would still be a problem in disposing of the contaminated foam. The best estimate for the cost of a procedure in which new scrap foam is sold (at no net loss or gain) and contaminated foam continues to be landfilled (at Warner-Robins ALC) is about $17,000 a year. This would be the cost of transporting and landfilling only the contaminated foam.

Potentially, the best method for foam disposal is incineration. Incineration can cleanly and efficiently dispose of scrap and contaminated foam at a reasonable cost. Recommendations for accomplishing foam incineration depend on the amount of waste generated and whether or not it is a hazardous waste.

1. Warner-Robins generates enough foam waste to warrant onbase incineration regardless of whether or not the waste is hazardous. Warner-Robins should consider acquiring an incinerator to dispose of all nonhazardous combustible solid wastes. Should contaminated foam ever be reclassified as a hazardous waste in Georgia, the incinerator could still be used for burning scrap foam (83 percent of waste foam).

However, according to the 40 CFR 264.340 Federal Regulation, if the foam is redefined as hazardous solely due to its ignitability or corrosivity characteristics, the foam can still be incinerated in a nonhazardous waste incinerator if the Regional EPA Administrator approves this. This Administrator may, however, require that the existing incinerator be retrofitted with air pollution control devices when incinerating contaminated foam.

A conservative estimated cost for incineration of foam at Warner-Robins ALC, using a dedicated incinerator, is $154,000 per year.

2. Other bases where foam is nonhazardous (Ogden ALC, most TAC and MAC bases) may wish to acquire an incinerator to burn all their nonhazardous combustible solid wastes, including foam. They may also try to contract to incinerate foam off-base. As discussed earlier, it may be possible to continue to use the existing nonhazardous waste incinerator to incinerate contaminated foam if a reclassification of the foam occurs. However, the decision would be up to the Regional EPA Administrator. In case foam is later reclassified as a hazardous waste, the bases should be prepared to switch to procedures outlined below in Number 3.

3. Bases where foam is hazardous should contract for foam disposal. A contractor who would incinerate waste foam would be preferable to one planning disposal in a landfill. Onbase incineration should only be considered if significant quantities of other hazardous, combustible, solid wastes are generated.

# SECTION IV

# FULL-SCALE INCINERATION TESTS

## DEFINITION OF INCINERATION

Many potential disposal processes for polyurethane foam were studied and most were found to be unfeasible for the application that is needed (Reference 7). The majority of these processes converted the foam waste into an undesirable or unusable form or simply transferred the responsibility of handling the waste. The Air Force would not be permanently rid of the waste foam and could have problems in the future. However, one of the processes that was studied, incineration, solved the majority of these problems.

Incineration can be one of the most environmentally safe and efficient methods of waste disposal available today. A two-chambered, afterburner-equipped unit has been designed to effectively reduce waste into an inert form, without producing any undesirable emissions. All wastes, whether listed as common, highly flammable, pathological, or hazardous, can be safely incinerated (Reference 63).

A volume and weight reduction of 90 percent or greater is possible for most wastes when incinerated (Reference 64). This is accomplished by subjecting the waste to temperatures in excess of 1600°F in the lower incinerator chamber. These high temperatures rapidly degrade the waste, and the majority of the combustible material is eliminated. Consequently, the foam produces very little ash. The material that is left can be safely landfilled.

The gases produced by the combustion of the waste are channeled into an upper chamber directly above the lower chamber and reburned at temperatures exceeding 2000°F. Any hazardous emissions that enter this chamber are thermally converted into harmless atmospheric gases (Reference 63).

## SPECIFICATIONS FOR TESTING

### Emission Components

A thorough search was conducted to determine the emission components that must be monitored during an incineration test to comply with applicable federal, state, and local regulations (References 65-72). The following is a list of these components.

- Nitrogen
- Nitrogen dioxides and other oxides of nitrogen
- Carbon monoxide
- Carbon dioxide
- Particulates
- Lead
- Organic compounds (hydrocarbons)
- Carbon
- Moisture content
- Combustible volatile characteristics

### Other Characteristics Monitored

Other characteristics of the stack gases that were determined were the following:

- Velocity of the stack gases
- Temperature of the stack gases
- Static gas pressure
- Gas density

The maximum charged volume that can be safely incinerated at one time (or the loading rate) was also determined. Ash samples were collected and analyzed.

### Incinerators Used for Testing

The incinerators used for the tests were supplied by the Thermal Reduction Company (TRC), Bellingham, Washington. The manufacturer of these units was Consumat Systems Inc., Richmond, Virginia.

The unit used in the first test series was a Consumat C-75 P pathological incinerator (75 $ft^3$ capacity). The rated charging/loading capacity of this unit was 175-360 lb/hr, depending on the type of waste. The fuel used for combustion was natural gas, and the installed thermal capacity of the unit was 1.2 MBTU/hr (Reference 73). A manual charging/loading method was used for this test.

The unit used in the second test series was a Consumat C-760 (760 $ft^3$ capacity). Its rated charging/loading capacity was 1600-2800 lb/hr, again depending on the type of waste. The fuel used for combustion was natural gas, and the installed thermal capacity of the unit was 3.5 MBTU/hr (Reference 73). A mechanical ram loader was used to charge/load the foam in this test.

These incinerators were rather old and in need of some repair. The particulate emissions that were produced in these tests should be considered as worst case. If newer, more modern units are used, the particulate emissions would be reduced.

## Federal, State, and Local Regulations

A search was conducted by Science Engineering Associates (SEA), Santa Fe, New Mexico, and NMERI to determine the applicable Air Quality Control regulations. The following regulations would have to be met if an incinerator with a charging/loading capacity of over 500 lb/hr were installed at Air Force installations. (See also Table 9.)

### California

Since the foam is considered a hazardous waste in California (Reference 5), the Federal Resource Conservation and Recovery Act (RCRA) regulations would have to be followed. Under these regulations, the incineration unit must have a Destruction and Removal Efficiency (DRE) of 99.99 percent for Principal Organic Hazardous Constituents (POHC).

TABLE 9. GEORGIA AND UTAH AIR QUALITY REGULATIONS.

| | |
|---|---|
| **Georgia** | |
| Particulate emissions | 0.2 gr/dscf (corrected to 12% $CO_2$)<br>0.2 lb/100 lb charged |
| Nitrogen oxide emissions | None for the size units that were tested. The regulation is for units of 250 MBTU heat input (thermal capacity) or greater. |
| Carbon monoxide | 10 mg/$m^3$ for an 8-hour average (8.59 ppm) |
| Lead | 1.5 micrograms/$m^3$ |
| **Utah** | |
| Particulate emissions | 0.08 gr/dscf (corrected to 12% $CO_2$) |
| Nitrogen oxide emissions | $4.25 \times 10^{-4}$ gr/dscf for a 24-hour average (0.5 ppm) |
| Carbon monoxide | 0.026 gr/dscf for an 8-hour average (50 ppm) |
| Lead | 0.1 micrograms/$m^3$ for a 24-hour average |

## TEST PREPARATION AND RESULTS

### Test Site Selection

Several incinerator manufacturers were contacted and asked to formally bid on conducting an incineration test of the foam. The manufacturers were evaluated according to the following criteria:

Cost
Ability to meet any schedule and/or test requirements
Availability of test equipment and personnel
Qualifications and experience of the testing company
Condition of the test facilities and the test incinerator

## Test Preparation

To properly conduct these incineration tests, three main preliminary items had to be accomplished. First, a certified emission testing company had to be located. Second, the incinerator had to be prepared for the test and the proper Air Quality Control officials notified of the test. Finally, sufficient scrap foam samples had to be shipped to the test site from the most convenient waste generation site.

Personnel at American Services Associates (ASA), Bellevue, Washington, were chosen as the emission testing company. They were briefed on the required emission components and other characteristics that were to be monitored. Standard EPA emission testing methods were to be used (Reference 74).

TRC personnel obtained and prepared the incinerators used in the tests. These incinerators were expected to meet NMERI specifications. These units were to be ones that use current, state-of-the-art incineration techniques and are readily available on the market.

Officials from the Georgia Department of Natural Resources, Environmental Protection Division (GEPD), the State of Washington Air Quality Control Office, and the local (Whatcom County, Washington) Air Quality Control Office--The Northwest Air Pollution Authority (NWAPA) were contacted. The officials were invited to both of the incineration tests, and test plans outlining the approach of the tests were sent to each office. Officials of NWAPA represented all three offices.

Since Warner-Robins ALC is by far the largest generator of scrap foam in the Air Force, it was chosen as a shipping point. The maintenance department at Warner-Robins agreed to ship approximately 15,000 pounds of mixed contaminated and uncontaminated scrap foam to the test site.

## Results--Test No. 1

The first series of incineration tests were conducted at the TRC waste disposal plant in Bellingham, Washington on 24 January 1986. Two identical series of tests were conducted on contaminated foam. This foam was of two types. The majority of the foam was taken from the fuel cells of aircraft at Warner-Robins ALC. The remainder of the foam was artificially contaminated at the test site with a 4 percent JP-4, 96 percent purge fluid mixture (representative of the fluid present in the foam after it is removed from the fuel cell). This mixture was provided by the Chemistry Department at Warner Robins ALC.

The foam was placed in polyethylene plastic bags in 1- to 2-pound amounts for loading into the incinerator. Combustion of polyethylene produces carbon monoxide when not combusted efficiently. No carbon monoxide was detected during the tests. A loading rate of 63 lb/hr was established as the maximum allowable loading rate.

The foam burned so hot that, once the incinerator was warmed up to its operating temperatures, the burners only had to occasionally ignite to maintain the chamber temperature. The lower chamber was maintained at a temperature of about 1500°F. The upper (or afterburner chamber) temperature was maintained at about 1700-2000°F.

The results of this test are printed in detail in Appendix A of this report, and summarized in Table 10.

The Air Quality regulation for this size of incinerator in Georgia limits particulate emissions to 1 lb/hr. There are no restrictions for nitrogen oxide emissions for a unit this size (Reference 75). Therefore, this series of tests passed the regulations for particulate and nitrogen oxide emissions in Georgia.

There were, however, problems associated with these tests. The loading rate was much too low (63 lb/hr). At this rate, only 92,000 lb/yr of foam could be incinerated. This could not handle all the waste foam that is annually generated at Warner-Robins ALC (530,000 lb/yr). Also, the foam burned so hot that the afterburner was occasionally overloaded, causing unwanted emissions to occur. These observations suggest that a larger incinerator would be needed at Air Force installations such as Warner-Robins.

TABLE 10. INCINERATION TEST RESULTS.

Test No. 1

Particulates--The particulate emissions were 0.127 gr/dscf and 0.277 gr/dscf (0.33 and 0.79 lb/hr) for runs No. 1 and 2, respectively.

Nitrogen oxides--The nitrogen oxide emissions were (on a heat input basis) 0.39 and 0.17 gr/dscf (465 and 201 ppm) for runs No. 1 and 2, respectively.

Stack gas contents:

| | | |
|---|---|---|
| $CO_2$ | 9.60-10.05 | percent |
| $O_2$ | 8.25-8.85 | percent |
| $N_2$ | 81.10-82.15 | percent |
| CO | 0.00 | percent |

| | |
|---|---|
| Moisture content of the stack gas | 11.7-14.3 percent |
| Velocity of the gases | 22.0-25.9 ft/s |
| Temperature of the gases | 2233.8-2381.7°F |
| Static gas pressure | 30.95 in. Hg |

Test No. 2

Particulates--The particulate emissions averaged 0.098 gr/dscf (0.19 pounds/100 pounds charged).

Nitrogen oxides--The nitrogen oxide emissions averaged 0.0869 gr/dscf (70 ppm).

Stack gas contents:

| | | |
|---|---|---|
| $CO_2$ | 5.70-6.06 | percent |
| $O_2$ | 12.14-12.80 | percent |
| $N_2$ | 81.14-82.16 | percent |
| CO | 0.00 | percent |

| | |
|---|---|
| Moisture content of the stack gases | 13.5-17.3 percent |
| Velocity of the gases | 22.5-26.3 ft/s |
| Temperature of the gases | 1161.6-1257.2°F |
| Static gas pressure | 30.96-30.99 in. Hg |
| Static gas density | 0.0763 $lb/ft^3$ |
| Lead | undetectable |
| Hydrogen cyanide gas | 1 ppmv |

There was also a problem with the method of loading used during the test. The manual loading procedure caused serious problems. First, the door to the incinerator had to be opened frequently (every 1-2 minutes to maintain the loading rate). This allowed more air than was necessary for combustion to enter the incinerator, causing the afterburner to momentarily overload and the emissions were increased. Frequently opening the incinerator door also proved hazardous to the operator. The foam tended to flash immediately as it was thrown into the hot chamber, exposing the operator to flames and unpleasant emissions. Also, loads had to be limited to 1-2 pounds of foam to prevent overloading. A mechanical loading system could feed the incinerator safely and more efficiently, and should be used for foam incineration.

### Results--Test No. 2

After evaluating the results from the first series of incineration tests, test personnel decided to test a larger incinerator with a mechanical loader. This second series of tests were again conducted at the TRC waste reduction plant in Bellingham, Washington. The test date was 3 March 1986.

Three identical series of tests were conducted on the foam. Only uncontaminated foam was used. The first series of tests were used to calibrate the incinerator, and the results of these tests are not representative of actual operating results.

The foam was loaded into the incinerator by a ram-loading mechanism. All foam was contained in the cardboard boxes it was shipped in when loaded into the incinerator. A foam loading rate of 400 lb/hr (880 lb/hr including the cardboard) was established as the maximum loading rate.

The afterburner chamber burner was used more in this series of tests, and an automatically operated water spray was used to control the combustion of the waste in the lower incinerator chamber. The lower chamber temperature was maintained at about 1500-1550°F. The upper (or afterburner chamber) temperature was maintained at about 1700-1900°F.

The results of this series of tests are presented in detail in Appendix A of this report, and is summarized in Table 10.

Laboratory studies showed that the total hydrocarbon in the stack gases was 0.015 gr/dscf. Laboratory studies also showed that the emissions coming out the stack were almost completely combusted.

Hydrogen cyanide gas was also monitored during this test. Results show that these emissions were an average of 1 ppm (ppmv). According to ASA personnel, the maximum exposure to persons at the base of the incinerator stack would be 1/1000 of this amount. As a comparison, the Threshold Limit Value-Time Weighted Average (TLV-TWA) for an 8-hour period is 10 ppmv (References 76-77).

The low particulate emissions (0.098 gr/dscf) will pass the Air Quality regulations for Georgia and will almost pass the particulate restriction in Utah (0.08 gr/dscf). This emission rate could have been reduced if the incinerator had been sealed better. Also, an incinerator equipped with an oversized afterburner chamber would significantly reduce the particulate and any other emissions by increasing the dwell time of the emissions in this chamber. Incinerators equipped with this option are readily available on the market.

## LABORATORY TESTING

### Volume/Weight Reduction Tests

Laboratory-scale testing was conducted at NMERI to determine the volume/weight reduction that would be possible when the foam is incinerated. Samples (0.04 g) of uncontaminated foam were placed in crucibles (60 ml) and then placed in a muffle furnace. They were then subjected to a temperature of 1710°F for approximately 6 hours. This temperature would be the temperature the foam would actually be subjected to inside an incinerator. A weight reduction of 98.10-99.45 percent resulted. This reduction amount could also approximate the volume reduction. Therefore, a volume and weight reduction of 98-100 percent could be possible if the foam were completely and efficiently incinerated.

### Ash Analysis

Ash samples were collected after each incineration test. These samples were analyzed at NMERI to determine if the ash could be landfilled. A detailed report of all the laboratory work conducted on the ash is included in Appendix B.

The ash residues from both tests were environmentally acceptable and not a hazardous waste, according to current RCRA and state regulations of Georgia and Utah. The ash could be landfilled in Georgia, Utah, and other states where the foam is not considered a hazardous waste. Since the ash residues from hazardous wastes are considered hazardous under RCRA, the ash, unless delisted, would be considered a hazardous waste in the states where foam is classified a hazardous waste (California, New Jersey, and South Carolina). There should be no technical problems with delisting the ash.

# SECTION V

# CONCEPTIONAL INCINERATION SYSTEM

## FOAM INCINERATION CHARACTERISTICS

The polyurethane foam used by the Air Force in fuel cells has several incineration characteristics which should be considered when selecting an incineration system. Its low-weight/high volume and high-combustibility properties make it an ideal incinerator fuel if the proper safety precautions are followed. The foam could, however, produce particulate and nitrogen oxide emissions which may not be acceptable in some states.

The low weight/high volume property of the foam causes it to be relatively easy to transport to the disposal site. However, this property could also cause problems with incinerator loading. The foam should be compacted slightly in the hopper of the loading mechanism to maximize the charge.

Foam, whether contaminated with fuel products or uncontaminated, has a high combustibility rating (13,000 BTU/lb). Therefore, foam could be used as an excellent source of heat energy in a boiler/steam generator system. However, this high combustibility could also create problems in loading and incinerating the foam. To correct this, automatic water cooling spray systems should be installed in the loading mechanism and in the incinerator lower chamber. These cooling spray systems should be used to soak the waste foam, when needed, to reduce its combustibility and allow it to burn more efficiently. Otherwise the foam could ignite in the loading mechanism or burn unevenly when loaded into the lower chamber.

Upon the initial loading of foam into the lower chamber, the foam tends at first to burn vigorously (for 1-5 seconds). While this could be controlled by a water spray system, this initial combustion surge would probably still occur. This would increase the particulate and nitrogen oxide emissions above certain states' regulated limits for short periods of time. This problem could be nonexistent if the incinerator were equipped with an oversized afterburner chamber or boiler/heat recovery system. Both of these options would increase the dwell time of the emissions in the incinerator and could practically eliminate the combustion surge problem.

UNIT RECOMMENDATION

The two separate incineration tests were conducted to determine the feasibility of incinerating both uncontaminated and fuel-contaminated foam. These tests proved favorable and several incinerator parameters were determined. After evaluating the test results and consulting with personnel from TRC and ASA, the type and size of the incinerator, loading rate and method, and recommended optional equipment were determined.

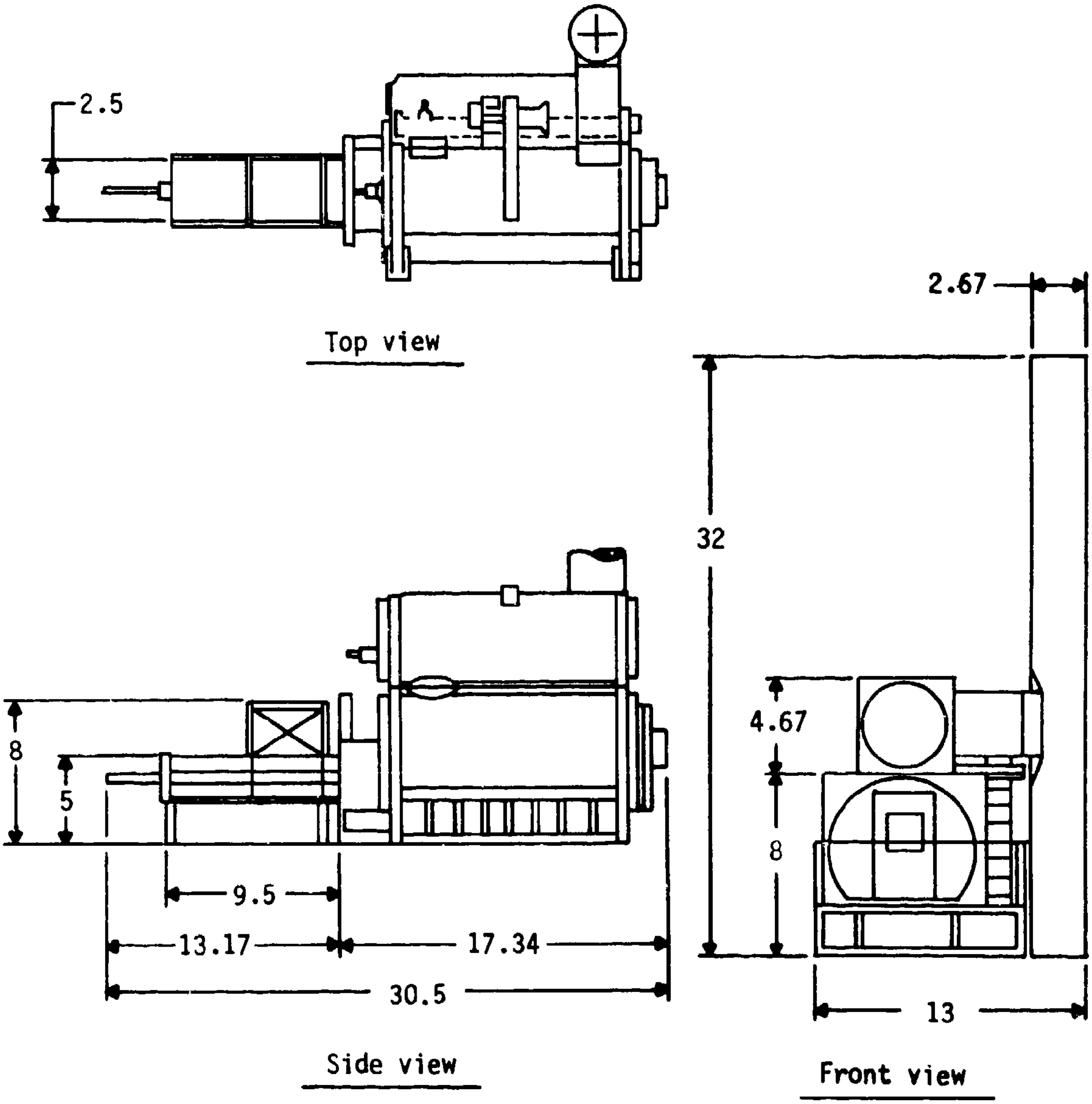
The following size recommendations are for a unit dedicated to foam incineration only. Note that the unit has not been field-tested. If other base wastes are to be incinerated with the foam, a larger unit would be necessary. A waste survey would have to be conducted to determine which unit should be used.

The incinerator should be a fixed-bed, two-chambered, refractory-lined unit (Figure 1). It sould be constructed of an outer lining of about 8- to 9-gage (.1875-inch) steel and about 12-gage (.1100-inch) steel in the exhaust stack. The unit should be lined throughout with approximately 3-4 inches of refractory and insulation materials which are capable of withstanding temperatures of 2600-3000°F. The bottom (or primary) burning chamber must be equipped to sustain operating temperatures of 1600-1800°F. The upper (or afterburner) chamber must sustain operating temperatures of 2000-2300°F. The burner fuel should be natural gas, but propane or fuel oil could be used.

An incinerator for Warner-Robins ALC should be capable of disposing 600,000 lb/yr of a mixture of contaminated and uncontaminated foam. This unit should have a minimum volume capacity of 225 $ft^3$ and should be equipped with an oversized afterburner chamber, mechanical ram-loading system, and a water spray cooling system.

The oversized afterburner chamber should be of cylindrical design and capable of a 1-second emission retention time. This chamber should have a minimum volume capacity of 150 $ft^3$.

The mechanical ram-loading system should be equipped with a water spray and have a minimum capacity of 41 $ft^3$. The minimum dimensions of the hopper



Top view

Side view

Front view

Note: All measurements are in feet.

Figure 1. Conceptual Incineration Design.

of the loader should be 73 by 31 by 31 inches. The cyclic feed rate should be adjustable and operate at 5-second intervals. When this loading system is used, the foam could either be stuffed into polyethylene bags or thrown into the cardboard boxes it was originally shipped in before loading into the hopper. The foam should be slightly compacted into the hopper in order to maximize the load.

The above recommendation should be used for Warner-Robins ALC only. The following recommendations should be applied to Ogden ALC, Sacramento ALC, and other bases.

For bases such as Ogden ALC and the majority of the TAC and MAC bases, the purchase of an incinerator dedicated for foam disposal is not justified. Although the foam is not considered a hazardous waste, the foam waste generated by these facilities would not be sufficient to warrant an incinerator. However, an incinerator could be purchased to dispose of all the nonhazardous waste, including the foam, that the base generates. As an alternative, foam disposal could be contracted to a waste contractor who would be required to incinerate the foam. Hospital incinerators should not be used to incinerate waste foam. Hand loading foam into an incinerator of this size would pose safety problems due to the flammability of the foam.

These bases should be alert for changes in regulations redefining contaminated foam as a hazardous waste. In that event, contaminated foam disposal should be handled by a hazardous waste contractor.

Sacramento ALC and other bases where the foam is considered a hazardous waste (New Jersey, South Carolina) would find that purchasing a hazardous waste incinerator for the foam alone would not be cost-effective. In addition to the high capital cost of the unit, stringent stack emission tests would have to be passed in order to license and permanently install this type of incinerator. A hazardous waste contractor could be hired to transport the foam off the base and incinerate it in a proper hazardous waste incinerator.

## OPTIONAL EQUIPMENT

The above recommendation is for the lowest cost incineration system possible. However, the following optional equipment could be used. Air pollution control equipment, boilers/heat recovery units, an automatic ash removal system, an incinerator shelter, and a foam storage area should be considered.

The incineration tests showed that no air pollution control equipment would be required to incinerate foam waste in Georgia. However, incineration units in Utah and California would require the use of these devices.

There are several types of Air Pollution Control Devices (APCD). Venturi scrubbers, wet scrubbers, packed towers, and cyclonic flow units all are commonly used on incineration units. These devices can effectively control particulate, nitrogen oxide, HCN gas, or other undesirable emissions.

Particulates are fine, solid particles of unburned matter that escape in the exhaust gases. Particulates (fly ash) can be controlled by forcing the emission gases to be subjected to high temperatures for a longer period of time or by scrubbing the gases with venturi or wet scrubbers. Packed towers, which cause the gases to travel through compartmentalizated, gravity-operated water spray chambers, or cyclonic flow units, which separate out the particulates by creating turbulence, can also be used. Bag house or fabric filters should not be used due to the high stack temperatures. Extensive particulate-sizing testing would be required once the unit is operational to determine the type and size unit that would be required.

Nitrogen oxides are formed by high temperatures and oxygen. The high temperatures of the stack gases would facilitate the formation of this gas. These temperatures could be lowered if a chamber equipped with a water spray to cool the gases were used. Venturi or wet scrubbers could accomplish this effectively.

Acid gases, such as HCN, could be removed by first quenching the hot exhaust gases to saturation temperature in a quench or water spray chamber. This should be followed by absorption in a packed tower absorber using an alkaline scrubbing solution.

Special alloy metals would be required for the construction of these units to control corrosion problems. The high temperatures, particle impingement, and condensation that would occur could cause corrosion to joints, crevices, and other areas in these units. The use of these alloys would dramatically increase the cost of the units. It is possible that the cost of the APCD could equal the cost of the incinerator itself.

A boiler/heat recovery unit could be used as a partial APCD. The emission gases would be funneled into a boiler (steam generator) in such a way as not to come in contact with any breathable air. The heat from these gases would be dissipated in the boiler chamber, causing the nitrogen oxide formation to decrease. The cooled gases could then be filtered through fabric filters to remove the particulates. The heat generated by the boiler could be used in the base heating system or for power generation.

The cost of this unit would be comparable to the cost of the APCD with one noticeable difference. This unit would eventually pay for itself by reducing the heating or power generation costs of the base.

The foam produces very little ash since its volume/weight reduction is 98-100 percent. The ash will accumulate, however, and must be removed from the lower incinerator chamber. Ash can be manually raked out of the chamber after the incinerator has cooled down. This method is dirty and undesirable for the workers. An automatic ash removal system is commercially available that can mechanically remove the ash without opening the incinerator.

An incinerator is designed to be used out-of-doors. It can be operated without a shelter and no major maintenance should occur. However, to lengthen the operational life of the unit, a simple shelter should be constructed over it. This structure should be constructed of steel and consist of a roof and supporting structure. The roof should be large enough to shelter the incineration system and partially shelter the working area. Space should be allowed in the roof for the incinerator stack to fit through.

A storage building for the waste foam could be constructed adjacent to the incinerator. This building should be placed on a concrete pad and constructed of steel or nonflammable materials. A building of 2400 $ft^3$ (10 by 20 by 12 feet) could store 1 day's accumulation of waste foam. A building of 12,000 $ft^3$ (10 by 40 by 30 feet) could store a week's accumulation of foam.

## INSTALLATION AND PERMITTING OF UNIT

The preparation for the permanent installation of an incineration unit at any base requires some construction work, state Air Quality construction and operation permits, and trial/compliance burning of the unit after it is installed.

First, the state Air Quality control office must be notified of the proposed incinerator before it is installed. Application forms for installation and operation permits in Georgia and California are included in the Appendix D of this report. Results of the incineration tests that were conducted on the foam were sent to the state Air Quality office in Georgia. Personnel in the office were informed of the tests, and approval of test plans for these tests was obtained from them before each test was conducted. This should help facilitate the application process; however, official compliance testing of the actual incineration unit will still probably have to be conducted.

According to RCRA (40 CFR 264.340), if the waste foam is ever reclassified as a hazardous waste due to its ignitability, permitting of the incinerator might not be difficult. At the discretion of the EPA Regional Administrator, all RCRA permitting requirements could be waived except at the closure of the facility and occasional waste characterization/inspection. This is an important clause if the ignitability of free liquids ever becomes an issue.

A site located near the foam waste generation sites, with reasonable access to gas/electrical hookups, must be chosen. This site must be cleared of all vegetation and burnables and leveled to a certain degree. A concrete pad must be poured that is large enough to accommodate the incinerator and a reasonably sized work area. The construction of a partial shelter (roof only) is not necessary but would cut down on the maintenance costs of the unit and increase its operational lifetime. This shelter and all fuel/electrical hookups should be installed after the incineration unit is in place.

The incineration units are shipped unassembled and without the refractory lining installed. Assembling the unit should be conducted at the site of operation under the supervision of a factory representative. Once assembly has been completed, the refractory lining can be installed. After the unit is operational, the lining must be cured. This is accomplished by operating the unit at reduced temperatures for a short period of time (4-5 hours).

## OPERATION OF THE INCINERATOR

The incinerator sizing calculations that were conducted in this project used an approximation of 1456 working hours per year. This approximation allows for a 6-hour work day, weekends, holidays, and sick leave.

The incinerator would require two personnel to operate/load the unit, monitor controls, and fill in for vacation/sick leave. One person could accomplish these tasks; however, the second person could assist or substitute for the operator.

The length of the warmup and cooldown periods would depend on the size of the incinerator. An incinerator can usually warm to its operating temperatures in 30-45 minutes. This can be facilitated if waste is loaded into the incinerator to raise the temperature of the chamber. The cooldown period can be considerably longer (4-5 hours). This can be better accomplished if the incinerator is allowed to cool overnight after the day's waste is incinerated. This cooldown period could be eliminated if an automatic ash removal system were used.

The foam could be manually loaded into the hopper of the loading mechanism in polyethelene bags and compacted until the hopper is full; however, this would be cumbersome to the operator. The foam could also be placed back into the cardboard boxes it was originally shipped in and loaded into the hopper with a loader machine, such as a small front loader vehicle. The box of foam could be compacted by the loader into the hopper quite effectively. This method was tested and proven effective during the second series of incineration testing.

## INCINERATOR MAINTENANCE

The maintenance required on an incinerator should be minimal if the unit is partially sheltered from the elements and is not abused. Daily, weekly, and monthly preventive checklists should be generated and adhered to.

Daily visual inspections should be made to check for fuel leaks, control response, and tightness of all clamps/bolts. The unit should also be cleaned of all excess debris, especially in the burner control and main control box areas. The loader should also be cleaned and inspected for malfunctions.

Weekly maintenance should include a more thorough check of all working parts. The burner ignitors and flame/temperature sensors should be cleaned as well as the combustion air ports. The refractory lining should be checked for any deterioration.

Once a month all moving parts must be lubricated, including blower motors, bearings, and all latches or hinges. The door seals of the incinerator should be inspected for deterioration.

The incinerator should be painted with a weather and heat-resistant paint once a year. This painting could be minimized if a partial shelter were constructed over the main parts of the unit to protect it from the elements.

## SECTION VI
## CONCLUSIONS AND RECOMMENDATIONS

Neither contaminated or uncontaminated fuel cell polyurethane foam as obtained under normal removal operations is classifiable as a hazardous waste at Warner Robins ALC or Ogden ALC under applicable federal, state, or local regulations. This situation may change as stricter waste regulations are approved. This is also true of the majority of the MAC and TAC bases throughout the world. Contaminated foam is classifiable as a hazardous waste under California environmental laws and Sacramento ALC regulations. This classification is also true in New Jersey and South Carolina. Disposal of both types of waste foam is being conducted in accordance with applicable laws and regulations at Warner-Robins ALC, Ogden ALC, and Sacramento ALC.

Possible methods of waste disposal were surveyed and evaluated. Most of these methods proved unfeasible. They would either not be cost-effective or would produce undesirable byproducts. There are only three feasible disposal processes for the foam waste: landfilling, recycling/rebonding, and incineration.

The current method of disposal, landfilling, could be continued. This method is low-cost and is already adapted to the base routine. However, environmental regulations are expected to become stricter, and the foam waste could be eventually classifiable as a hazardous waste in states where it is now classified as nonhazardous. This would cause landfilling to become too difficult and expensive. Landfill site cleanup where the foam has been deposited could also become manditory in the future.

The uncontaminated foam could be sold to recycling and rebonding companies. This method is environmentally sound and could be cost-effective. Other disposal methods would have to be considered for the contaminated foam. The cost of additional equipment needed for sorting, packaging, and shipping the foam and the instability of the scrap foam market could make this method of disposal unreasonable.

Incineration of the foam waste, both contaminated and uncontaminated, has been proven by full-scale tests to be an effective and environmentally safe disposal method. Recommendations for accomplishing foam incineration are made for Warner-Robins ALC, for bases where foam is classified as nonhazardous, and for bases where it is hazardous.

Warner-Robins ALC should acquire an incinerator to dispose of waste foam. If the incinerator is dedicated to foam disposing, it should be a two-chambered (or afterburner-equipped) incineration unit with a minimum capacity of 225 $ft^3$ in the lower chamber and 150 $ft^3$ in the afterburner chamber. This recommendation is made with some reservation since this unit was never field-tested. This unit should be capable of disposing 600,000 lb/yr of a mixture of contaminated and uncontaminated foam. It should be equipped with a mechanical loading mechanism that has a loading capacity of 41 $ft^3$ and can complete a loading cycle in approximately 5 seconds. Both the incinerator and the loader should be equipped with a water-spray cooling system. If wastes other than the foam are to be incinerated, a larger unit would be necessary and a waste survey would have to be conducted to determine its size. This unit would cost between $200,000 and $300,000, with $100,000 to $200,000 shipping and installation costs. If contaminated foam is reclassified as a hazardous waste, the same incinerator could still be used for scrap foam disposal. Permits may be required and the incinerator may have to be retrofitted with air pollution control devices for contaminated foam incineration to continue.

At other bases where foam is not currently a hazardous waste (Ogden ALC, most TAC and MAC bases), an incinerator used solely for disposing foam would not be cost-effective. However, an incinerator purchased to incinerate all nonhazardous wastes (including the foam) may be cost-effective. Moreover, local industries which need a cheap fuel source for furnaces or kilns could be contracted to remove the foam and use it for fuel.

Bases should be alert for changes in regulations reclassifying foam as a hazardous waste. In that event, foam disposal should be handled by a hazardous waste contractor.

At bases in states where foam is considered hazardous (California, New Jersey, South Carolina), foam should be incinerated by a hazardous waste contractor. The permitting and unit costs of a hazardous waste incinerator would make such a unit dedicated for foam disposal unreasonable. Bases should consider on-base incineration of hazardous foam only if they generate significant quantities of other hazardous combustible solid waste.

Optional equipment, such as boilers/heat recovery units, automatic ash removal systems, an incinerator shelter, and a foam storage area, should be considered. Also, in states other than Georgia, APCDs may be required to operate an incinerator.

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# APPENDIX A

This Appendix is a Reproduction of the

ATMOSPHERIC EMISSION EVALUATIONS,

JANUARY 1986 AND MARCH 1986

This is a self-contained document with its own internal style, which varies from our format.

# ATMOSPHERIC EMISSION EVALUATION

USAF/NMERI FUEL TANK FOAM

DEMONSTRATION INCINERATOR PROJECT

THERMAL REDUCTION COMPANY

JANUARY 1986

**AMERICAN SERVICES ASSOCIATES**
15049 Bel-Red Road, Bellevue, WA 98007 (206)641-6130

American Services Associates
Consultants in Air, Water, Energy, Hygiene & Management

February 10, 1986

## PURPOSE

This atmospheric emission evaluation was performed on a CONSUMAT, Model C75P, demonstration incinerator set-up for the NEW MEXICO ENGINEERING RESEARCH INSTITUTE (NMERI) to burn foam used in the fuel tanks of UNITED STATES AIR FORCE (USAF) planes as a static electricity eliminator and sloshing inhibitor. The incinerator was located at THERMAL REDUCTION COMPANY (TRC) in Bellingham, Washington. The tests were performed in accordance with the procedures and equipment described herein and the UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA). Mr. Warren Krug and Ms. Julie O'Shaughnessy of the NORTHWEST AIR POLLUTION AUTHORITY (NWAPA) observed this evaluation project. Mr. Mike Lee of NMERI was the Client Project Manager and Captain Edward Heyse and Mr. O.H. Carstarfen represented the USAF on the evaluation project. Messers. Wesley D. Snowden and Thomas W. Valentine of AMERICAN SERVICES ASSOCIATES (ASA) performed this evaluation on January 24, 1986.

## SUMMARY

Particulate emissions were found to be 0.127 and 0.277 grains per dry standard cubic foot (gr/dscf) coprrected to 12% carbon dioxide ($CO_2$) less the auxiliary fuel $CO_2$ contribution or also 0.33 and 0.79 pounds per hour (lb/hr) for Run #'s 1 & 2 respectively. The nitrogen oxides emissions on a heat input basis were 1.59 and 1.19 lb/MBTU heat input (i.e. assuming 10,000 BTU/lb of foam) or also 1.2 and 0.6 lb/hr for Run #'s 1 & 2 respectively.

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## DISCUSSION

The emissions from the demonstration incinerator are shown in Table A1. The incinerator was tested for particulate and nitrogen oxides (i.e. NO and NO2) at the stack outlet. The stack was fitted with a single sample port with approximately four (4) diameters ahead and one (1) diameters behind of straight and unobstructed stack. The sample port location required thirty-six (36) sampling traverse points (i.e. eighteen (18) in the one available sample port).

Table A1. NMERI/USAF Foam Incinerator Emission Test @ TRC 1/86

| Run No./ Sample ID. | Emission Parameter | |
|---|---|---|
| | Concentration | Mass Rate (lb/hr) |
| 1 / M5 | 0.127 gr/dscf | 0.33 lb/hr |
| 1 / NOX | 465 ppm | 1.20 lb/hr |
| 2 / M5 | 0.277 gr/dscf | 0.79 lb/hr |
| 2 / NOX | 201 ppm | 0.60 lb/hr |
| Avg / M5 | 0.202 gr/dscf | 0.56 lb/hr |
| Avg / NOX | 333 ppm | 0.90 lb/hr |

* Average emissions can be used to project daily emissions assuming the NMERI/USAF incinerator operates 8 hours/day. The particulate emissions are 4.5 pounds per day and the nitrogen oxides emissions are 7.2 pounds per day.

The samples collected on this project were collected per the procedures specified in the most current edition of the United States Environmental Protection Agency (EPA) as particulate or EPA Method 5 and Nitrogen Oxides or EPA Method 7. The cleanup and analysis procedures for the two (2) types of samples collected on this project are included after their respective computer printout of the results. The computer printouts are organized in this report with the section of this report discussing particulate first and nitrogen oxides (NOX) second.

The process operating parameters monitored during this evaluation included in the "Incinerator Operating Log" which is included after the field data sheets. The burning rates for the two (2) samples were 75.3 and 50.5 pounds/hr for Run #'s 1 and 2 respectively.

The ash produced during the operation of this demonstration incineration test was sampled by Mr. Mike Lee of NMERI following the day of emission sampling. Analysis of the ash is available from Mr. Lee.

Frequent opening of the charging door was required because of the high combustibility of the foam. The charging door was required to be opened because the combustion chamber was too small to allow a larger charges than those resolved during the experimental charging procedures prior to sampling (i.e. 2 to 3 lb per two minutes to 1 lb per one minute periods for Run #'s 1 and 2 respectively. The opening of the door at such frequent periods did not allow the combustion process to equilibrate and was the cause of higher than desired emissions (i.e. 0.1 gr/dscf at 12% CO2 without auxiliary fuel CO2 contribution). No auxiliary fuel was burned during these two (2) samples because the heating value of the USAF fuel tank foam alone was adequate to maintain over the desired 1800 degrees Fahrenheit temperature in the afterburner.

An ignition test on the Run #1 and Run #2 particulate collected on the filter and probe wash was performed to determine if the material collected on the front-half of the EPA Method 5 sampling train was of a combustible nature. The front-half sample lost 2.7%, 55.8% and 82.1% of its beginning weight upon temperature increases to 500, 780 and 1160 degrees Farenheit respectively. The ignition test on the Run #2 particulate collected lost 1.1%, 69.1% and 90.3% of its weight upon temperature increases to 500, 780 and 1160 degrees Farenheit respectively. The igniton test indicates that a significant amount of the particulate collected was combustible and therefore that the emissions coming from the demonstration incinerator were incompletely combusted. An adequate retention time (i.e. because the combustion chamber was too small) was apparently not available to completely combust the foam and thereby minimize the particulate emissions on this test.

This report is arranged in the order in which the data can be most readily used. The report is arranged as follows:

- "EPA Method 5 Summary" (a summary of test results)
- "Terminology & Equations" used in calculating the results
- "Procedure" illustrating how samples are typically collected
- "PMR Calculation" illustrates how calculations are performed for non-isokinetics
- "EPA Method 5 Particulate Sampling Train" schematic illustrates parts
- "Clean-up and Analysis" procedures utilized on this project
- NOX (EPA Method 7) "Analysis of NOX Emissions" Computer Printouts
- NOX Terminology & Equations
- NOX "Procedure" for Sampling
- "EPA Method 7 (NOX) Sampling Train" Schematic
- EPA Method 7 (NOX) "Sample Clean-up & Analysis" Procedure
- "EPA Method 5 Particulates" calculation sheet utilizes field traverse data sheet for input to the computer with one output sheet per Run
- "Particulate Calculation" utilizes laboratory data and calculates total particulate with one sheet per Run and sequentially placed with the above computer output sheets
- "Traverse Sampling Data Sheet" contains data collected from the field
- "Method 7 NOX Field Data Sheets" - Four samples per data sheet
- "Volumes of NOX Flasks & Valve Assemblies"
- "Incinerator Operating Log" - Maintained by TRC during sample collection
- "Calibration Records" of the equipment utilized on this project. Spot calibrations are performed before and after the field work. If within 2%, no changes are made in the calibration records.

AMERICAN SERVICES ASSOCIATES E.P.A. METHOD 5 SUMMARY

CLIENT: UNIVERSITY OF NEW MEXICO ENGINEERING RESEARCH INSTITUTE / USAF

SAMPLING LOCATION: THERMAL REDUCTION CO. C-75P DEMONSTRATION INCINERATOR

| | RUN # 1 1/24/86 | RUN # 2 1/24/86 | RUN |
|---|---|---|---|
| LAB NUMBER | 18-6 | 13-6 | |
| 24 HOUR START TIME | 1433 | 1717 | 0 |
| 24 HOUR STOP TIME | 1528 | 1814 | 0 |
| ELAPSED SAMPLING TIME, MIN | 54 | 54 | 0 |
| VOLUME SAMPLED, CU FT | 31.034 | 31.814 | 0 |
| VOLUME SAMPLED STANDARD, CU FT | 32.1541 | 32.7383 | 0 |
| MOISTURE CONTENT OF STACK GAS, % | 14.3339 | 11.7046 | 0 |
| MOLEC. WT OF STACK GAS, LB/LB MOLE | 28.2268 | 28.4983 | 0 |
| STACK PRESSURE, IN HG | 30.9478 | 30.9478 | 0 |
| PITOT COEFFICIENT | .854 | .854 | 0 |
| VELOCITY OF STACK GAS, FT/SEC | 22.0131 | 25.8893 | 0 |
| STACK AREA, SQR FT | 1.57625 | 1.57625 | 0 |
| STACK GAS FLOW RATE, ACTUAL CU FT/MIN, WET | 2081.89 | 2448.48 | 0 |
| TEMPERATURE OF STACK, DEG F | 2233.78 | 2381.67 | 0 |
| STACK GAS FLOW RATE, STD CU FT/MIN, DRY | 361.582 | 415.492 | 0 |
| DIAMETER OF NOZZLE, INCHES | .665 | .665 | 0 |
| PERCENT ISOKINETIC OF TEST, % | 107.619 | 95.3572 | 0 |
| WEIGHT PARTICULATE COLLECTED, MG | 213.4 | 482.3 | 0 |
| PARTICULATE CONCENTRATION, GRAINS/STD CU FT | .102207 | .226873 | 0 |
| PERCENT CO2 OF STACK GAS FOR 12% CORRECTION | 10.05 | 9.6 | 0 |
| PART. CONC AT 12% CO2, GR/STD CU FT | .122038 | .283591 | 0 |
| POLLUTANT MASS RATE (CONC. METHOD), LB/HR | .316751 | .807936 | 0 |
| POLLUTANT MASS RATE (AREA RAT. METHOD), LB/HR | .340902 | .770463 | 0 |
| POLLUTANT MASS RATE (AVERAGE OF ABOVE), LB/HR | .328826 | .7892 | 0 |
| PARTICULATE CONCENTRATION (CORRECTED) | .126684 | .277001 | 0 |

# PARTICULATE CONCENTRATION AND PMR CALCULATION TERMINOLOGY ‡

(Page 1)

VOLM, $VOL_m$ ($V_m$) = Dry gas meter volume @ meter temperature and pressure, dry-acf

PM, $P_m$ ($P_{bar} + \frac{\Delta H}{13.6}$) = Dry gas meter pressure (recorded as inlet deflection across orifice meter) - "Hg

PBAR ($P_{bar}$) = Barometric Pressure @ sampling site (inches of Hg)

TM, $T_m$ ($T_m$) = Dry gas meter temperature (average of inlet and outlet) - °F (Use °R = 460 + °F in equations)

PSTD, $P_{STD}$ ($P_{std}$) = Standard atmospheric pressure, absolute - (29.92 "Hg)

TSTD, $T_{STD}$ ($T_{std}$) = Standard temperature, absolute - °R

VOLSTD, $VOL_{STD}$ ($V_{m(std)}$) = Standardized gas that passes through the sampling train - cubic feet, 70°F, 1 atmosphere pressure, and dry

VOLW, $VOL_W$ ($V_{w(std)}$) Volume of water collected (expressed as vapor at standard temperature and pressure) - scf

VOLH2O ($V_{1c}$) = Volume of $H_2O$ collected (expressed in milliliters)

M, %M ($100\ B_{ws}$) = %water, calculated from amount the train collected in impinger, bubblers, and on silica gel

MF ($1-B_{ws}$) = Mole fraction of dry gas

WD, $W_D$ ($M_d$) = Molecular weight of dry stack gas - lb/lb mole

WW, $W_W$ ($M_s$) = Molecular weight of wet stack gas - lb/lb mole

$W_a$ (*) = Molecular weight of air (28.95 lb/lb mole)

CD, $C_D$ (*) = Velocity correction coefficient for gas density at STP

PSN, $P_{SN}$ ($P_s$) = Stack pressure (static + barometric), absolute - "Hg

CS, $C_S$ (*) = Velocity correction coefficient for stack pressure

VH, $VH_n$ ($\Delta P$) = Individual pitot tube pressure differential readings - inches water

n (*) = Number of velocity head readings

VO, $V_0$ ($V_s$) = Stack velocity @ stack conditions - fps

QO, $Q_0$ (*) = Stack flow rate at stack conditions - acfm

TS, $T_s$ ($T_{s(ave)}$) = Average stack temperature, absolute - °F (Use °R = 460 + °F in equations)

DELTA H ($\Delta H$) = Deflection on orifice flow meter when sample air flows through meter box (inches of water)

## PARTICULATE CONCENTRATION AND PMR CALCULATION TERMINOLOGY

(Page 2)

Y (Y) = Dry gas meter calibration factor

Qs, $Q_{os}$ ($Q_{SD}$) = Stack flow rate at standard conditions - scfm (dry)

T ($\theta$) = Time over which sample was collected - minutes

VN, $V_n$ ($V_{S(std)}$) = Velocity of gases inside nozzle during sampling, at STP -fps

I (I) = % Isokinetic (± 10% desirable)

CO, $C_o$ ($C_S$) = Particulate concentration - grains/scf

N (%$CO_2$) = %$CO_2$ by volume in stack (12 indicates no % $CO_2$ correction is to be made

TS, $T_s$ ($T_{si}$) = Temperature of stack gas at each sampling point - °F (Use °R = 460 + °F in equations)

C (*) = Particulate concentration corrected to 12% $CO_2$

PMRC, $PMR_c$ (*) = Pollutant mass rate - "concentration method" - lb/hr

PMRR, $PMR_r$ (*) = Pollutant mass rate - "area ratio method" - lb/hr

PMRAVG, $\overline{PMR}$ (*) = Average pollutant mass rate - lb/hr

CPRIME, C' (*) = Particulate concentration corrected for non-isokinetic sampling condition - grains/scf

PT, $P_T$ ($M_n$) = Total particulate collected by sampling train - mg

A1, A2, $A_s$ (A) = Area of stack - $FT^2$ A2 = 0 if round stack

$A_n$ ($A_n$) = Area of nozzle - $FT^2$

DN (*) = Diameter of nozzle in $IN^2$

CP, $C_p$ ($C_p$) = Velocity correction coefficient for type pitot tube used - dimensionless, normally 0.80 to 0.90 for "S" type pitot tube and 1.0 for "P" type pitot tube

KA, $K_a$ (*) = Average $\sqrt{VH \times T_s}$

‡Notation in parenthesis to the right of the ASA nomenclature is the equivalent EPA 40 CFR 60 Method 5 notation

* Notation used by ASA for calculations not required by 40 CFR 60 Method 5

## PARTICULATE CONCENTRATION AND PMR CALCULATION EQUATIONS

1. $VOL_{STD} = \frac{(Y)(VOL_m)(P_m)(T_{STD})}{(P_{STD})(T_m)}$

2. $\%M = \frac{(100)(VOL_w)}{VOL_{STD} + VOL_w}$

3. $MF = \frac{100 - M}{100}$

4. $W_w = (W_d)(MF) + 18\ (1-MF)$

5. $C_D = \sqrt{W_a/W_w}$

6. $C_S = \sqrt{P_{STD}/P_{SN}}$

7. $K_a = \sum \sqrt{(VH_n \times T_{S_n})}/n$

*8. $V_o = 2.9\ (K_a)(C_p)(C_D)(C_S)$

9. $Q_o = (V_o)(A_S)(60)$

10. $Q_{Os} = \frac{(Q_o)(T_{STD})(P_{SN})(M_F)}{(T_S)(P_{STD})}$

11. $V_n = \frac{(VOL_{STD})(P_{STD})(T_S)}{(M_F)(T_{STD})(P_{SN})(T)(A_N)(60)}$

12. $I = (100)\ V_n/V_o$

*13. $C_o = (0.0154)\ P_T/VOL_{STD}$

14. $C = \frac{(C_c)(12)}{N}$

*15. $PMR_c = (C_o)(Q_s)(0.008571$

*16. $PMR_r = \frac{(P_T)(A_s)}{(T)(A_n)}\ (0.000132)$

*17. $\overline{PMR} = (PMR_c + PMR_r)/2$

*18. $C' = (\overline{PMR})(1400)/Q_{os}N$

* UNITS FOR THE CONSTANTS USED ARE GIVEN BELOW:

8. $2.9\ \frac{(FT)}{(SEC)}(\text{INCHES OF } H_2O \times {}^oR)^{-\frac{1}{2}}$ based on Bernoulli's equation at STP and a molecular weight of dry gas of 28.95 and english units.

13. $.0154\ \text{grain/mg} = \frac{(mg)}{(ft^3)}\frac{(7000\ \text{grains})}{(1b)}\left(\frac{1b}{(453.6g)}\right)\left(\frac{g}{(1000mg)}\right)$

15. $.008571\ \frac{(\text{min-lbs})}{(\text{hr-grains})} = \frac{(\text{grains})}{(ft^3)}\frac{(ft^3)}{(\text{min})}\frac{(60\ \text{min})}{(\text{hr})}\left(\frac{\text{lbs}}{(7000\ \text{grains})}\right)$

16. $.000132\ \frac{(\text{lb-min})}{(\text{mg-hr})} = \frac{(mg)}{(\text{min})}\frac{(ft^2)}{(ft^2)}\left(\frac{g}{(1000mg)}\right)\left(\frac{1b}{(453.6g)}\right)\frac{(60\ \text{min})}{(\text{hr})}$

18. $1400\ \frac{(\text{hr-grains})}{(\text{min-lb})} = \frac{(1b)}{(\text{hr})}\frac{(\text{min})}{(ft^3)}\frac{(12)}{(n)}\left(\frac{\text{hr}}{(60\ \text{min})}\right)\frac{(7000\ \text{grains})}{(1b)}$

# PROCEDURE

## EPA METHOD 5 PARTICULATE SAMPLING TRAIN

### Sampling Train Preparation:

A tared and labeled glass fiber filter was placed in a glass filter holder. The filter (MSA1106BH) was desiccated and weighed to a constant weight to the nearest 0.5 mg. The condenser section consisted of four glass containers in series: one hundred milliliters of distilled-deionized water in a bubbler; one hundred milliliters in an impinger; a dry bubbler; and, a bubbler filled with approximately 500 grams of silica gel. All of the containers were weighed to the nearest 0.1 gram. The sampling train was assembled with connecting glassware so that sample gas would pass through the filter, the bubbler, impinger, the dry bubbler and the silica gel respectively.

A nozzle of a size that would allow for isokinetic sampling was selected and cleaned. A probe and liner of appropriate length to traverse the stack was chosen and the liner cleaned with acetone and a brush. The nozzle was connected with a cleaned union to the probe and liner. The probe was connected in front of the filter. A schematic of the sampling equipment is included in this report.

A leak test was performed on the assembled sampling train. The leak rate did not exceed 0.02 cfm at a vacuum of 10 inches Hg. The probe was heated and maintained at or above 250 degrees plus or minus 25 degrees F. The filter was heated and maintained at 250 degrees plus or minus 25 degrees F to avoid condensation of moisture on the filter. Crushed ice was placed around the condenser at the beginning of the test with new ice being added as required to keep the gases leaving the sampling train below 70 degrees F.

### Sample Collection:

Sampling ports were selected and installed. The number of sampling points was determined based on the number of stack diameters from any flow disturbance to the port(s). The location of each sampling point was based on equal areas within the stack.

The time at each point was dependent on the stack velocity and the desired volume to be sampled.

The probe was inserted into the stack to the first traverse point with the nozzle tip pointing directly into the gas stream. The pump was started and immediately adjusted to sample at isokinetic velocities. Equal time was spent at each time interval. The EPA designed nomograph or equivalent was used to maintain isokinetic sampling throughout the sampling period. At the conclusion of the run the pump was turned off, and a final leak test was performed at the maximum vacuum incurred during sampling. If the post-test leak rate was found to be over 0.02 cfm the actual leak rate was recorded.

## PMR CALCULATIONS

The weight of the dust per volume and weight of dust per time were calculated using two procedures:

### 1) The Concentration Method

The concentration of dust entering the sampling nozzle is calculated and then multiplied by the volumetric flow rate of the stack gases to obtain the pollutant mass rate on a concentration basis ($PMR_c$).

Concentration in Nozzle x Volumetric Flow Rate =
Pollutant Mass Rate On Concentration Basis

$$(P_T/VOL_{STD}) \times Q_s = PMR_c$$

Assuming the nozzle velocity is greater than the average stack gas velocity ($V_n$ greater than $V_o$), the calculated pollutant mass rate will be less than the true pollutant mass rate because the heavier dust particles will leave their velocity streamline and not enter the nozzle. If $V_n$ is less than $V_o$ then the calculated $PMR_c$ will be greater than the true PMR.

### 2) The Area Ratio Method

The weight of dust collected is divided by the sampling time and multiplied by the ratio of the stack area to the nozzle area to obtain the calculated pollutant mass rate based on the area ratio method ($PMR_r$).

$$\frac{\text{Weight Collected}}{\text{Sample Time}} \times \frac{\text{Area of Stack}}{\text{Area of Nozzle}} = \text{Pollutant Mass Rate on Area Ratio Basis}$$

$$(P_T/T) \times A_s/A_n = PMR_r$$

Assuming the nozzle velocity is greater than the average stack gas velocity ($V_n$ greater than $V_o$), the calculated pollutant mass rate will be greater than the true pollutant mass rate because the lighter particles in the dust laden stream follow their streamlines and enter the sampling nozzle resulting in $P_T/T$ being greater than true. If $V_n$ is less than $V_o$, the calculated $PMR_r$ will be less than the true PMR.

To obtain a more true pollutant mass rate, the two calculated pollutant mass rates are averaged. This allows some of the bias introduced because of non-isokinetic sampling calculated by one method to offset the bias of the other method. The degree of bias is related to particle size and density.

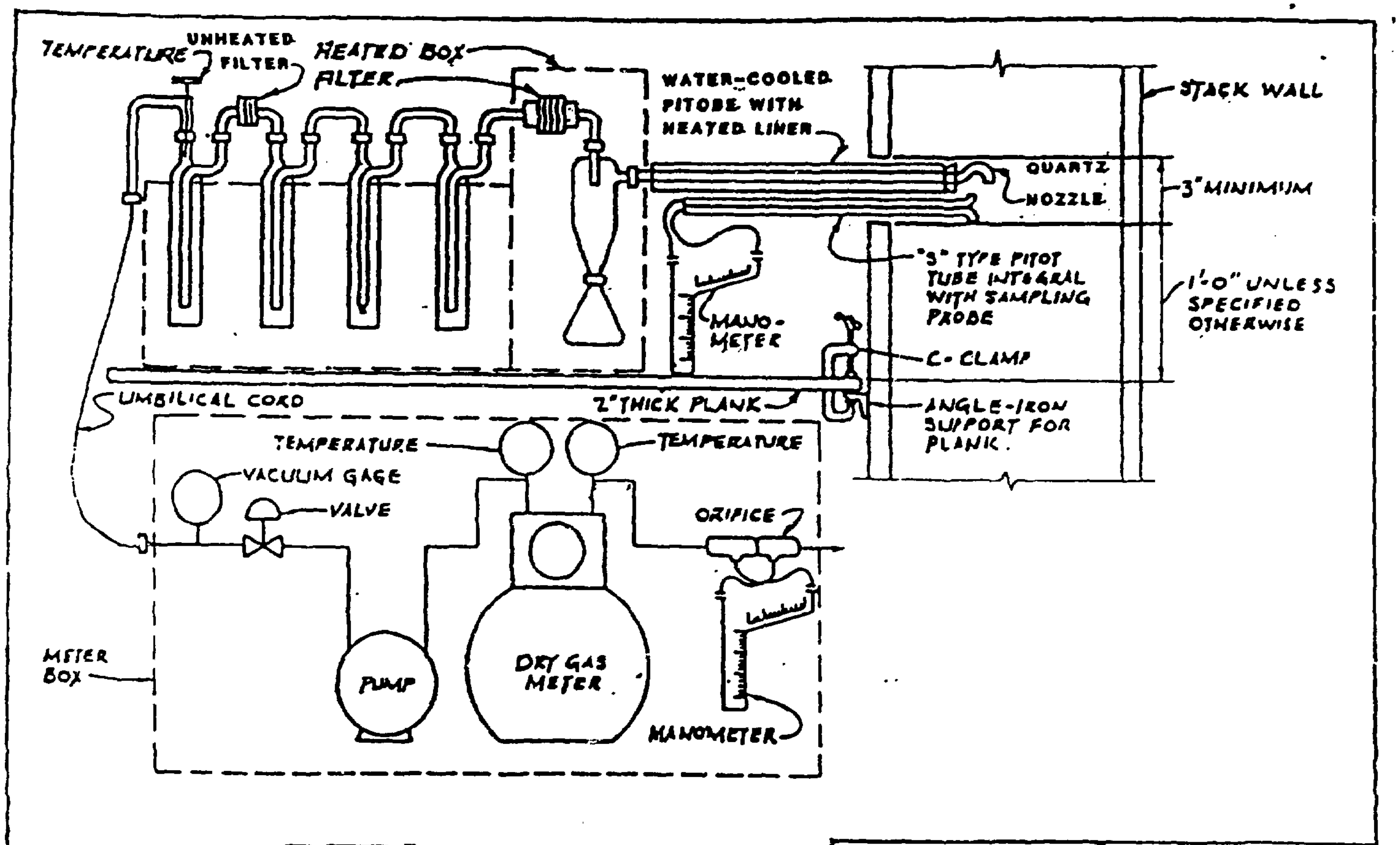

FIGURE A1.

EPA METHOD 5 PARTICULATE SAMPLING TRAIN MODIFIED FOR SAN DIEGO APCD

DRAWN RSC
CHECKED WS.
DATE 9/30/74

AMERICAN SERVICES ASSOCIATES
BELLEVUE, WA.

## CLEAN-UP & ANALYSIS

Clean-up of the modified EPA train was performed by carefully removing the heated filter placed ahead of the condenser and placing it in a petri dish marked "Run X, Container A-1" and carefully removing the filter placed behind the condenser and placing it in a petri dish marked "Run X, Container A-2".

Reagent grade acetone and pre-cleaned brushes were used to clean the nozzle, probe liner and pre-filter glass. At least six (6) washes or more were performed to achieve a clear wash for each individual wash of the nozzle, probe and pre-filter glass. The acetone wash was placed in a container marked "Run X, Container B-1". The same procedure was followed utilizing distilled water and was placed in a container marked "Run X, Container B-2".

The volume of water in the glass impinger and bubblers (i.e. condenser) was weighed in their respective containers to the nearest 0.1 gram. The silica gel was weighed in a bubbler before and after the run. The original weights in the impingers and bubblers were then subtracted from the final weights and the difference added to the water weight gain of the silica gel. The total weight gain of the condenser section constitutes the amount of water collected during the run. The water from the glassware and a water wash of the glassware and all post-filter glassware (not including the silica gel container) was performed and placed in a container marked "Run X, Container C". An acetone wash of the condenser was performed following the water rinse and placed in a container marked "Run X, Container D".

Analysis of the samples was performed according to the following:

Run X, Containers A-1 & A-2: The petri dishes containing the filters and any loose particulate was opened and placed, for at least 24 hours, in a desiccator containing anhydrous calcium chloride or its equivalent. The filter was then weighed to a constant weight (i.e. two (2) consecutive weighings at least four (4) hours apart which agree within 0.5 milligrams). Results were reported to the nearest 0.1 milligram.

Run X, Containers B-1 & B-2: The volumes were measured to the nearest 1 milliliter for the purposes of subtracting blank weights from the sample weights. The B-1 acetone wash was transferred from the field container into a tared beaker, evaporated at ambient temperature with charcoal filtered air, desiccated for at least 24 hours and weighed to a constant weight. The B-2 water wash was transferred to a tared beaker, evaporated at an elevated temperature, desiccated for at least 24 hours and weighed to a constant weight. The results were reported to the nearest 0.1 milligram.

Run X, Container C - The volume was measured to the nearest 1 milliliter. The organic particulate was extracted from the water solution with three 25 milliliter portions of Methylene Chloride. The Methylene Chloride extracts were transferred to a tared beaker. This solution was evaporated at ambient temperature until no solvent remained. This was accomplished by blowing air that had been charcoal filtered over the sample. The samples were then desiccated for at least 24 hours and weighed to a constant weight. The results were reported to the nearest 0.1 milligram. After the extraction, the remaining water was evaporated to dryness at 212 degrees F. The results were reported to the nearest 0.1 milligram.

Run X, Container D - The volume was measured to the nearest 1 milliliter. The acetone washings were transferred to a tared beaker and evaporated to dryness at ambient temperature and pressure. The samples were desiccated for at least 24 hours and weighed to a constant weight. The results were reported to the nearest 0.1 milligram.

Blanks were taken on the acetone, Methylene Chloride, and deionzed water and subtracted from the respective sample volume. The filter paper used with this modified EPA train was a Mine Safety Appliance 1106 BH, heat treated glass fiber filter mat.

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AMERICAN SERVICES ASSOCIATES                    ANALYSIS OF NOX EMISSIONS

CLIENT: NEW MEXICO ENGINEERING RESEARCH INSTITUTE/USAF E.P.A. METHOD 7

LOCATION: TEST BURN FOAM IN 75P INCINERATOR    DATE: 1/24/86

****************************************************

FILE:206 LAB#: 20-6 COMMENT: NMERI/USAF Fuel Tank Foam burn at TRC-1/86 - Run #1-1

PBINIT= 30.95 PBFINL= 30.2 PACIN=-29.6 PACFIN=-.2
VOLF= 2064.8 PINIT= 1.35 PFINAL= 30 TEMPIN= 58 TEMPFL= 68
ABS1 =  .0792  ABS2 =  .1648  ABS3 =  .2684  ABS4 =  .3552  % MOIST =  14.33
Kc =  727.979  ABSORB =  1.43  DILFAC =  1  O2 =  8.25 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 2602.53
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 8.32927E-05
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  698.964
CONCENTRATION OF NOX AS NO2 (WET) PPM =  598.802
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  9.15232E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)(DRY) PPM =  768.031

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FILE:216 LAB#: 21-6 COMMENT: NMERI/USAF Fuel Tank Foam burn at TRC-1/86 - RUN #1-2

PBINIT= 30.95 PBFINL= 30.2 PACIN=-29.2 PACFIN= 0
VOLF= 2075.2 PINIT= 1.75 PFINAL= 30.2 TEMPIN= 55 TEMPFL= 68
ABS1 =  .0792  ABS2 =  .1648  ABS3 =  .2684  ABS4 =  .3552  % MOIST =  14.33
Kc =  727.979  ABSORB =  .247  DILFAC =  1  O2 =  8.25 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 449.527
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 1.44238E-05
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  121.04
CONCENTRATION OF NOX AS NO2 (WET) PPM =  103.695
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  1.58491E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)(DRY) PPM =  133

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FILE:226 LAB#: 22-6 COMMENT: NMERI/USAF Fuel Tank Foam burn at TRC-1/86 - Run #1-3

PBINIT= 30.95 PBFINL= 30.2 PACIN=-29.6 PACFIN= 0
VOLF= 2091.7 PINIT= 1.35 PFINAL= 30.2 TEMPIN= 54 TEMPFL= 68
ABS1 =  .0792  ABS2 =  .1648  ABS3 =  .2684  ABS4 =  .3552  % MOIST =  14.33
Kc =  727.979  ABSORB =  1.2  DILFAC =  1  O2 =  8.25 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 2183.94
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 6.8533E-05
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  575.105
CONCENTRATION OF NOX AS NO2 (WET) PPM =  492.693
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  7.53051E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)(DRY) PPM =  631.934
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AMERICAN SERVICES ASSOCIATES                    ANALYSIS OF NOX EMISSIONS

CLIENT: NEW MEXICO ENGINEERING RESEARCH INSTITUTE/USAF     E.P.A. METHOD 7

LOCATION: TEST BURN FOAM IN 75P INCINERATOR     DATE: 1/24/86

********************************************************

FILE:236 LAB#: 23-6 COMMENT: NMERI/USAF Fuel Tank Foam burn at TRC-1/86 - Run #1-4

PBINIT= 30.95 PBFINL= 30.2 PACIN=-28.8 PACFIN= 0
VOLF= 2099.4 PINIT= 2.15 PFINAL= 30.2 TEMPIN= 54 TEMPFL= 68
ABS1 =  .0792  ABS2 =  .1648  ABS3 =  .2684  ABS4 =  .3552  % MOIST =  14.33
Kc =  727.979  ABSORB =  0  DILFAC =  1  O2 =  8.25 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 0
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 0
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  0
CONCENTRATION OF NOX AS NO2 (WET) PPM =  0
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  0
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)(DRY) PPM =  0
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AMERICAN SERVICES ASSOCIATES                    ANALYSIS OF NOX EMISSIONS

CLIENT: NEW MEXICO ENGINEERING RESEARCH INSTITUTE/USAF     E.P.A. METHOD 7

LOCATION: DEMONSTRATION BURN FOAM IN C75P INCINERATOR      DATE: 1/24/86

*****************************************************

FILE:246 LAB#: 24-6 COMMENT: NMERI/USAF Fuel Tank Foam burn at TRC-1/86 - Run #2-1

PBINIT= 30.95 PBFINL= 30.2 PACIN=-27.8 PACFIN= 0
VOLF= 2074.1 PINIT= 3.15 PFINAL= 30.2 TEMPIN= 48 TEMPFL= 68
ABS1 =  .0792  ABS2 =  .1648  ABS3 =  .2684  ABS4 =  .3552  % MOIST =  11.7
Kc =  727.979  ABSORB =  .0985  DILFAC =  1  O2 =  8.85 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 179.265
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 6.07141E-06
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  50.9491
CONCENTRATION OF NOX AS NO2 (WET) PPM =  44.9881
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  7.00353E-06
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)(DRY) PPM =  58.7712

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FILE:256 LAB#: 25-6 COMMENT: NMERI/USAF Fuel Tank Foam burn at TRC-1/86 - RUN #2-2

PBINIT= 30.95 PBFINL= 30.2 PACIN=-28.3 PACFIN= 0
VOLF= 2032 PINIT= 2.65 PFINAL= 30.2 TEMPIN= 51 TEMPFL= 68
ABS1 =  .0792  ABS2 =  .1648  ABS3 =  .2684  ABS4 =  .3552  % MOIST =  11.7
Kc =  727.979  ABSORB =  .5365  DILFAC =  1  O2 =  8.85 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 976.402
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 3.3104E-05
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  277.797
CONCENTRATION OF NOX AS NO2 (WET) PPM =  245.295
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  3.81864E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)(DRY) PPM =  320.447

*****************************************************

FILE:266 LAB#: 26-6 COMMENT: NMERI/USAF Fuel Tank Foam burn at TRC-1/86 - Run #2-3

PBINIT= 30.95 PBFINL= 30.2 PACIN=-27.7 PACFIN= 0
VOLF= 2035 PINIT= 3.25 PFINAL= 30.2 TEMPIN= 50 TEMPFL= 68
ABS1 =  .0792  ABS2 =  .1648  ABS3 =  .2684  ABS4 =  .3552  % MOIST =  11.7
Kc =  727.979  ABSORB =  .3495  DILFAC =  1  O2 =  8.85 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 636.072
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 2.2036E-05
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  184.918
CONCENTRATION OF NOX AS NO2 (WET) PPM =  163.283
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  2.54191E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)(DRY) PPM =  213.308
```

```
AMERICAN SERVICES ASSOCIATES                    ANALYSIS OF NOX EMISSIONS

CLIENT: NEW MEXICO ENGINEERING RESEARCH INSTITUTE/USAF     E.P.A. METHOD 7

LOCATION: TEST BURN FOAM IN 75P INCINERATOR     DATE: 1/24/86

***************************************************

FILE:276 LAB#: 27-6 COMMENT: NMERI/USAF Fuel Tank Foam burn at TRC-1/86 - Run #2-4

PBINIT= 30.95 PBFINL= 30.2 PACIN=-28.1 PACFIN= 0
VOLF= 2030.5 PINIT= 2.85 PFINAL= 30.2 TEMPIN= 50 TEMPFL= 68
ABS1 =  .0792  ABS2 =  .1648  ABS3 =  .2684  ABS4 =  .3552  % MOIST =  11.7
Kc =  727.979  ABSORB =  .556  DILFAC =  1  O2 =  8.85 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 1011.89
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 3.46005E-05
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  290.356
CONCENTRATION OF NOX AS NO2 (WET) PPM =  256.384
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  3.99127E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)(DRY) PPM =  334.933
```

NITROGEN OXIDES TERMINOLOGY

| | | |
|---|---|---|
| VOLF, | $V_f$ | = Volume of flask and flask valve |
| PINIT, | $P_i$ | = Initial absolute pressure of flask, inch Hg. |
| PBINIT, | $P_{bi}$ | = Initial barometric pressure, inches Hg. |
| PACIN, | $P_{ai}$ | = Actual pressure of flask, initial, inch Hg. |
| TEMPIN, | $T_i$ | = Initial absolute temperature of flask, R |
| PFINAL, | $P_f$ | = Final absolute pressure of flask, inches Hg. |
| PBFINL, | $P_{bf}$ | = Final barometric pressure, inches Hg. |
| PACFIN, | $P_{af}$ | = Actual pressure of flask, final, inches Hg. |
| TEMPFL, | $T_f$ | = Final absolute temperature of flask, R |
| TSTD, | $T_{std}$ | = Standard temperature, 528 R |
| PSTD, | $P_{std}$ | = Standard pressure, 29.92 inches Hg. |
| VOLSTD, | $V'_{sc}$ | = Sample volume at standard conditions (dry basis) ml |
| ABSORB, | A | = Absorbance of Sample |
| ABS1-4, | $A_n$ | = Individual absorbances of known standards |
| DILFAC, | F | = Dilution factor (required only if sample dilution was needed to reduce the absorbtion into rate of calibration.) |
| KC, | $K_c$ | = Calibration factor |
| M1, | m | = Mass of $NO_2$ in gas sample, microgram. |
| O2, | $O_2$ | = Oxygen in gas sample, %. |
| C1, | C | = Concentration of $NO_x$ as $NO_2$ (dry basis) lb/dscf<br>6.243 x $10^{-5}$ = Conversion factor to obtain lb/dscf from micrograms/ml |
| C2, | C' | = Concentration of $NO_x$ as $NO_2$ (dry basis) parts per million by volume<br>523.891 = Conversion factor to obtain ppm from micrograms/ml<br>$= \frac{(6.243 \times 10^{-5} \text{ lb/dscf})/(\text{microgram/ml})}{(2.59 \times 10^{-9} \text{ lb/dscf-ppm}) \quad (46.01)}$ |
| C3, | C3 | = Concentration of $NO_x$ as $NO_2$ (corrected for $O_2$) lb/dscf |
| C4, | C4 | = Concentration of $NO_x$ as $NO_2$ (corrected for $O_2$) (dry) ppm |
| MOIST, | MOIST | = Percentage moisture in stack gas |
| C5, | C5 | = Concentration of $NO_x$ as $NO_2$ (wet) ppm |

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## NITROGEN OXIDES
## EQUATIONS & CALCULATIONS SHEET

. $$Kc = 100 \text{ X } \frac{(A1 + 2A2 + 3A3 + 4A4)}{(A1*A1 + A2*A2 + A3*A3 + A4*A4)}$$

2. $$Vsc = \frac{Tstd}{Pstd} (Vf-Va)((Pf/Tf)-(Pi/Ti))$$

$$= 17.64 \; (Vf-25ml)((Pf/Tf)-(Pi/Ti))$$

3. $M1 = 2KcAF$

4. $C1 = 6{,}243 \text{ E-5 } (M1/Vsc)$

5. $C2 = 523.891 \; (M1/Vsc)$

6. $C3 = C1 \; ((20.9-O2 \text{ Std})/(20.9-O2))$

7. $C4 = C2 \; ((20.9-O2 \text{ Std})/(20.9-O2))$

8. $C5 = C2 \; (1.00-(Moist/100))$

# PROCEDURE

## (OXIDES OF NITROGEN)

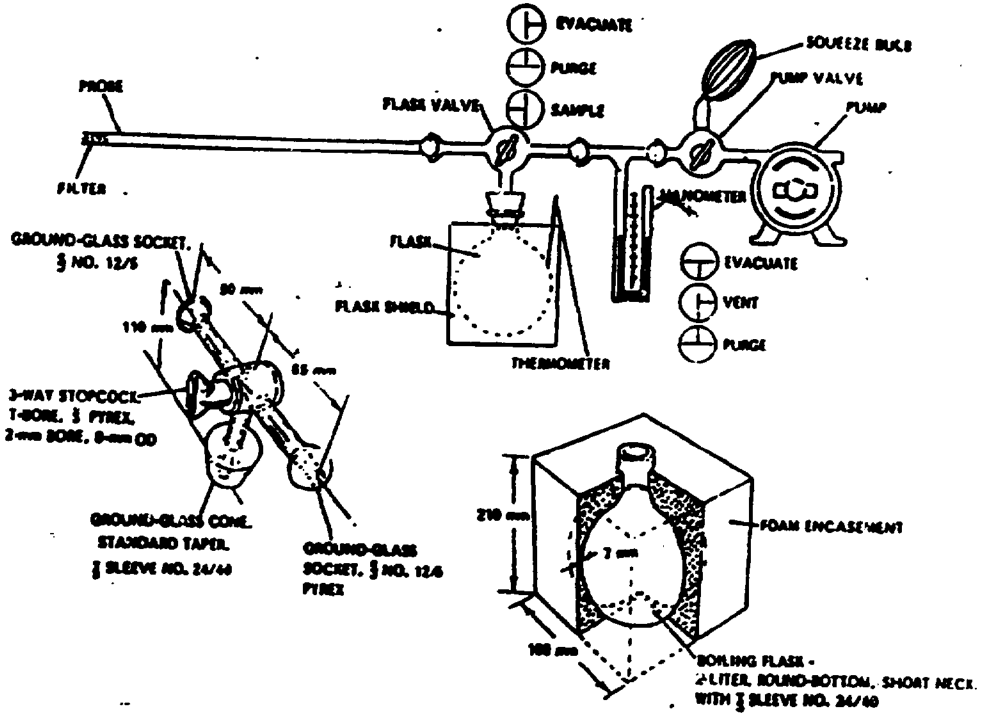
Stack gas sampling equipment designed by the United States Environmental Protection Agency (EPA), Office of Air Programs was used on this evaluation. A schematic of the sampling train is included in this report.

The sampling train was prepared and operated as follows:

25ml of absorbing solution (2.8ml $H_2SO_4$ and 6ml 3% $H_2O_2$ to 1l $H_2O$) was pipetted into a sample flask. The flask was evacuated to 3 inches of mercury absolute pressure or less. The pump valve was closed and the manometer checked for fluctuations in mercury level. With no fluctuation noted over a one minute time span the flask volume and temperature were recorded along with the barometric pressures. With the flask and pump valves in the purge position the probe and vacuum tube were purged using the squeeze bulb. If condensation occured in the probe and flask valve area, the probe was heated until the condensation disappeared. The flask pressure was then measured. With the pump valve closed the flask valve was opened to allow the sample to enter the flask until the pressure in the flask and sample line were equal. If sufficient oxygen was not present in the stack gas to convert NO to $NO_2$ additional oxygen was added. The valves were then closed and the flask was shaken for 5 minutes and then allowed to set for at least 16 hours. After the 16 hour period elapsed, the flask was shaken for 2 minutes and the flask pressure, flask temperature, and the barometer pressure were recorded.

## EPA METHOD 7 (NOX)

## SAMPLING TRAIN



## SAMPLE CLEAN-UP AND ANALYSIS (OXIDES OF NITROGEN)

After rinsing the flask with two 5 ml portions of distilled water and adding the rinse to the sample, the pH was adjusted to between 9 and 12 using 1 N sodium hydroxide. The sample was then transferred to a polyethylene storage container for shipment. A blank containing 25 ml of absorbing solution was taken and treated in the same manner.

The samples were diluted to a known volume (50 ml). An aliquot (25 ml) was taken and evaporated on a steam bath in a porcelain evaporating dish to dryness and then cooled.

Phenoldisulfonic acid solution (2 ml) was added to the dried residue and thoroughly triturated with a polyethylene policeman. One milliliter of distilled water and 4 drops of concentrated sulfuric acid were added. The samples were then heated for three minutes with occasional stirring on a steam bath. After cooling, 30 milliliters of distilled water was mixed into the sample and the pH adjusted to 10 with concentrated ammonium hydroxide. If the sample contained solids they were filtered out with a Whatman No. 41 filter paper. The samples were then quantitatively tranferred and diluted to 100 mls. in a volumetric flask.

The absorbance of each sample was measured at the optimum wave length (approximately 410 nm) using the blank as a zero. The total quantity of NOx (as NO2) for each sample was determined from a graph plotted from using suitable standards. The standard line was positioned by statistical calculations.

```
AMERICAN SERVICES ASSOCIATES            E.P.A. METHOD 5 - PARTICULATES

JOB NAME:  UNIVERSITY OF NEW MEXICO ENGINEERING RESEARCH INSTITUTE / USAF

PREPARED BY:  W. D. SNOWDEN             DATE:  1/24/86

SUBJECT:  FUEL TANK FOAM C-75P PILOT INCINERATION PROJECT - RUN #1

******************************************************

VOLM = 31.034   PBAR = 30.95   DELTA H = .996   TM = 70.3   LAB # =18-6

PM = 31.0232  VOL(STD) = 32.1541  VOLH2O = 114.3  Y= 1.0036

CO2 =  10.05 CO2 + O2 = 18.3 CO2 + O2 + CO = 18.3 O2 = 8.25 CO = 0

VOLW = 5.3801   WD = 29.938   PS =-.03   PSN = 30.9478   CP = .854

M = 14.3339  MF = .856661  WW = 28.2268  CD = 1.01273  CS = .983255

A1 = 17  A2 = 0  AS = 1.57625  T = 54  DN = .665  PT = 213.4  N = 10.05

OBS     VH     TS       KA               OBS     VH     TS       KA

1       .02    2034   7.06258             2      .02    1238   5.82752
3       .023   1262   6.29333             4      .026   2472   8.7311
5       .025   2472   8.56154             6      .027   2472   8.89742
7       .032   2472   9.68628             8      .03    2260   9.03327
9       .032   2472   9.68628            10      .036   2274   9.92089
11      .036   2472   10.2739            12      .036   2472   10.2739
13      .033   2472   9.83646            14      .032   2373   9.52135
15      .032   2106   9.06157            16      .033   2146   9.27351
17      .03    2318   9.12908            18      .032   2421   9.60167
****************************************************

START TIME = 1433   STOP TIME = 1528   FILE = 186

KA = 8.9262  TS = 2233.78  V0 = 22.0131  Q0 = 2081.89  QS = 361.582

VN = 23.6904   I = 107.619   C0 = .102207   C = .122038

PMRC = .316751  PMRR = .340902  PMRAVG = .328826  C' = .126684
```

AMERICAN SERVICES ASSOCIATES PARTICULATE CALCULATION

CLIENT: UNIVERSITY OF NEW MEXICO ENGINEERING RESEARCH INSTITUTE / USAF

LOCATION: THERMAL REDUCTION COMPANY C-75 FOAM TEST BURN

SAMPLE DATE: 1/24/86 ANALYSIS DATE: 1/27-31/86

RUN # 1 LAB # 18-6

*****************************************************

I. EVAPORATION OF 182 ml OF ACETONE RINSE AND (B)
BRUSHING OF NOZZLE, PROBE AND GLASSWARE BEFORE FILTER.

FINAL 80321 mg - TARE 80246.4 mg
- BLANK (( 8E-03 mg/ml) ( 182 ml) = 1.456 mg) = 73.144 mg

II. FILTER CATCH - FILTER MSA1106BH - NUMBER 15-6 (A)

FINAL 502.3 mg - TARE 362.1 mg = 140.2 mg

VI. BACKUP FILTER CATCH - MEDIA TYPE MSA1106BH - NUMBER 19-6

FINAL 365.3 mg - TARE 365.2 mg = .1 mg

VII. TOTAL PARTICULATE = SUM OF ABOVE = 213.444 mg

BLANKS

ACETONE (FINAL 81738.5 mg - TARE 81737.7 mg = .8 mg)
/ 100 ml = 8E-03 mg/ml

```
AMERICAN SERVICES ASSOCIATES            E.P.A. METHOD 5 - PARTICULATES

JOB NAME:  UNIVERSITY OF NEW MEXICO ENGINEERING RESEARCH INSTITUTE / USAF

PREPARED BY:  W. D. SNOWDEN             DATE:  1/24/86

SUBJECT:  FUEL TANK FOAM C-75P PILOT INCINERATION PROJECT - RUN #2

*******************************************************

VOLM = 31.814   PBAR = 30.95   DELTA H = 1.053   TM = 74   LAB # =13-6

PM = 31.0274  VOL(STD) = 32.7383  VOLH2O = 92.2  Y= 1.0036

CO2 =  9.6 CO2 + O2 = 18.45 CO2 + O2 + CO = 18.45 O2 = 8.85 CO = 0

VOLW = 4.33985   WD = 29.89   PS =-.03   PSN = 30.9478   CP = .854

M = 11.7046  MF = .882954  WW = 28.4983  CD = 1.00789  CS = .983255

A1 = 17  A2 = 0  AS = 1.57625  T = 54  DN = .665  PT = 482.3  N = 9.6

OBS     VH     TS       KA                 OBS     VH     TS        KA

1       .03    2472    9.3787               2      .04    2472    10.8296
3       .04    2472    10.8296              4      .038   2472    10.5554
5       .038   2472    10.5554              6      .03    2472    9.3787
7       .04    2472    10.8296              8      .036   2472    10.2739
9       .04    2293    10.4938              10     .04    2472    10.8296
11      .04    2472    10.8296              12     .042   2383    10.9273
13      .046   2425    11.52                14     .044   2137    10.6896
15      .04    2317    10.5395              16     .042   1997    10.1584
17      .042   2126    10.4217              18     .04    2472    10.8296

*****************************************************

START TIME = 1717   STOP TIME = 1814   FILE = 196

KA = 10.5483  TS = 2381.67  V0 = 25.8893  Q0 = 2448.48  QS = 415.492

VN = 24.6873   I = 95.3572   CO = .226873   C = .283591

PMRC = .807936  PMRR = .770463  PMRAVG = .7892  C' = .277001
```

AMERICAN SERVICES ASSOCIATES PARTICULATE CALCULATION

CLIENT: UNIVERSITY OF NEW MEXICO ENGINEERING RESEARCH INSTITUTE / USAF

LOCATION: THERMAL REDUCTION COMPANY C-75 FOAM TEST BURN

SAMPLE DATE: 1/24/86 ANALYSIS DATE: 1/27-31/86

RUN # 2 LAB # 19-6

*****************************************************

I. EVAPORATION OF 200 ml OF ACETONE RINSE AND (B)
BRUSHING OF NOZZLE, PROBE AND GLASSWARE BEFORE FILTER.

FINAL 76336.5 mg - TARE 76170.4 mg
- BLANK (( 8E-03 mg/ml) ( 200 ml) = 1.6 mg) = 164.5 mg

II. FILTER CATCH - FILTER MSA1106BH - NUMBER 13-6 (A)

FINAL 678.1 mg - TARE 360.9 mg = 317.2 mg

VI. BACKUP FILTER CATCH - MEDIA TYPE MSA1106BH - NUMBER 1-6

FINAL 160 mg - TARE 159.4 mg = .6 mg

VII. TOTAL PARTICULATE = SUM OF ABOVE = 482.3 mg

BLANKS

ACETONE (FINAL 81738.5 mg - TARE 81737.7 mg = .8 mg)
/ 100 ml = 8E-03 mg/ml

# ATMOSPHERIC
# EMISSION
# EVALUATION

USAF/NMERI FUEL TANK FOAM
DEMONSTRATION INCINERATOR PROJECT
THERMAL REDUCTION COMPANY
MARCH 1986

**AMERICAN SERVICES ASSOCIATES**
15049 Bel-Red Road, Bellevue, WA 98007 (206)641-6130

American Services Associates
Consultants in Air, Water, Energy, Hygiene & Management

March 31, 1986

## PURPOSE

This atmospheric emission evaluation was performed for the NEW MEXICO ENGINEERING RESEARCH INSTITUTE (NMERI) on a CONSUMAT, Model C760, municipal solid waste (MSW) incinerator to perform a demostration burn on foam used in the fuel tanks of UNITED STATES AIR FORCE (USAF) planes. The foam is utilized as a static electricity eliminator and sloshing inhibitor. The incinerator was operated by and located at the THERMAL REDUCTION COMPANY (TRC) plant in Bellingham, Washington. The tests were performed in accordance with the procedures and sampling equipment described herein and the UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA). Ms. Julie O'Shaughnessy of the NORTHWEST AIR POLLUTION AUTHORITY (NWAPA) observed this evaluation project. Mr. Mike Lee of NMERI was the Client Project Manager and represented the USAF on this evaluation project. Messers. Wesley D. Snowden and Thomas W. Valentine of AMERICAN SERVICES ASSOCIATES (ASA) performed this evaluation on March 3, 1986.

## SUMMARY

Particulate emissions were found to be 0.098 grains per dry standard cubic foot (gr/dscf) corrected to 12% carbon dioxide (CO2) less the auxiliary fuel CO2 contribution, 1.64 pounds per hour (lb/hr) and 0.19 lb/100 lb charged (i.e. foam plus cardboard) for the for the last two (2) of three (3) samples collected. Nitrogen oxides emissions were found to be 0.39 lb/MBTU heat input (i.e. assuming 10,000 BTU/lb for foam and 7900 BTU/lb for cardboard) and 3.04 lb/hr. Cyanide emissions were found to be 1 ppmv and 0.02 lb/hr.

AMERICAN SERVICES ASSOCIATES

Wesley D. Snowden, P.E.

15049 Bel-Red Road, Suite 500 Bellevue, Washington 98007 (206) 641-5130

## DISCUSSION

This test was performed on a full-scale operational municipal solid waste (MSW) incinerator burning waste foam (i.e. foam installed inside the jet fuel tanks which is used to minimize static electricity and sloshing of the fuel) which is generated by the UNITED STATES AIR FORCE (USAF). During the first sample collected on 3/3/86, the CONSUMAT, Model C760 municipal solid waste (MSW) incinerator was adjusted with relatively less primary chamber air, relatively less auxiliary fuel in the afterburner and relatively more air in the afterburner to minimize the rapid burning rate of the foam upon first placement in the incinerator.

These atmospheric emission tests were performed to evaluate the feasibility of combusting the UNITED STATES AIR FORCE (USAF) waste fuel tank foam in a commercially available incinerator while meeting the air pollution emission standards. The tests performed on this project were performed in accordance with current UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA) sampling procedures and equipment. The results of the emission tests performed on this project are shown in Table A2.

Table A2. NMERI/USAF Foam Incinerator Emission Test @ TRC 3/86

| Run No./ | Emission Parameter | |
|---|---|---|
| Sample ID. | Concentration | Mass Rate (lb/hr) |
| 1 / M5 | 0.159 gr/dscf | 2.54 lb/hr |
| 1 / NOX | 70 ppm | 1.99 lb/hr |
| 1 / CYANIDE | 1 ppm | 0.02 lb/hr |
| 2 / M5 | 0.089 gr/dscf | 1.65 lb/hr |
| 2 / NOX | 131 ppm | 4.06 lb/hr |
| 2 / CYANIDE | 1 ppm | 0.02 lb/hr |
| 3 / M5 | 0.108 gr/dscf | 1.64 lb/hr |
| 3 / NOX | 112 ppm | 3.06 lb/hr |
| 3 / CYANIDE | 1 ppm | 0.01 lb/hr |
| Avg/M5(#2&#3) | 0.098 gr/dscf | 1.64 lb/hr |
| Avg/NOX(#1,2&3) | 104 ppm | 3.04 lb/hr |
| Avg CYANIDE | 1 ppm | 0.02 lb/hr |

* Average emissions can be used to project daily emissions assuming the NMERI/USAF incinerator operates 8 hours/day. The particulate emissions are 13.1 pounds per day, nitrogen oxides emissions are 24.3 pounds per day and cyanide emissions are 0.2 pounds per day.

These tests were performed at the maximum burning rate of the foam at which the CONSUMAT C760 MSW incinerator could burn the foam without creating unacceptable smoke emissions just after charging of the incinerator. The burning rate resolved from trial burns on the previous Friday (i.e. 2/28/86) burns of the incinerator resolved that one box of waste USAF foam (i.e. 50 pounds of foam plus 90 pounds of cardboard storage container) could be burned at 7.5 minute intervals. Adjustments during Run #1 in the air and auxiliary fuel which are described above make Run #1 unrepresentative. Run #'s 2 & 3 were therefore used for determination of the average particulate emissions. The burning rate resolved for the three (3) samples collected on this project was held constant and included;

- 400 pound of waste USAF foam per hour
- 480 pounds per hour of cardboard

880 pounds of foam plus container per hour

ASA performed three (3) emission tests for each of the parameters evaluated on this project. The operating conditions of the incinerator were monitored by NMERI and audited by the ASA Project Manager. One (1) eight-hour day of demonstration incinerator operation at the selected burning rate was utilized to perform this emission testing project.

The operating parameters monitored by NMERI and audited by ASA are shown on the Incinerator Operating Log included in the Appendix of this report. The time of charges, average weight per charge, temperature of the primary and secondary chambers were monitored during the exhaust gas sampling. The average auxiliary fuel consumption for each incinerator at the TRC plant over the immediate past month was utilized to determine the average natural gas consumed during operation of the incinerator during the demonstration burn. The average natural gas or auxiliary fuel conmsumption for the average incinerator was utilized because a gas meter was not installed on the incinerator (i.e. the entire plant had one gas meter and seven (7) incinerators were normally operating at any one time) utilized for this demonstration burn.

Carbon dioxide, oxygen and carbon monoxide were measured with an Orsat analyzer (nitrogen assumed as remaining) and used to calculate the molecular weight of the exhaust gases. The gas samples were collected during the Method 5 tests and from an outlet "T" on the orifice meter of the Method 5 sampling train. The gas tests were performed according to EPA Method 3 procedures, including full stack traverses. An integrated bag of the exhaust gas which ASA collects from the outlet of the EPA Method 5 sampling train was collected during each sample and analyzed on-site. Nitrogen oxides were sampled because nitrogen is one of the components in the waste foam. A description of the foam is shown in Table A3.

Table A3. USAF/NMERI Jet Fuel Tank Foam Description

| Descriptor | Descriptor Value & Units of Value |
|---|---|
| Density | 1.3 lb/cubic foot |
| Heating Value | 13,000 BTU/cubic foot |
| Moisture | 1.1 % by weight - wet basis |
| Volatile Content | 98.2 % by weight - dry basis |
| Ash Content | 0.1 % by weight - dry basis |
| Fixed Carbon | 1.7 % by weight - dry basis |
| Carbon | 64.4 % by weight - dry basis |
| Hydrogen | 8.1 % by weight - dry basis |
| Nitrogen | 8.0 % by weight - dry basis |
| Sulfur | 0 % by weight - dry basis |

Cyanide emissions were sampled on this emission testing project because a significant amount of nitrogen was present in the fuel. It was hypothesized that the nitrogen could become fixed with carbon in the process of combusting the foam thereby producing cyanide. The stack emissions of cyanide were found to be 1 ppm on a volume basis (ppmv). The threshold limit value (TLV) for workers exposed to cyanide for eight hour periods is 4.5 ppmv and the expected concentration that persons could be exposed to for 24-hour periods is approximately 1 ppmv. Therefore, the cyanide emissions from the exhaust stack of the incinerator when burning the foam is within the 1 ppmv expected allowable concentration that a person could breath for 24-hour periods. Persons will not be exposed to the incinerator stack emissions directly (the maximum exposure to persons at ground level is expected to be less than 1/1000 of the stack concentration). Cyanide emissions are considered insignificant from this incineration process.

The GEORGIA ENVIRONMENTAL PROTECTION DIVISION (GEPD) projected atmospheric emissions are listed in Table A4. The emission standards are dependent upon burning rate and location of the permanent incinerator. Emissions reported can be compared to the lowest projected GEPD emission standard.

**Table A4. USAF Fuel Foam Incinerator Emission Standards @ GEPD**

| Pollutant | GEPD Projected Emission Standard |
|---|---|
| Particulate | 1.0 lb/hr if burning less than 500 lb/hr |
| " | 0.2 lb/100 lb charged if more than 500 lb/hr |
| Nitrogen Oxides | 0.5 lb/million BTU heat(i.e. waste) input or |
| " " | Calculated based upon dispersion modeling |
| " " | (Ref. Mr. John Yntema @ GEPD (404)656-4867) |

The foam waste as described in Table A3. is basically the equivalent of diesel oil on a heat content per pound basis but the foam is markedly different on the basis of density. The challenge on this demonstration project was to determine the charging procedure for the foam waste that will allow a high heat content and low density waste to be burned completely. Commercial incinerators are not set-up to burn high BTU and low density waste. A incinerator with 1) a large and frequently-operated automatic charging system, 2) a relatively small and air-tight primary chamber and 3) an oversized afterburner were attempted to be set-up on this foam burning demonstration project to most completely burn the foam.

The incinerator utilized for this project was operated by TRC. The incinerator was a CONSUMAT, Model C760 incinerator which is classified as a Controlled-Air Incinerator with an afterburner to complete combustion of the vaporized gases from the primary chamber. The burning rate resulting was 400 pounds of fuel tank foam per hour. No emission control was provided on the emissions reported herein.

An ignition test on the Run #2 particulate collected on the filter was performed to determine if the material collected on the front-half of the EPA Method 5 sampling train was combustible. The front-half sample lost 1%, 3% and 2% of its beginning weight upon temperature increases to 300, 500 and 900 degrees Fahrenheit for Run 2. The ignition test indicates that little of the particulate collected was combustible and therefore that the emissions coming from the demonstration incinerator were relatively completely combusted.

The hydrocarbon and lead emissions from this emission test are shown in Table A5. The hydrocarbon includes the hydrocarbon condensed in the condenser section of the EPA Method 5 particulate sampling train and the gaseous hydrocarbon collected from the outlet of the sampling train. Silica gel was not utilized in the condenser of the EPA Method 5 sampling train to allow more accurate gaseous hydrocarbon collection. Table A5 illustrates that the gaseous hydrocarbon fraction constituted 97% of the hydrocarbon found on this project. The hydrocarbon is reported as "acetone" which was identified as the major hydrocarbon found in the samples.

The lead was analyzed from the particulate collected in the "front-half" of the EPA Method 5 particulate sampling train. The absence of lead in the samples may be due to burning predominently non-fuel exposed foam during this foam burning demonstration.

Table A5. NMERI/USAF Foam Hydrocarbon & Lead Emissions 3/3/86

| Run # / Emission Parameter | Conc. (gr/dscf) | PMR (lb/hr) |
|---|---|---|
| 1 / Hydrocarbon - M5 | 0.000 | 0.01 |
| 1 / Hydrocarbon - Gas | 0.016 | 0.55 |
| 1 / Lead | BDL * | BDL * |
| 2 / Hydrocarbon - M5 | 0.000 | 0.02 |
| 2 / Hydrocarbon - Gas | 0.006 | 0.23 |
| 2 / Lead | BDL | BDL |
| 3 / Hydrocarbon - M5 | 0.001 | 0.02 |
| 3 / Hydrocarbon - Gas | 0.023 | 0.77 |
| 3 / Lead | BDL | BDL |
| Avg Hydrocarbon - M5 | 0.000 | 0.02 |
| Avg Hydrocarbon - Gas | 0.015 | 0.52 |
| Total Hydrocarbon | 0.015 | 0.54 |
| Avg Lead | BDL | BDL |

* BDL refers to the analyses not detecting the element desired or the results were below the detectable limit of the analysis procedure.

This report is arranged hereafter in a manner in which the data can be most readily used as follows:

- "EPA Method 5 Summary" (a summary of test results).
- "Terminology & Equations" used in calculating the results
- "Procedure" illustrating how samples are typically collected
- "PMR Calculation" illustrates how calculations are performed for non-isokinetics.
- "EPA Method 5 Particulate Sampling Train" schematic illustrates parts
- "Clean-up and Analysis" procedures utilized on this project
- NOX (EPA Method 7) "Analysis of NOX Emissions" Computer Printouts
- NOX Terminology & Equations
- NOX "Procedure for Sampling
- "EPA Method 7 Sampling Train" Schematic
- EPA Method 7 (NOX) "Sample Clean-up & Analysis Procedure
- "Cyanide Emission Calculations" per NIOSH P&CAM 116
- ATTACHMENT 1

- ATTACHMENT 1 CONTENTS
- "EPA Method 5-Particulates" calculation sheet utilizes field traverse data sheet for input to the computer with one output sheet per Run
- "Particulate Calculation" utilizes laboratory data and calculates total particulate with one sheet per Run and sequentially placed with the above
- "Incinerator Operating Log" contains charging loads & charging rates
- "Traverse Sampling Data Sheet" contains data collected from the field
- "Calibration Records" of the equipment utilized on this project. Spot calibrations are performed before and after the field work. If within 2%, no changes are made in the calibration records.

AMERICAN SERVICES ASSOCIATES E.P.A. METHOD 5 SUMMARY

CLIENT: NEW MEXICO ENGINEERING RESEARCH INSTITUTE / USAF

SAMPLING LOCATION: FUEL TANK FOAM DEMO BURN IN C760 INCINERATOR AT TRC

| | RUN # 1<br>3/3/86 | RUN # 2<br>3/3/86 | RUN # 3<br>3/3/86 |
|---|---|---|---|
| LAB NUMBER | 66-6 | 67-6 | 68-6 |
| 24 HOUR START TIME | 1109 | 1440 | 1620 |
| 24 HOUR STOP TIME | 1224 | 1528 | 1708 |
| ELAPSED SAMPLING TIME, MIN | 72 | 48 | 48 |
| VOLUME SAMPLED, CU FT | 40.785 | 30.904 | 26.655 |
| VOLUME SAMPLED STANDARD, CU FT | 41.6795 | 31.6593 | 27.2696 |
| MOISTURE CONTENT OF STACK GAS, % | 13.4834 | 13.6807 | 17.3363 |
| MOLEC. WT OF STACK GAS, LB/LB MOLE | 27.8712 | 27.8881 | 27.4435 |
| STACK PRESSURE, IN HG | 30.9563 | 30.9563 | 30.9963 |
| PITOT COEFFICIENT | .825 | .825 | .854 |
| VELOCITY OF STACK GAS, FT/SEC | 22.4948 | 26.2571 | 23.8967 |
| STACK AREA, SQR FT | 10.0847 | 10.0847 | 10.0847 |
| STACK GAS FLOW RATE, ACTUAL CU FT/MIN, WET | 13611.2 | 15887.7 | 14459.[illegible] |
| TEMPERATURE OF STACK, DEG F | 1161.58 | 1257.21 | 1246.1[illegible] |
| STACK GAS FLOW RATE, STD CU FT/MIN, DRY | 3967.15 | 4362.83 | 3832.04 |
| DIAMETER OF NOZZLE, INCHES | .515 | .515 | .515 |
| PERCENT ISOKINETIC OF TEST, % | 101.726 | 105.393 | 103.355 |
| WEIGHT PARTICULATE COLLECTED, MG | 200.4 | 88.2 | 86.9 |
| PARTICULATE CONCENTRATION, GRAINS/STD CU FT | .0740451 | .0429031 | .0490715 |
| PERCENT CO2 OF STACK GAS FOR 12% CORRECTION | 5.62 | 5.93 | 5.55 |
| PART. CONC AT 12% CO2, GR/STD CU FT | .158103 | .0868191 | .106109 |
| POLLUTANT MASS RATE (CONC. METHOD), LB/HR | 2.51771 | 1.60431 | 1.61185 |
| POLLUTANT MASS RATE (AREA RAT. METHOD), LB/HR | 2.56131 | 1.69092 | 1.666 |
| POLLUTANT MASS RATE (AVERAGE OF ABOVE), LB/HR | 2.53951 | 1.64762 | 1.63892 |
| PARTICULATE CONCENTRATION (CORRECTED) | .159464 | .0891582 | .107886 |

## PARTICULATE CONCENTRATION AND PMR CALCULATION TERMINOLOGY‡

(Page 1)

VOLM, $VOL_m$ ($V_m$) = Dry gas meter volume @ meter temperature and pressure, dry-acf

PM, $P_m$ ($P_{bar} + \frac{\Delta H}{13.6}$) = Dry gas meter pressure (recorded as inlet deflection across orifice meter) - "Hg

PBAR ($P_{bar}$) = Barometric Pressure @ sampling site (inches of Hg)

TM, $T_m$ ($T_m$) = Dry gas meter temperature (average of inlet and outlet) - $^{o}F$ (Use $^{o}R = 460 + {}^{o}F$ in equations)

PSTD, $P_{STD}$ ($P_{std}$) = Standard atmospheric pressure, absolute - (29.92 "Hg)

TSTD, $T_{STD}$ ($T_{std}$) = Standard temperature, absolute - $^{o}R$

VOLSTD, $VOL_{STD}$ ($V_{m(std)}$) = Standardized gas that passes through the sampling train - cubic feet, $70^{o}F$, 1 atmosphere pressure, and dry

VOLW, $VOL_w$ ($V_{w(std)}$) Volume of water collected (expressed as vapor at standard temperature and pressure) - scf

VOLH20 ($V_{1c}$) = Volume of $H_2O$ collected (expressed in milliliters)

M, %M (100 $B_{ws}$) = %water, calculated from amount the train collected in impinger, bubblers, and on silica gel

MF ($1-B_{ws}$) = Mole fraction of dry gas

WD, $W_o$ ($M_d$) = Molecular weight of dry stack gas - lb/lb mole

WW, $W_w$ ($M_s$) = Molecular weight of wet stack gas - lb/lb mole

$W_a$ (*) = Molecular weight of air (28.95 lb/lb mole)

CD, $C_D$ (*) = Velocity correction coefficient for gas density at STP

PSN, $P_{SN}$ ($P_s$) = Stack pressure (static + barometric), absolute - "Hg

CS, $C_S$ (*) = Velocity correction coefficient for stack pressure

VH, $VH_n$ ($\Delta P$) = Individual pitot tube pressure differential readings - inches water

n (*) = Number of velocity head readings

VO, $V_o$ ($V_s$) = Stack velocity @ stack conditions - fps

QO, $Q_o$ (*) = Stack flow rate at stack conditions - acfm

TS, $T_s$ ($T_{s(ave)}$) = Average stack temperature, absolute - $^{o}F$ (Use $^{o}R = 460 + {}^{o}F$ in equations)

DELTA H ($\Delta H$) = Deflection on orifice flow meter when sample air flows through meter box (inches of water)

## PARTICULATE CONCENTRATION AND PMR CALCULATION TERMINOLOGY

(Page 2)

Y (Y) = Dry gas meter calibration factor

Qs, $Q_{os}$ ($Q_{SD}$) = Stack flow rate at standard conditions - scfm (dry)

T ($\Theta$) = Time over which sample was collected - minutes

VN, $V_n$ ($V_{S(std)}$) = Velocity of gases inside nozzle during sampling, at STP -fps

I (I) = % Isokinetic (± 10% desirable)

CO, $C_o$ ($C_S$) = Particulate concentration - grains/scf

N (%$CO_2$) = %$CO_2$ by volume in stack (12 indicates no % $CO_2$ correction is to be made

TS, $T_s$ ($T_{si}$) = Temperature of stack gas at each sampling point - °F (Use °R = 460 + °F in equations)

C (*) = Particulate concentration corrected to 12% $CO_2$

PMRC, $PMR_c$ (*) = Pollutant mass rate - "concentration method" - lb/hr

PMRR, $PMR_r$ (*) = Pollutant mass rate - "area ratio method" - lb/hr

PMRAVG, $\overline{PMR}$ (*) = Average pollutant mass rate - lb/hr

CPRIME, C' (*) = Particulate concentration corrected for non-isokinetic sampling condition - grains/scf

PT, $P_T$ ($M_n$) = Total particulate collected by sampling train - mg

A1, A2, $A_s$ (A) = Area of stack - $FT^2$ A2 = 0 if round stack

$A_n$ ($A_n$) = Area of nozzle - $FT^2$

DN (*) = Diameter of nozzle in $IN^2$

CP, $C_p$ ($C_p$) = Velocity correction coefficient for type pitot tube used - dimensionless, normally 0.80 to 0.90 for "S" type pitot tube and 1.0 for "P" type pitot tube

KA, $K_a$ (*) = Average $\sqrt{VH \times T_s}$

‡Notation in parenthesis to the right of the ASA nomenclature is the equivalent EPA 40 CFR 60 Method 5 notation

* Notation used by ASA for calculations not required by 40 CFR 60 Method 5

## PARTICULATE CONCENTRATION AND PMR CALCULATION EQUATIONS

1. $VOL_{STD} = \frac{(Y)(VOL_m)(P_m)(T_{STD})}{(P_{STD})(T_m)}$

2. $\%M = \frac{(100)(VOL_w)}{VOL_{STD} + VOL_w}$

3. $MF = \frac{100 - M}{100}$

4. $W_w = (W_d)(MF) + 18\ (1-MF)$

5. $C_D = \sqrt{W_a/W_w}$

6. $C_S = \sqrt{P_{STD}/P_{SN}}$

7. $K_a = \sum \sqrt{(VH_n \times T_{S_n})}/n$

*8. $V_o = 2.9\ (K_a)(C_p)(C_D)(C_S)$

9. $Q_o = (V_o)(A_S)(60)$

10. $Q_{Os} = \frac{(Q_o)(T_{STD})(P_{SN})(M_F)}{(T_S)(P_{STD})}$

11. $V_n = \frac{(VOL_{STD})(P_{STD})(T_S)}{(M_F)(T_{STD})(P_{SN})(T)(A_N)(60)}$

12. $I = (100)\ V_n/V_o$

*13. $C_o = (0.0154)\ P_T/VOL_{STD}$

14. $C = (\frac{C_o}{}) \frac{(12)}{N}$

*15. $PMR_c = (C_o)(Q_s)(0.008571$

*16. $PMR_r = (\frac{P_T)(A_s}{(T)(A_n}) (0.000132)$

*17. $\overline{PMR} = (PMR_c + PMR_r)/2$

*18. $C' = (\overline{PMR})(1400)/Q_{os}N$

*** UNITS FOR THE CONSTANTS USED ARE GIVEN BELOW:**

8. $2.9\ \frac{(FT)}{(SEC)}(\text{INCHES OF } H_2O \times {}^{o}R)^{-1/2}$ based on Bernoulli's equation at STP and a molecular weight of dry gas of 28.95 and english units.

13. $.0154\ \text{grain/mg} = \frac{(mg)}{(ft^3)} \frac{(7000\ \text{grains})}{(lb)} \left(\frac{lb}{453.6g}\right)\left(\frac{g}{1000mg}\right)$

15. $.008571\ \frac{(\text{min-lbs})}{(\text{hr-grains})} = \frac{(\text{grains})}{(ft^3)} \frac{(ft^3)}{(\text{min})} \frac{(60\ \text{min})}{(\text{hr})} \left(\frac{\text{lbs}}{7000\ \text{grains}}\right)$

16. $.000132\ \frac{(\text{lb-min})}{(\text{mg-hr})} = \frac{(mg)}{(\text{min})} \frac{(ft^2)}{(ft^2)} \left(\frac{g}{1000mg}\right)\left(\frac{lb}{453.6g}\right) \frac{(60\ \text{min})}{(\text{hr})}$

18. $1400\ \frac{(\text{hr-grains})}{(\text{min-lb})} = \frac{(lb)}{(hr)} \frac{(\text{min})}{(ft^3)} \frac{(12)}{(n)} \left(\frac{\text{hr}}{60\ \text{min}}\right) \frac{(7000\ \text{grains})}{(lb)}$

# PROCEDURE

## EPA METHOD 5 PARTICULATE SAMPLING TRAIN

### Sampling Train Preparation:

A tared and labeled glass fiber filter was placed in a glass filter holder. The filter (MSA1106BH) was desiccated and weighed to a constant weight to the nearest 0.5 mg. The condenser section consisted of four glass containers in series: one hundred milliliters of distilled-deionized water in a bubbler; one hundred milliliters in an impinger; a dry bubbler; and, a bubbler filled with approximately 500 grams of silica gel. All of the containers were weighed to the nearest 0.1 gram. The sampling train was assembled with connecting glassware so that sample gas would pass through the filter, the bubbler, impinger, the dry bubbler and the silica gel respectively.

A nozzle of a size that would allow for isokinetic sampling was selected and cleaned. A probe and liner of appropriate length to traverse the stack was chosen and the liner cleaned with acetone and a brush. The nozzle was connected with a cleaned union to the probe and liner. The probe was connected in front of the filter. A schematic of the sampling equipment is included in this report.

A leak test was performed on the assembled sampling train. The leak rate did not exceed 0.02 cfm at a vacuum of 10 inches Hg. The probe was heated and maintained at or above 250 degrees plus or minus 25 degrees F. The filter was heated and maintained at 250 degrees plus or minus 25 degrees F to avoid condensation of moisture on the filter. Crushed ice was placed around the condenser at the beginning of the test with new ice being added as required to keep the gases leaving the sampling train below 70 degrees F.

### Sample Collection:

Sampling ports were selected and installed. The number of sampling points was determined based on the number of stack diameters from any flow disturbance to the port(s). The location of each sampling point was based on equal areas within the stack.

The time at each traverse point was dependent on the stack velocity and the desired volume to be sampled. The probe was inserted into the stack to the first traverse point with the nozzle tip pointing directly into the gas stream. The pump was started and immediately adjusted to sample at isokinetic velocities. Equal time was spent at each time interval. The EPA designed nomograph or equivalent was used to maintain isokinetic sampling throughout the sampling period. At the conclusion of the run the pump was turned off, and a final leak test was performed at the maximum vacuum incurred during sampling. If the post-test leak rate was found to be over 0.02 cfm the actual leak rate was recorded.

# PMR CALCULATIONS

The weight of the dust per volume and weight of dust per time were calculated using two procedures:

## 1) The Concentration Method

The concentration of dust entering the sampling nozzle is calculated and then multiplied by the volumetric flow rate of the stack gases to obtain the pollutant mass rate on a concentration basis (PMRc).

Concentration in Nozzle x Volumetric Flow Rate =
Pollutant Mass Rate On Concentration Basis

$$(Pt/VOLstd) \times Q0s = PMRc$$

Assuming the nozzle velocity is greater than the average stack gas velocity (Vn greater than V0), the calculated pollutant mass rate will be less than the true pollutant mass rate because the heavier dust particles will leave their velocity streamline and not enter the nozzle. If Vn is less than V0 then the calculated PMRc will be greater than the true PMR.

## 2) The Area Ratio Method

The weight of dust collected is divided by the sampling time and multiplied by the ratio of the stack area to the nozzle area to obtain the calculated pollutant mass rate based on the area ratio method (PMRr).

$$\frac{\text{Weight Collected}}{\text{Sample Time}} \times \frac{\text{Area of Stack}}{\text{Area of Nozzle}} = \begin{array}{l}\text{Pollutant Mass Rate}\\ \text{on Area Ratio Basis}\end{array}$$

$$(Pt/T) \times As/An = PMRr$$

Assuming the nozzle velocity is greater than the average stack gas velocity (Vn greater than V0), the calculated pollutant mass rate will be greater than the true pollutant mass rate because the lighter particles in the dust laden stream follow their streamlines and enter the sampling nozzle resulting in Pt/T being greater than true. If Vn is less than V0, the calculated PMRr will be less than the true PMR.

To obtain a more true pollutant mass rate, the two calculated pollutant mass rates are averaged. The averaging of the two (2) offsetting calculations allows some of the bias introduced because of non-isokinetic sampling calculated by one method to offset the bias of the other method. The degree of bias is related to particle size and density.

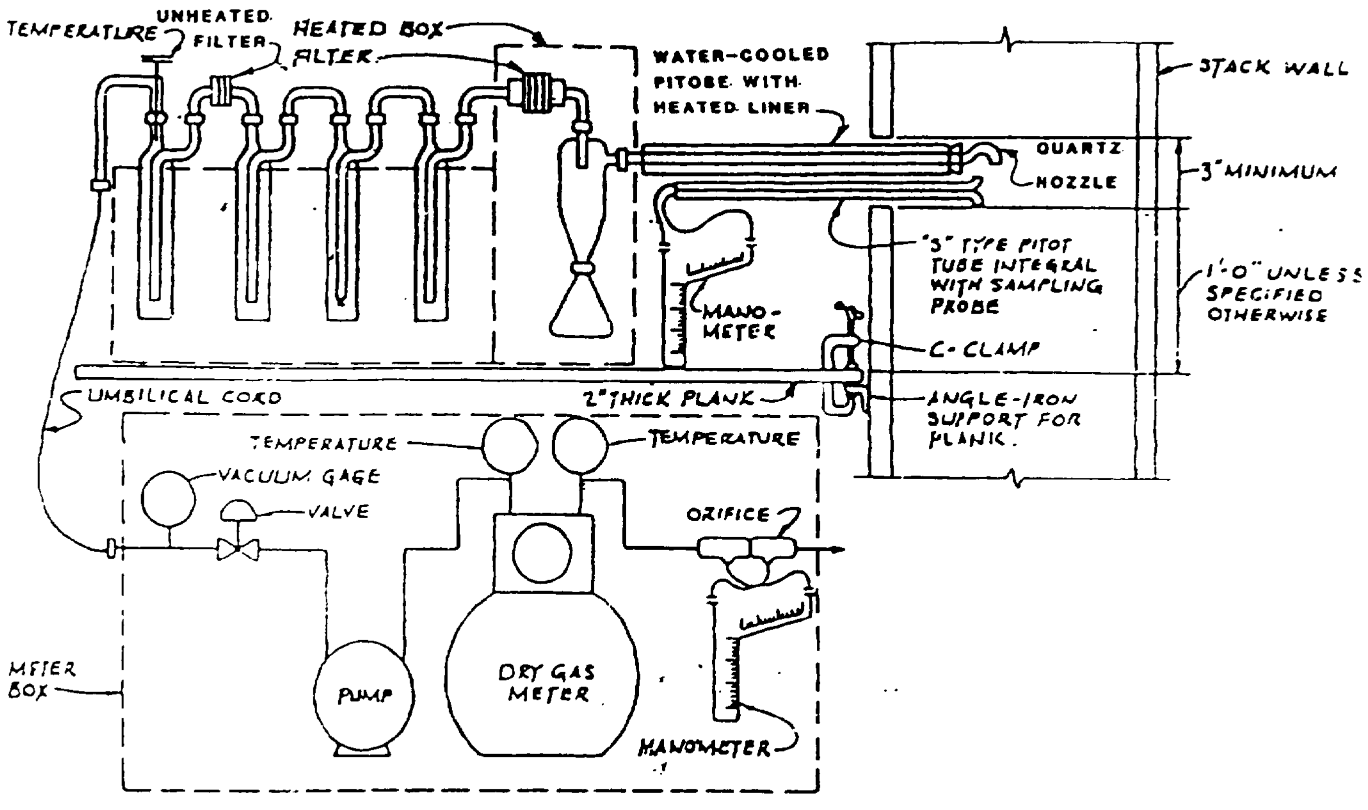


FIGURE A2.

EPA METHOD 5 PARTICULATE SAMPLING TRAIN
MODIFIED FOR SAN DIEGO APCD

DRAWN RSC
CHECKED WS
DATE 9/30/74

AMERICAN SERVICES
ASSOCIATES
BELLEVUE, WA.

## CLEAN-UP & ANALYSIS

**Clean-up** of the modified EPA train was performed by carefully removing the **heated** filter placed ahead of the condenser and placing it in a petri dish marked "Run X, Container A-1" and carefully removing the filter placed behind the condenser and placing it in a petri dish marked "Run X, Container A-2".

Reagent grade acetone and pre-cleaned brushes were used to clear the nozzle, probe liner and pre-filter glass. At least six (6) washes or more were performed to achieve a clear wash for each individual wash of the nozzle, probe and pre-filter glass. The acetone wash was placed in a container marked "Run X, Container B-1". The same procedure was followed utilizing distilled water and was placed in a container marked "Run X, Container B-2".

The volume of water in the glass impinger and bubblers (i.e. condenser) was weighed in their respective containers to the nearest 0.1 gram. The silica gel was weighed in a bubbler before and after the run. The original weights in the impingers and bubblers were then subtracted from the final weights and the difference added to the water weight gain of the silica gel. The total weight gain of the condenser section constitutes the amount of water collected during the run. The water from the glassware and a water wash of the glassware and all post-filter glassware (not including the silica gel container) was performed and placed in a container marked "Run X, Container C". An acetone wash of the condenser was performed following the water rinse and placed in a container marked "Run X, Container D".

**Analysis** of the samples was performed according to the following:

Run X, Containers A-1 & A-2: The petri dishes containing the filters and any loose particulate was opened and placed, for at least 24 hours, in a desiccator containing anhydrous calcium chloride or its equivalent. The filter was then weighed to a constant weight (i.e. two (2) consecutive weighings at least four (4) hours apart which agree within 0.5 milligrams). Results were reported to the nearest 0.1 milligram.

Run X, Containers B-1 & B-2: The volumes were measured to the nearest 1 milliliter for the purposes of subtracting blank weights from the sample weights. The B-1 acetone wash was transferred from the field container into a tared beaker, evaporated at ambient temperature with charcoal filtered air, desiccated for at least 24 hours and weighed to a constant weight. The B-2 water wash was transferred to a tared beaker, evaporated at an elevated temperature, desiccated for at least 24 hours and weighed to a constant weight. The results were reported to the nearest 0.1 milligram.

Run X, Container C - The volume was measured to the nearest 1 milliliter. The organic particulate was extracted from the water solution with three 25 milliliter portions of Methylene Chloride. The Methylene Chloride extracts were transferred to a tared beaker. This solution was evaporated at ambient temperature until no solvent remained. This was accomplished by blowing air that had been charcoal filtered over the sample. The samples were then desiccated for at least 24 hours and weighed to a constant weight. The results were reported to the nearest 0.1 milligram. After the extraction, the remaining water was evaporated to dryness at 212 degrees F. The results were reported to the nearest 0.1 milligram.

Run X, Container D - The volume was measured to the nearest 1 milliliter. The acetone washings were transferred to a tared beaker and evaporated to dryness at ambient temperature and pressure. The samples were desiccated for at least 24 hours and weighed to a constant weight. The results were reported to the nearest 0.1 milligram.

Blanks were taken on the acetone, Methylene Chloride, and deionzed water and subtracted from the respective sample volume. The filter paper used with this modified EPA train was a Mine Safety Appliance 1106 BH, heat treated glass fiber filter mat.

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AMERICAN SERVICES ASSOCIATES                   ANALYSIS OF NOX EMISSIONS

CLIENT: NEW MEXICO ENGINEERING RESEARCH INSTITUTE/USAF      E.P.A. METHOD 7

LOCATION: DEMONSTRATION BURN OF FOAM IN C760 INCINERATOR DATE: 3/3/86

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FILE:696 LAB#: 69-6 COMMENT: NMERI/USAF Fuel Tank Facm Demo Burn 3/86 - Run #1-1

PBINIT= 30.96 PBFINL= 30.34 PACIN=-28 PACFIN=-.9
VOLF= 2044.4 PINIT= 2.96 PFINAL= 29.44 TEMPIN= 62 TEMPFL= 68
ABS1 =  .122  ABS2 =  .225  ABS3 =  .403  ABS4 =  .542  % MOIST =  13.5
Kc =  756.975  ABSORB =  .246  DILFAC =  1  O2 =  12.2 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 372.432
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 1.30315E-05
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  109.356
CONCENTRATION OF NOX AS NO2 (WET) PPM =  94.5925
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  2.08204E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2) (DRY) PPM =  174.717

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FILE:706 LAB#: 70-6 COMMENT: NMERI/USAF Fuel Tank Foam Demo Burn - 3/86 - Run 1-2

PBINIT= 30.96 PBFINL= 30.34 PACIN=-26.7 PACFIN=-.7
VOLF= 2063.9 PINIT= 4.26 PFINAL= 29.64 TEMPIN= 60 TEMPFL= 68
ABS1 =  .122  ABS2 =  .225  ABS3 =  .403  ABS4 =  .542  % MOIST =  13.5
Kc =  756.975  ABSORB =  .062  DILFAC =  1  O2 =  12.2 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 93.8649
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 3.39834E-06
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  28.5177
CONCENTRATION OF NOX AS NO2 (WET) PPM =  24.6678
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  5.42954E-06
CONC OF NOX AS NO2(CORRECTED TO  7 % O2) (DRY) PPM =  45.5628

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FILE:716 LAB#: 71-6 COMMENT: NMERI/USAF Fuel Tank Foam Demo Burn 3/3/86 - Run #1-3

PBINIT= 30.96 PBFINL= 30.34 PACIN=-27.1 PACFIN=-.4
VOLF= 2060.3 PINIT= 3.86 PFINAL= 29.94 TEMPIN= 60 TEMPFL= 68
ABS1 =  .122  ABS2 =  .225  ABS3 =  .403  ABS4 =  .542  % MOIST =  13.5
Kc =  756.975  ABSORB =  .117  DILFAC =  1  O2 =  12.2 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 177.132
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 6.25E-06
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  52.4478
CONCENTRATION OF NOX AS NO2 (WET) PPM =  45.3674
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DS   =  9.98563E-06
CONC OF NOX AS NO2(CORRECTED TO  7 % O2) (DRY) PPM =  83.7959
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AMERICAN SERVICES ASSOCIATES                      ANALYSIS OF NOX EMISSIONS

CLIENT: NEW MEXICO ENGINEERING RESEARCH INSTITUTE/USAF E.P.A. METHOD 7

LOCATION: DEMONSTRATION BURN OF FOAM IN C760 INCINERATOR      DATE: 3/3/86

*******************************************************

FILE:726 LAB#: 72-6 COMMENT: NMERI/USAF Fuel Tank Foam Demo Burn 3/3/86 - Run #1-4

PBINIT= 30.96 PBFINL= 30.34 PACIN=-27.5 PACFIN=-.4
VOLF= 2068 PINIT= 3.46 PFINAL= 29.94 TEMPIN= 60 TEMPFL= 6
ABS1 =  .122  ABS2 =  .225  ABS3 =  .403  ABS4 =  .542  % MOIST =  13.5
Kc =  756.975  ABSORB =  .207  DILFAC =  1  O2 =  12.2 O2 td =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 313.388
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 1.08467E-05
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  91.0218
CONCENTRATION OF NOX AS NO2 (WET) PPM =  78.7339
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  1.73298E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2) (DRY) PPM =  145.426
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AMERICAN SERVICES ASSOCIATES                    ANALYSIS OF NOX EMISSIONS

CLIENT: NEW MEXICO ENGINEERING RESEARCH INSTITUTE/USAF     E.P.A. METHOD 7

LOCATION: DEMONSTRATION BURN OF FOAM IN C760 INCINERATOR     DATE: 3/3/86

****************************************************

FILE:736 LAB#: 73-6 COMMENT: NMERI/USAF Fuel Tank Foam Demo Burn 3/3/86 - Run #2-1

PBINIT= 30.96 PBFINL= 30.34 PACIN=-28 PACFIN=-.4
VOLF= 2064.8 PINIT= 2.96 PFINAL= 29.94 TEMPIN= 62 TEMPFL= 68
ABS1 =  .122  ABS2 =  .225  ABS3 =  .403  ABS4 =  .542  % MOIST =  13.7
Kc =  756.975  ABSORB =  .126  DILFAC =  1  O2 =  12.14 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 193.786
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 6.58823E-06
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  55.2861
CONCENTRATION OF NOX AS NO2 (WET) PPM =  47.7119
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  1.04539E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)(DRY) PPM =  87.7257

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FILE:746 LAB#: 74-6 COMMENT: NMERI/USAF FUEL TANK FOAM DEMO BURN 3/3/86 - RUN #2-2

PBINIT= 30.96 PBFINL= 30.34 PACIN=-28 PACFIN=-.1
VOLF= 2075.2 PINIT= 2.96 PFINAL= 30.24 TEMPIN= 62 TEMPFL= 68
ABS1 =  .122  ABS2 =  .225  ABS3 =  .403  ABS4 =  .542  % MOIST =  13.7
Kc =  756.975  ABSORB =  .561  DILFAC =  1  O2 =  12.14 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 849.326
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 2.84122E-05
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  238.425
CONCENTRATION OF NOX AS NO2 (WET) PPM =  205.761
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  4.50832E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)(DRY) PPM =  378.323

****************************************************

FILE:758 LAB#: 75-6 COMMENT: NMERI/USAF Fuel Tank Foam Demo Burn 3/3/86 - Run #2-3

PBINIT= 30.96 PBFINL= 30.34 PACIN=-27.7 PACFIN=-.1
VOLF= 2091.7 PINIT= 3.26 PFINAL= 30.24 TEMPIN= 60 TEMPFL= 68
ABS1 =  .122  ABS2 =  .225  ABS3 =  .403  ABS4 =  .502  % MOIST =  13.7
Kc =  789.503  ABSORB =  .157  DILFAC =  1  O2 =  12.14 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 247.904
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 8.32341E-06
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  69.8471
CONCENTRATION OF NOX AS NO2 (WET) PPM =  60.2781
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  1.32072E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)(DRY) PPM =  110.831
```

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AMERICAN SERVICES ASSOCIATES                    ANALYSIS OF NOX EMISSIONS

CLIENT: NEW MEXICO ENGINEERING RESEARCH INSTITUTE/USAF E.P.A. METHOD 7

LOCATION: DEMONSTRATION BURN OF FOAM IN C760 INCINERATOR     DATE: 3/3/86

**************************************************

FILE:766 LAB#: 76-6 COMMENT: NMERI/USAF Fuel Tank Faom Demo Burn 3/3/86 - Run #2-4

PBINIT= 30.96 PBFINL= 30.34 PACIN=-27.8 PACFIN=-.1
VOLF= 2099.4 PINIT= 3.16 PFINAL= 30.24 TEMPIN= 60 TEMPFL= 68
ABS1 =  .122  ABS2 =  .225  ABS3 =  .403  ABS4 =  .542  % MOIST =  13.7
Kc =  756.975  ABSORB =  .376  DILFAC =  1  O2 =  12.14 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 569.245
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 1.897E-05
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  159.19
CONCENTRATION OF NOX AS NO2 (WET) PPM =  137.381
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  3.01008E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)(DRY) PPM =  252.595
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AMERICAN SERVICES ASSOCIATES                    ANALYSIS OF NOX EMISSIONS

CLIENT: NEW MEXICO ENGINEERING RESEARCH INSTITUTE/USAF E.P.A. METHOD 7

LOCATION: DEMONSTRATION BURN OF FOAM IN C760 INCINERATOR     DATE: 3/3/86

*****************************************************

FILE:776 LAB#: 77-6 COMMENT: NMERI/USAF Fuel Tank Foam Demo Burn 3/3/86 - Run #3-1

PBINIT= 31 PBFINL= 30.34 PACIN=-27.7 PACFIN= 0
VOLF= 2074.1 PINIT= 3.3 PFINAL= 30.34 TEMPIN= 59 TEMPFL= 68
ABS1 =  .122  ABS2 =  .225  ABS3 =  .403  ABS4 =  .542  % MOIST =  17.3
Kc =  756.975  ABSORB =  .042  DILFAC =  1  O2 =  12.8 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 63.5859
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 2.14902E-06
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  18.0338
CONCENTRATION OF NOX AS NO2 (WET) PPM =  14.9139
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  3.68782E-06
CONC OF NOX AS NO2(CORRECTED TO  7 % O2) (DRY) PPM =  30.9469

*****************************************************

FILE:786 LAB#: 78-6 COMMENT: NMERI/USAF Fuel Tank Foam Demo Burn 3/3/86 - Run #3-2

PBINIT= 31 PBFINL= 30.34 PACIN=-27.7 PACFIN= 0
VOLF= 2032.2 PINIT= 3.3 PFINAL= 30.34 TEMPIN= 60 TEMPFL= 68
ABS1 =  .122  ABS2 =  .225  ABS3 =  .403  ABS4 =  .542  % MOIST =  17.34
Kc =  756.975  ABSORB =  .159  DILFAC =  1  O2 =  12.8 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 240.718
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 8.30348E-06
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  69.6793
CONCENTRATION OF NOX AS NO2 (WET) PPM =  57.5969
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  1.4249E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2) (DRY) PPM =  119.573

*****************************************************

FILE:796 LAB#: 79-6 COMMENT: NMERI/USAF Fuel Tank Foam Demo Burn 3/3/86 - Run #3-3

PBINIT= 31 PBFINL= 30.34 PACIN=-27.4 PACFIN= 0
VOLF= 2035 PINIT= 3.6 PFINAL= 30.34 TEMPIN= 59 TEMPFL= 68
ABS1 =  .122  ABS2 =  .225  ABS3 =  .403  ABS4 =  .542  % MOIST =  17.34
Kc =  756.975  ABSORB =  .083  DILFAC =  1  O2 =  12.8 O2std =  7

CONCENTRATION OF NOX AS NO2 (DRY) MICROGRAMS= 125.658
CONCENTRATION OF NOX AS NO2 (DRY)LBS/DSCF= 4.37901E-06
CONCENTRATION OF NOX AS NO2 (DRY) PPM  =  36.7471
CONCENTRATION OF NOX AS NO2 (WET) PPM =  30.3752
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  7.5146E-06
CONC OF NOX AS NO2(CORRECTED TO  7 % O2) (DRY) PPM =  63.0599
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AMERICAN SERVICES ASSOCIATES                    ANALYSIS OF NOX EMISSIONS

CLIENT: NEW MEXICO ENGINEERING RESEARCH INSTITUTE/USAF     E.P.A. METHOD 7

LOCATION: DEMONSTARAION BURN OF FOAM IN C760 INCINERATOR     DATE: 3/3/86

*****************************************************************

FILE:806 LAB#: 80-6 COMMENT: NMERI/USAF Fuel Tank Faom Demo Burn 3/3/86 - Run #3-4

PBINIT= 31 PBFINL= 30.34 PACIN=-27.8 PACFIN= 0
VOLF= 2030.5 PINIT= 3.2 PFINAL= 30.34 TEMPIN= 60 TEMPFL= 68
ABS1 =  .122  ABS2 =  .225  ABS3 =  .403  ABS4 =  .542  % MOIST =  17.34
Kc =  756.975  ABSORB =  .352  DILFAC =  1  O2 =  12.8 O2std =  7

CONCENTRATION OF NOX AS NO2  (DRY) MICROGRAMS= 532.91
CONCENTRATION OF NOX AS NO2  (DRY)LBS/DSCF= 1.8329E-05
CONCENTRATION OF NOX AS NO2  (DRY) PPM  =  153.811
CONCENTRATION OF NOX AS NO2  (WET) PPM =  127.14
CONC OF NOX AS NO2(CORRECTED TO  7 % O2)LB/DSCF =  3.14535E-05
CONC OF NOX AS NO2(CORRECTED TO  7 % O2) (DRY) PPM =  263.947
```

## NITROGEN OXIDES TERMINOLOGY

VOLF, $V_f$ = Volume of flask and flask valve

PINIT, $P_i$ = Initial absolute pressure of flask, inch Hg.

PBINIT, $P_{bi}$ = Initial barometric pressure, inches Hg.

PACIN, $P_{ai}$ = Actual pressure of flask, initial, inch Hg.

TEMPIN, $T_i$ = Initial absolute temperature of flask, R

PFINAL, $P_f$ = Final absolute pressure of flask, inches Hg.

PBFINL, $P_{bf}$ = Final barometric pressure, inches Hg.

PACFIN, $P_{af}$ = Actual pressure of flask, final, inches Hg.

TEMPFL, $T_f$ = Final absolute temperature of flask, R

TSTD, $T_{std}$ = Standard temperature, 528 R

PSTD, $P_{std}$ = Standard pressure, 29.92 inches Hg.

VOLSTD, $V_{sc}$ = Sample volume at standard conditions (dry basis) ml

ABSORB, $A$ = Absorbance of Sample

ABS1-4, $A_n$ = Individual absorbances of known standards

DILFAC, $F$ = Dilution factor (required only if sample dilution was needed to reduce the absorbtion into rate of calibration.)

KC, $K_c$ = Calibration factor

M1, $m$ = Mass of $NO_2$ in gas sample, microgram.

O2, $O_2$ = Oxygen in gas sample, %.

C1, $C$ = Concentration of $NO_x$ as $NO_2$ (dry basis) lb/dscf
$6.243 \times 10^{-5}$ = Conversion factor to obtain lb/dscf from micrograms/ml

C2, $C'$ = Concentration of $NO_x$ as $NO_2$ (dry basis) parts per million by volume
523.891 = Conversion factor to obtain ppm from micrograms/ml

$$= \frac{(6.243 \times 10^{-5}\ \text{lb/dscf})/(\text{microgram/ml})}{(2.59 \times 10^{-9}\ \text{lb/dscf-ppm})\ (46.01)}$$

C3, C3 = Concentration of $NO_x$ as $NO_2$ (corrected for $O_2$) lb/dscf

C4, C4 = Concentration of $NO_x$ as $NO_2$ (corrected for $O_2$) (dry) ppm

MOIST, MOIST= Percentage moisture in stack gas

C5, C5 = Concentration of $NO_x$ as $NO_2$ (wet) ppm

**American Services Associates**
Consultants in Air, Water, Energy, Hygiene & Management

## NITROGEN OXIDES
## EQUATIONS & CALCULATIONS SHEET

1. $$Kc = 100 \times \frac{(A1 + 2A2 + 3A3 + 4A4)}{(A1*A1 + A2*A2 + A3*A3 + A4*A4)}$$

2. $$Vsc = \frac{Tstd}{Pstd} (Vf-Va)((Pf/Tf)-(Pi/Ti))$$
$$= 17.64\ (Vf-25ml)((Pf/Tf)-(Pi/Ti))$$

3. $M1 = 2KcAF$

4. $C1 = 6.243\ E{-}5\ (M1/Vsc)$

5. $C2 = 523.891\ (M1/Vsc)$

6. $C3 = C1\ ((20.9-O2\ Std)/(20.9-O2))$

7. $C4 = C2\ ((20.9-O2\ Std)/(20.9-O2))$

8. $C5 = C2\ (1.00-(Moist/100))$

# PROCEDURE

## (OXIDES OF NITROGEN)

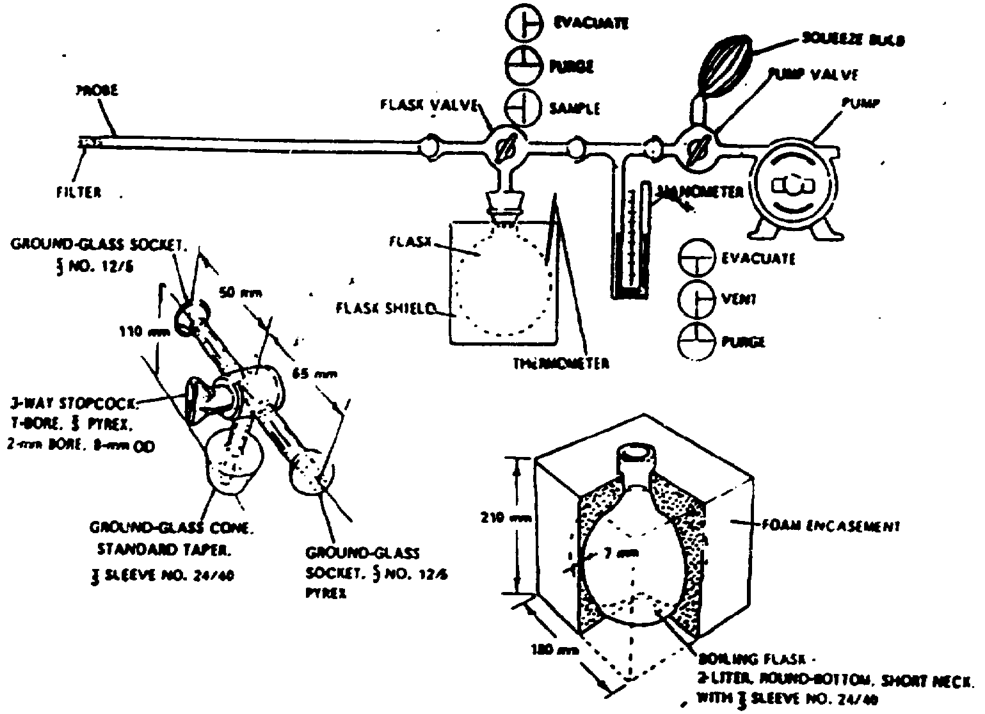
Stack gas sampling equipment designed by the United States Environmental Protection Agency (EPA), Office of Air Programs was used on this evaluation. A schematic of the sampling train is included in this report.

The sampling train was prepared and operated as follows:

25ml of absorbing solution (2.8ml $H_2SO_4$ and 6ml 3% $H_2O_2$ to 1l $H_2O$) was pipetted into a sample flask. The flask was evacuated to 3 inches of mercury absolute pressure or less. The pump valve was closed and the manometer checked for fluctuations in mercury level. With no fluctuation noted over a one minute time span the flask volume and temperature were recorded along with the barometric pressures. With the flask and pump valves in the purge position the probe and vacuum tube were purged using the squeeze bulb. If condensation occured in the probe and flask valve area, the probe was heated until the condensation disappeared. The flask pressure was then measured. With the pump valve closed the flask valve was opened to allow the sample to enter the flask until the pressure in the flask and sample line were equal. If sufficient oxygen was not present in the stack gas to convert NO to $NO_2$ additional oxygen was added. The valves were then closed and the flask was shaken for 5 minutes and then allowed to set for at least 16 hours. After the 16 hour period elapsed, the flask was shaken for 2 minutes and the flask pressure, flask temperature, and the barometer pressure were recorded.

## EPA METHOD 7 (NOX)

## SAMPLING TRAIN



# SAMPLE CLEAN-UP AND ANALYSIS
## (OXIDES OF NITROGEN)

After rinsing the flask with two 5 ml portions of distilled water and adding the rinse to the sample, the pH was adjusted to between 9 and 12 using 1 N sodium hydroxide. The sample was then transferred to a polyethylene storage container for shipment. A blank containing 25 ml of absorbing solution was taken and treated in the same manner.

The samples were diluted to a known volume (50 ml). An aliquot (25 ml) was taken and evaporated on a steam bath in a porcelain evaporating dish to dryness and then cooled.

Phenoldisulfonic acid solution (2 ml) was added to the dried residue and thoroughly triturated with a polyethylene policeman. One milliliter of distilled water and 4 drops of concentrated sulfuric acid were added. The samples were then heated for three minutes with occasional stirring on a steam bath. After cooling, 20 milliliters of distilled water was mixed into the sample and the pH adjusted to 10 with concentrated ammonium hydroxide. If the sample contained solids they were filtered out with a Whatman No. 41 filter paper. The samples were then quantitatively tranferred and diluted to 100 mls. in a volumetric flask.

The absorbance of each sample was measured at the optimum wave length (approximately 410 nm) using the blank as a zero. The total quantity of NOx (as NO2) for each sample was determined from a graph plotted from using suitable standards. The standard line was positioned by statistical calculations.

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AMERICAN SERVICES ASSOCIATES                    CYANIDE EMISSION CALCULATIONS

CLIENT : NEW MEXICO ENGINEERING RESEARCH INSTITUTE/USAF    NIOSH P&CAM 116

LOCATION: DEMONSTRATION BURN OF USAF FOAM w/ C760     DATE: 3/3/86

****************************************************

FILE: 816 LAB #: 81-6 COMMENT: NMERI/USAF Foam Demo Burn w/ C760 at TRC 3/3/86 - Run #1

Vm = 1.105 Pbar = 30.96 Delta H = 0 Y =  1.0057 Pm = 30.96 Tm = 76.5
Vmstd = 1.13171 CO2 = 5.76 CO2 + O2 = 17.96 CO2 + O2 + CO = 17.96 O2 = 12.2 CO = 0
Psw =-.05 WtH2O = 3.75239 Bws = .135 Cp = .825  Md = 29.4096
A1 = 43 A2 = 0 A =  10.0847 square feet    ;  Weight of Cyanide collected =  .04  milligrams

Obs  Delta P  Ts        Obs  Delta P  Ts       Obs  Delta P  Ts

 1    .035    1471       2     .04   1271       3    .032  1166
 4    .05     2001       5     .06   914        6    .065  1387
 7    .06     1244       8     .06   1136       9    .073  1400
 10   .07     1186       11    .095  615        12   .085  1044
 13   .072    1109       14    .06   726        15   .058  1056
 16   .035    1070       17    .06   1095       18   .048  950
 19   .06     1344       20    .045  1062       21   .04   1032
 22   .05     1409       23    .05   1175       24   .042  1015

Tsavg = 1161.58 vs = 22.4955 Qs = 13611.7 Qsdm = 3966.51 Qsd = 237990
Concentration of Cyanide =  5.44964E-04  grains/dscf  &  1.15507  ppmv
Mass Emission Rate of Cyanide =  .018528  pounds/hour

****************************************************

FILE: 826 LAB #: 82-6 COMMENT: NMERI/USAF Foam Demo Burn w/ C760 at TRC 3/3/86 - Run #2

Vm = .581 Pbar = 30.96 Delta H = 0 Y =  1.0057 Pm = 30.96 Tm = 66.5
Vmstd = .606345 CO2 = 6.06 CO2 + O2 = 18.2 CO2 + O2 + CO = 18.2 O2 = 12.14 CO = 0
Psw =-.05 WtH2O = 2.04496 Bws = .137 Cp = .825  Md = 29.4552
A1 = 43 A2 = 0 A =  10.0847 square feet    ;  Weight of Cyanide collected =  .02  milligrams

Obs  Delta P  Ts        Obs  Delta P  Ts       Obs  Delta P  Ts

 1    .046    1225       2     .05   1236       3    .05   1170
 4    .06     1209       5     .06   1165       6    .07   1300
 7    .066    1232       8     .07   1253       9    .07   1200
 10   .08     1247       11    .09   1271       12   .078  1231
 13   .08     1189       14    .09   1567       15   .082  1226
 16   .073    1223       17    .07   1146       18   .082  15
 19   .08     1273       20    .066  1237       21   .064  1144
 22   .08     1504       23    .07   1242       24   .06   1168

Tsavg = 1194.71 vs = 25.6106 Qs = 15496.5 Qsdm = 4415.14 Qsd = 264908
Concentration of Cyanide =  5.08572E-04  grains/dscf  &  1.07794  ppmv
Mass Emission Rate of Cyanide =  .0192464  pounds/hour
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AMERICAN SERVICES ASSOCIATES                    CYANIDE EMISSION CALCULATIONS

CLIENT : NEW MEXICO ENGINEERING RESEARCH INSTITUTE/USAF    NIOSH P&CAM 116

LOCATION: DEMONSTRATION BURN OF USAF FOAM w/ C760    DATE: 3/3/86

*****************************************************

FILE: 836 LAB #: 83-6 COMMENT: NMERI/USAF Foam Demo Burn w/ C760 at TRC 3/3/86 - Run #3

Vm = .774 Pbar = 31 Delta H = 0 Y =  1.0057 Pm = 31 Tm = 68
Vmstd = .80651 CO2 = 5.7 CO2 + O2 = 18.5 CO2 + O2 + CO = 18.5 O2 = 12.8 CO = 0
Psw =-.05 WtH2O = 3.58431 Bws = .173 Cp = .854  Md = 29.424
A1 = 43 A2 = 0 A =  10.0847 square feet   ;  Weight of Cyanide collected =  .02  milligrams

Obs  Delta P  Ts        Obs  Delta P  Ts      Obs  Delta P  Ts

 1    .04      1178      2     .045  1459      3     .05   1270
 4    .03      1203      5     .043  1169      6     .05   1389
 7    .07      1443      8     .04   1214      9     .065  1234
 10   .065     1220      11    .075  1441      12    .065  1216
 13   .06      1188      14    .06   1177      15    .075  1285
 16   .075     1377      17    .05   1181      18    .05   1183
 19   .065     1204      20    .055  1219      21    .055  1217
 22   .05      1170      23    .04   1155      24    .03 · 1116

Tsavg = 1246.17 vs = 23.8949 Qs = 14458.4 Qsdm = 3833.42 Qsd = 230005
Concentration of Cyanide =  3.82351E-04  grains/dscf  &  .81041  ppmv
Mass Emission Rate of Cyanide =  .0125633  pounds/hour
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# ATTACHMENT 1

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AMERICAN SERVICES ASSOCIATES            E.P.A. METHOD 5 - PARTICULATES

JOB NAME:  NEW MEXICO ENGINEERING RESEARCH INSTITUTE/USAF AT TRC

PREPARED BY:  W. D. SNOWDEN             DATE:  3/3/86

SUBJECT:  FUEL TANK FOAM C-760 DEMONSTRATION BURN   RUN # 1

************************************************************

VOLM = 40.765   PBAR = 30.96   DELTA H = .979   TM = 77.8   LAB # =66-6

PM = 31.032  VOL(STD) = 41.6795  VOLH2O = 138  Y= 1.0036

CO2 =  5.76 CO2 + O2 = 17.96 CO2 + O2 + CO = 17.96 O2 = 12.2 CO = 0

VOLW = 6.49566   WD = 29.4096   PS =-.05   PSN = 30.9563   CP = .825

M = 13.4834  MF = .865166  WW = 27.8712  CD = 1.01917  CS = .983119

A1 = 43  A2 = 0  AS = 10.0847  T = 72  DN = .515  PT = 200.4  N = 5.62

OBS      VH     TS        KA              OBS      VH     TS         KA

1        .035   1471   8.22101            2        .04    1271   8.32106
3        .032   1166   7.21332            4        .05    2001   11.0928
5        .06    914    9.07965            6        .065   1387   10.957
7        .06    1244   10.1114            8        .06    1136   9.78571
9        .073   1400   11.6525            10       .07    1186   10.7341
11       .095   615    10.1057            12       .085   1044   11.3066
13       .072   1109   10.6286            14       .06    726    8.43564
15       .058   1056   9.377              16       .035   1070   7.31779
17       .06    1095   9.65919            18       .048   950    8.22679
19       .06    1344   10.4038            20       .045   1062   8.27587
21       .04    1032   7.72528            22       .05    1409   9.66696
23       .05    1175   9.04157            24       .042   1015   7.87083
*******************************************************

START TIME = 1109   STOP TIME = 1224   FILE = 666

KA = 9.38376  TS = 1161.58  VO = 22.4948  QO = 13611.2  QS = 3967.15

VN = 22.8831   I = 101.726   CO = .0740451   C = .158103

PMRC = 2.51771  PMRR = 2.56131  PMRAVG = 2.53951  C' = .159464
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AMERICAN SERVICES ASSOCIATES          PARTICULATE CALCULATION

CLIENT: NEW MEXICO ENGINEERING RESEARCH INST./USAF

LOCATION: C760 INCINERATOR DEMO BURN OF USAF FOAM AT TRC

SAMPLE DATE: 3/3/86                   ANALYSIS DATE: 3/4-10/86

RUN # 1                               LAB # 66-6

***************************************************

I.  EVAPORATION OF  220 ml OF ACETONE RINSE AND (B)
    BRUSHING OF NOZZLE, PROBE AND GLASSWARE BEFORE FILTER.

    FINAL  78260.8 mg - TARE  78186.1 mg
    - BLANK (( 1E-03 mg/ml) ( 220 ml) =  .22 mg)           = 74.48 mg

II.  FILTER CATCH - FILTER MSA1106BH - NUMBER 41-6 (A)

     FINAL  471.2 mg - TARE  363.2 mg                      = 108 mg

III.  HYDROCARBON OBTAINED BY  75 ml METHYLENE-CHLORIDE
      EXTRACTION ON WATER IN IMPINGER AND BUBBLERS. (Cx)

      FINAL 80753 mg - TARE 80752.4 mg
      - BLANK (( 1E-03 mg/ml) ( 75 ml) =  .075 mg)         = .525 mg

IV.  PARTICULATE FROM EVAPORATION OF  565 ml WATER (C)
     IN IMPINGER AND BUBBLERS FOLLOWING EXTRACTION

     FINAL 77320.3 mg - TARE 77308.4 mg
     - BLANK (( 1E-03 mg/ml) ( 565 ml INITIAL
     -  127.5 ml CONDENSED =  437.5 ml) = .4375 mg)        = 11.4625 mg

V.  PARTICULATE FROM 109 ml OF ACETONE RINSE OF IMPINGER
    BUBBLERS, AND CONNECTORS AFTER FILTER (D)

    FINAL 77666.6 mg - TARE 77665.4 mg
    - BLANK (( 1E-03 mg/ml) ( 109 ml) = .109 mg)           = 1.091 mg

VI.  BACKUP FILTER CATCH - MEDIA TYPE MSA1106BH - NUMBER 45-6

    FINAL 367.6 mg - TARE 362.8 mg                         = 4.8 mg

VII.  TOTAL PARTICULATE = SUM OF ABOVE                     = 200.359 mg
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    BLANKS
    ------

    ACETONE (FINAL 77576.7 mg - TARE 77576.6 mg =  .1 mg)
          /  100 ml =  1E-03 mg/ml

    METHYLENE-CHLORIDE (FINAL 77108.8 mg - TARE 77108.70000000001 mg =  .1  mg)
          /  100  ml =  1E-03  mg/ml

    WATER (FINAL 77237.7 mg - TARE 77237.6 mg = .1 mg)
          / 100 ml = 1E-03 mg/ml
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AMERICAN SERVICES ASSOCIATES          E.P.A. METHOD 5 - PARTICULATES

JOB NAME:  NEW MEXICO ENGINEERING RESEARCH INSTITUTE / USAF AT TRC

PREPARED BY:  W. D. SNOWDEN             DATE:  3/3/86

SUBJECT:  FUEL TANK FOAM C-760 DEMONSTRATION BURN    RUN # 2

********************************************************

VOLM = 30.904   PBAR = 30.96   DELTA H = 1.228   TM = 76.8   LAB # =67-6

PM = 31.0503  VOL(STD) = 31.6593  VOLH2O = 106.6  Y= 1.0036

CO2 =  6.06 CO2 + O2 = 18.2 CO2 + O2 + CO = 18.2 O2 = 12.14 CO = 0

VOLW = 5.01766  WD = 29.4552   PS =-.05   PSN = 30.9563   CP = .825

M = 13.6807  MF = .863193  WW = 27.8881  CD = 1.01886  CS = .983119

A1 = 43  A2 = 0  AS = 10.0847  T = 48  DN = .515  PT = 88.2  N = 5.93

OBS      VH      TS          KA                OBS      VH      TS          KA

1        .046   1225    8.80398                 2       .05    1236    9.20869
3        .05    1170    9.02774                 4       .06    1209    10.007
5        .06    1165    9.87421                 6       .07    1300    11.0996
7        .066   1232    10.5675                 8       .07    1253    10.9503
9        .07    1200    10.7796                 10      .08    1247    11.6859
11       .09    1271    12.4816                 12      .078   1231    11.4847
13       .08    1189    11.4856                 14      .09    1567    13.5067
15       .082   1226    11.7581                 16      .073   1223    11.0842
17       .07    1146    10.6028                 18      .082   1515    12.726
19       .08    1273    11.7745                 20      .066   1237    10.5831
21       .064   1144    10.1319                 22      .08    1504    12.5348
23       .07    1242    10.9151                 24      .06    1168    9.88332

*******************************************************

START TIME = 1440   STOP TIME = 1528   FILE = 676

KA = 10.9565  TS = 1257.21  VO = 26.2571  QO = 15887.7  QS = 4362.83

VN = 27.6733   I = 105.393   CO = .0429031   C = .0868191

PMRC = 1.60431  PMRR = 1.69092  PMRAVG = 1.64762  C' = .0891582
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AMERICAN SERVICES ASSOCIATES            PARTICULATE CALCULATION

CLIENT: NEW MEXICO ENGINEERING RESEARCH INST./USAF

LOCATION: C760 INCINERATOR DEMO BURN OF USAF FOAM AT TRC

SAMPLE DATE: 3/3/86                     ANALYSIS DATE: 3/4-10/86

RUN # 2                                 LAB # 07-6

*****************************************************

I.  EVAPORATION OF  140 ml OF ACETONE RINSE AND (B)
    BRUSHING OF NOZZLE, PROBE AND GLASSWARE BEFORE FILTER.

    FINAL  69775.3 mg - TARE  69750.2 mg
    - BLANK (( 1E-03 mg/ml) ( 140 ml) =  .14 mg)              = 24.96 mg

II.  FILTER CATCH - FILTER MSA1106BH - NUMBER 44-6 (A)

     FINAL  424.8 mg - TARE  364.3 mg                         = 60.5 mg

III.  HYDROCARBON OBTAINED BY  75 ml METHYLENE-CHLORIDE
      EXTRACTION ON WATER IN IMPINGER AND BUBBLERS. (Cx)

      FINAL 77648.3 mg - TARE 77648.2 mg
      - BLANK (( 1E-03 mg/ml) ( 75 ml) =  .075 mg)            = .025 mg

IV.  PARTICULATE FROM EVAPORATION OF  470 ml WATER (C)
     IN IMPINGER AND BUBBLERS FOLLOWING EXTRACTION

     FINAL 66548.3 mg - TARE 66546.8 mg
     - BLANK (( 1E-03 mg/ml) ( 470 ml INITIAL
     -  98 ml CONDENSED =  372 ml) = .372 mg)                 = 1.128 mg

V.  PARTICULATE FROM 99 ml OF ACETONE RINSE OF IMPINGER
    BUBBLERS, AND CONNECTORS AFTER FILTER (D)

    FINAL 79405.1 mg - TARE 79404.5 mg
    - BLANK (( 1E-03 mg/ml) ( 99 ml) = .099 mg)               = .501 mg

VI.  BACKUP FILTER CATCH - MEDIA TYPE MSA1106BH - NUMBER 9-6

    FINAL 155.8 mg - TARE 154.7 mg                            = 1.1 mg


VII.  TOTAL PARTICULATE = SUM OF ABOVE                        = 88.214 mg
----  ----- ----------- - --- -- -----                        ----------


    BLANKS
    ------

    ACETONE (FINAL 77576.7 mg - TARE 77576.6 mg =  .1 mg)
           /  100 ml =  1E-03 mg/ml

    METHYLENE-CHLORIDE (FINAL 77108.8 mg - TARE 77108.70000000001 mg =  .1  mg)
           /  100  ml =  1E-03  mg/ml

    WATER (FINAL 77237.7 mg - TARE 77237.6 mg = .1 mg)
           / 100 ml = 1E-03 mg/ml
```

```
AMERICAN SERVICES ASSOCIATES          E.P.A. METHOD 5 - PARTICULATES

JOB NAME:  NEW MEXICO ENGINEERING RESEARCH INSTITUTE / USAF

PREPARED BY:  W. D. SNOWDEN           DATE:  3/3/86

SUBJECT:  FUEL TANK FOAM C760 DEMONSTRATION BURN   RUN # 3

*******************************************************

VOLM = 26.655   PBAR = 31   DELTA H = .978   TM = 77.9   LAB # =68-6

PM = 31.0719  VOL(STD) = 27.2696  VOLH2O = 121.5  Y= 1.0036

CO2 =  5.7 CO2 + O2 = 18.5 CO2 + O2 + CO = 18.2 O2 = 12.8 CO =-.299999

VOLW = 5.71901   WD = 29.424   PS =-.05   PSN = 30.9963   CP = .854

M = 17.3363  MF = .826637  WW = 27.4435  CD = 1.02708  CS = .982485

A1 = 43  A2 = 0  AS = 10.0847  T = 48  DN = .515  PT = 86.9  N = 5.55

OBS     VH     TS        KA              OBS     VH    TS        KA

1       .04    1178    8.09444            2     .045  1459    9.29274
3       .05    1270    9.30054            4     .03   1203    7.06329
5       .043   1169    8.36941            6     .05   1389    9.61509
7       .07    1443    11.5417            8     .04   1214    8.18291
9       .065   1234    10.4933           10     .065  1220    10.4499
11      .075   1441    11.9405           12     .065  1216    10.4374
13      .06    1188    9.94384           14     .06   1177    9.9106
15      .075   1285    11.4401           16     .075  1377    11.7378
17      .05    1181    9.05814           18     .05   1183    9.06367
19      .065   1204    10.4              20     .055  1219    9.60963
21      .055   1217    9.60391           22     .05   1170    9.02774
23      .04    1155    8.03741           24     .03   1116    6.87604
*****************************************************

START TIME = 1620   STOP TIME = 1708   FILE = 686

KA = 9.56209  TS = 1246.17  V0 = 23.8967  Q0 = 14459.5  QS = 3832.04

VN = 24.6984   I = 103.355   C0 = .0490752   C = .106109

PMRC = 1.61185  PMRR = 1.666  PMRAVG = 1.63892  C' = .107886
```

```
AMERICAN SERVICES ASSOCIATES             PARTICULATE CALCULATION

CLIENT: NEW MEXICO ENGINEERING RESEARCH INST./USAF

LOCATION: C760 INCINERATOR DEMO BURN OF USAF FOAM AT TRC

SAMPLE DATE: 3/3/86                      ANALYSIS DATE: 3/4-10/86

RUN # 3                                  LAB # 68-6

*******************************************************

I.   EVAPORATION OF  173 ml OF ACETONE RINSE AND (B)
     BRUSHING OF NOZZLE, PROBE AND GLASSWARE BEFORE FILTER.

     FINAL  82607.8 mg - TARE  82589 mg
     - BLANK (( 1E-03 mg/ml) ( 173 ml) =  .173 mg)            = 18.627 mg

II.   FILTER CATCH - FILTER MSA1106BH - NUMBER 37-6 (A)

      FINAL  418 mg - TARE  358.8 mg                          = 59.2 mg

III.   HYDROCARBON OBTAINED BY  75 ml METHYLENE-CHLORIDE
       EXTRACTION ON WATER IN IMPINGER AND BUBBLERS. (Cx)

       FINAL 78570.4 mg - TARE 78569.8 mg
     - BLANK (( 1E-03 mg/ml) ( 75 ml) =  .075 mg)             = .525 mg

IV.   PARTICULATE FROM EVAPORATION OF  465 ml WATER (C)
      IN IMPINGER AND BUBBLERS FOLLOWING EXTRACTION

      FINAL 77647.2 mg - TARE 77640 mg
      - BLANK (( 1E-03 mg/ml) ( 465 ml INITIAL
      -  113.5 ml CONDENSED =  351.5 ml) = .3515 mg)          = 6.8485 mg

V.   PARTICULATE FROM 118 ml OF ACETONE RINSE OF IMPINGER
     BUBBLERS, AND CONNECTORS AFTER FILTER (D)

     FINAL 76878.8 mg - TARE 76878.2 mg
     - BLANK (( 1E-03 mg/ml) ( 118 ml) = .118 mg)             = .482 mg

VI.   BACKUP FILTER CATCH - MEDIA TYPE MSA1106BH - NUMBER 8-6

     FINAL 154.4 mg - TARE 153.2 mg                           = 1.2 mg


VII.  TOTAL PARTICULATE = SUM OF ABOVE                        = 86.8825 mg
----  ----- ----------- - --- -- -----                          ----------


     BLANKS
     ------

     ACETONE (FINAL 77576.7 mg - TARE 77576.6 mg =  .1 mg)
           /  100 ml =  1E-03 mg/ml

     METHYLENE-CHLORIDE (FINAL 77108.8 mg - TARE 77108.70000000001 mg =  .1  mg)
           /  100  ml =  1E-03  mg/ml

     WATER (FINAL 77237.7 mg - TARE 77237.6 mg = .1 mg)
           / 100 ml = 1E-03 mg/ml
```

# APPENDIX B

This Appendix is a Reproduction of the

FUEL CELL POLYURETHANE FOAM:

ASH CHARACTERIZATION,

APRIL 1986

This is a self-contained document with its own internal consistent style.

ADVANCED PROTECTION TECHNOLOGIES DIVISION
REPORT APT 10

# FUEL CELL POLYURETHANE FOAM: ASH CHARACTERIZATION

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April 1986

Prepared for
Subtask 4.01
Effective Disposal of Fuel Cell Polyurethane Foam

# PREFACE

This report was prepared by the Advanced Protection Technologies (APT) Division, New Mexico Engineering Research Institute (NMERI), University of New Mexico, Albuquerque, New Mexico 87131, for use in the completion of Subtask 4.01, "Effective Disposal of Fuel Cell Polyurethane Foam." The physical property studies, combustion work, moisture determinations, extractions, and selected gas chromatography (GC) investigations were planned with and performed by Mary M. Searles, Sue H. Kellogg, and Thomas Debevec in the NMERI APT Division's Alamo Building Environmental and Combustion Laboratories. The gas chromatography/mass spectrometry (GC/MS) and some of the GC determinations were conducted in the UNM Department of Chemistry GC/MS Instrumentation Laboratory by Pelayo F. Fernandez and Fwu Lin Lii. Ruby Ju performed the elemental analyses in the UNM Microanalytical Laboratory.

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# INTRODUCTION

On 24 January and 3 March 1986, demonstration burns on polyurethane foam used in aircraft fuel tanks by the United States Air Force were conducted at the Thermal Reduction Company in Bellingham, Washington. The first test series (Series 1) employed a CONSUMAT Model C75P demonstration incinerator. The second series (Series 2) used a CONSUMAT C760 municipal solid waste incinerator. Atmospheric emission evaluations were performed during the burns by American Services Associates. Following each series of tests, ash samples were removed from the incinerator by Mr. Michael Lee, Principal Investigator for Subtask 4.01, and were delivered to the New Mexico Engineering Research Institute (NMERI) Environmental and Combustion Laboratories for characterization. One sample (A1) was obtained from Series 1 and three samples (B1, B2, B3) were obtained at the conclusion of Series 2. The latter three samples differed only in the collection location within the incinerator. They were removed at the same time.

The ash resulted from the combustion of both foam and foam packaging material (cardboard and polyethylene). The residues were brown to grey-black, layered, irregular pieces and fines. Red-brown deposits, apparently rust, discolored the ash. The material was highly porous with voids up to several millimeters in diameter in the residue from Series 1 and smaller voids in the residues from Series 2. The samples from Series 2 were very wet owing to the use of a water deluge cooling system.

# DENSITY DETERMINATIONS

That the ash was very porous and fragile and consisted of irregular chunks made the density determinations difficult. Densities were determined for ash residue both including and excluding air spaces (respectively termed "gross" and "net" densities). The densities were calculated from sample masses and volumes (determined by displacement of water). The volume determinations suffered from the largest errors. The ash from samples B1, B2, and B3 was dried at 120°C to a constant weight (about 4 hours) before performing the density measurements. The ash from sample A1 was not dried.

Samples containing approximately 0.1 to 0.3 grams of crushed, ground ash and fines (for net density) or of individual pieces (for gross densities) were weighed out for the separate determinations. The samples were placed in a 10-ml graduated cylinder filled with 8 ml of water and the volume change of the water was recorded. For the net density measurements on the ground material, several drops of Aerosol$^R$, a 10% solution of sodium dioctylsulfosuccinate surfactant, were added to the water in the graduated cylinder to aid in immersing the material, and the cylinder was evacuated through a septum to remove air bubbles. These procedures were not performed for the gross density measurements. All samples, except the individual pieces for the gross density determinations for the Series 1 residue, sank spontaneously in the water. Individual pieces for Series 1 were forcibly submerged using a small wire. The densities were calculated by dividing the masses by the volumes.

## TABLE B1. DENSITIES OF FOAM INCINERATION RESIDUES.

| Sample | Description | Mass, grams | Volume, milliliters | Density, g/ml |
|---|---|---|---|---|
| | | Net Density | | |
| A1 | Ground pieces, no fines | 0.2522 | 0.20 | 1.26 |
| A1 | | 0.2714 | 0.21 | 1.29 |
| A1 | | 0.2677 | 0.20 | 1.34 |
| | | | Avg. | 1.30 ± 0.03 |
| B1 | Ground pieces and fines | 0.3106 | 0.10 | 3.11 |
| B2 | | 0.3084 | 0.11 | 2.80 |
| B3 | | 0.3090 | 0.10 | 3.09 |
| | | | Avg. | 3.00 ± 0.13 |
| B1 | Ground pieces, no fines | 0.2409 | 0.10 | 2.41 |
| B2 | | 0.3981 | 0.15 | 2.65 |
| B3 | | 0.3464 | 0.15 | 2.31 |
| | | | Avg. | 2.46 ± 0.03 |
| | | Gross Density | | |
| A1 | Single piece | 0.3978 | 0.50 | 0.80 |
| A1 | | 0.0935 | 0.11 | 0.85 |
| A1 | | 0.0809 | 0.11 | 0.75 |
| | | | Avg. | 0.80 ± 0.03 |
| B1 | Single piece | 0.1933 | 0.10 | 1.98 |
| B2 | | 0.3243 | 0.18 | 1.80 |
| B3 | | 0.2031 | 0.12 | 1.69 |
| | | | Avg. | 1.83 ± 0.10 |

## ELEMENTAL ANALYSES

Residue from Series 2 was dried at 120°C to constant weight. Residues from both series were then separately ground and small samples were submitted for microanalyses. The material was analyzed for carbon, hydrogen, nitrogen, and residue. The carbon and hydrogen percentages (Table B2) were determined by oxidizing the samples and collecting and weighing the carbon dioxide and water produced. The nitrogen concentrations (Table B3) were determined by measuring the volume of elemental nitrogen gas produced at a given temperature and pressure. The residue percentages (Table B4) were determined from ash samples heated in a muffle furnace in air.

TABLE B2. CARBON, HYDROGEN ANALYSES.

| Sample | Sample mass, mg | Carbon dioxide, mg | Water, mg | Carbon, % by weight | Hydrogen, % by weight |
|---|---|---|---|---|---|
| A1 | 5.753 | 13.132 | 1.360 | 62.29 | 2.65 |
| B1 | 11.141 | 0.377 | 0.263 | 0.92 | 0.26 |
| B2 | 10.314 | 0.255 | 0.312 | 0.67 | 0.34 |
| B3 | 11.445 | 0.237 | 0.250 | 0.57 | 0.24 |

## TABLE B3. NITROGEN ANALYSES.

| Sample | Sample mass, mg | Nitrogen gas temperature, °C | Nitrogen gas pressure, Torr | Nitrogen gas volume, ml | Nitrogen, % by weight |
|---|---|---|---|---|---|
| A1 | 5.020 | 29 | 636 | 0.270 | 5.09 |
| B1 | 35.408 | 27 | 624 | 0.010 | 0.03[a] |
| B2 | 36.845 | 27 | 624 | 0.005 | 0.01[a] |

[a] Value is too small to be of significance.

## TABLE B4. NONCOMBUSTIBLE RESIDUE.

| Sample | Sample mass, mg | Temperature, °C | Time, minutes | Residue mass, mg | Residue, % by weight |
|---|---|---|---|---|---|
| A1 | 42.728 | 800 | ----[a] | 7.991 | 18.70 |
| B1 | 39.254 | 800 | 180 | 38.487 | 98.05 |
| B2 | 37.368 | 840 | 30 | 37.133 | 99.37 |
| B3 | 33.443 | 840 | 30 | 33.168 | 99.18 |

[a] Not recorded.

## MOISTURE DETERMINATIONS

Samples of ash were weighed into porcelain crucibles and heated at 120°C to constant weight. The crucibles were cooled in a desicator before weighing. The samples were not crushed or otherwise processed prior to heating. The results are presented in Table B5. The reported heating times are approximate.

TABLE B5. ASH MOISTURE CONTENTS.

| Sample | Sample mass, grams | Heating time, hours | Final mass, grams | Moisture, % by weight |
|---|---|---|---|---|
| A1 | 4.7781 | 4 | 4.7085 | 1.46 |
| B1 | 21.4790 | 6 | 15.3474 | 28.55 |
| B2 | 24.6205 | 6 | 19.1394 | 22.26 |
| B3 | 22.1552 | 6 | 19.0299 | 14.12 |

# IGNITABILITY

Ash samples (both pieces and fines) were placed under a hood on fire brick and were heated with a propane torch. The heating was done carefully to avoid material loss. All observations were recorded.

Sample A1 was slightly flammable but would not sustain flame for more than a few seconds. The sample became red hot and popped and sparked during which time the color changed from brownish to grey-black. This test was done twice with the same results.

Sample B1 did not sustain a flame but did seem to burn. It became red hot and popped and sparked. The color changed from brownish to grey-black. The test was performed twice with the same results.

Sample B2 did not appear to burn. It became red hot, popped and sparked, but cooled quickly. The test was repeated twice with same results.

Sample B3 did not appear to burn significantly. The material stayed red hot slightly longer than sample B2. Like the others, the material popped and sparked. It appeared to melt and changed color to a dark black. The test was repeated twice with same results.

## LOSS ON COMBUSTION

For each sample a porcelain crucible was heated several times with a Bunsen burner to give a constant weight, the sample was added to it, and the crucible plus sample weighed. The crucible and contents were then heated on the bottom with a Bunsen burner for 5 minutes, cooled in a desiccator, and reweighed. This procedure was repeated until the weight became nearly constant (four times for the Series 1 residue and three times for the Series 2 material). Samples B1, B2, and B3 were combined to prepare the samples used for characterization of the ash from the Series 2 incinerator tests. The results are shown in Table B6.

TABLE B6. LOSS ON COMBUSTION.

| | | Mass sample plus crucible, grams | | Mass loss | |
|---|---|---|---|---|---|
| Sample | Sample mass, grams | before heating | after heating | grams | % by weight |
| A1 | 1.5031 | 19.8134 | 18.8700 | 0.9434 | 62.76 |
| A1 | 1.8136 | 19.1724 | 18.2113 | 0.9611 | 52.99 |
| B1+B2+B3 | 2.6137 | 19.9718 | 19.9460 | 0.0258 | 0.99 |
| B1+B2+B3 | 2.7530 | 21.0633 | 21.0407 | 0.0226 | 0.82 |

# EXTRACTION PROCEDURE (EP) TOXICITY TESTS

The Extraction Procedure (EP) Toxicity Characteristic Test is designed to simulate the leaching a waste will undergo if disposed of in a sanitary landfill. A representative sample of the waste is extracted with distilled water maintained at a pH of 5 with acetic acid. The extract obtained is analyzed to determine if any of the thresholds established for eight elements (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver), four specified pesticides, and two specified herbicides have been exceeded. If the EP extract contains one or more of these substances in an amount equal to or exceeding the levels specified in 40 CFR 261.24, the waste possesses the characteristic of EP toxicity. Since no route exists for the introduction of pesticides or herbicides in fuel cell polyurethane foam, no analyses for these substances were performed on the ash.

The EP Toxicity Tests were performed as described in Reference B1. A new procedure (Toxicity Characteristic Leaching Procedure, TCLP) is being proposed to better mimic leaching of organic constituents; however, the existing EP test is believed by the EPA to be adequate for elemental contaminants (Reference B2). The extracts from sample A1 (Incineration Test Series 1 residue) and from combined samples B1, B2, and B3 were analyzed by Atomic Absorption Spectroscopy and the results are reported in Table B7.

## TABLE B7. CONTAMINANT CONCENTRATION FROM EP TOXICITY TESTS.

| | Concentration, milligrams/liter | | | |
|---|---|---|---|---|
| Contaminant | A1 | Combined B1+B2+B3 | Nominal detection limits | Maximum allowable |
| Arsenic | <0.05 | <0.05 | 0.05 | 5.0 |
| Barium | 0.12 | 1.67 | 0.005 | 100.0 |
| Cadmium | <0.01 | <0.01 | 0.01 | 1.0 |
| Chromium | <0.05 | <0.05 | 0.05 | 5.0 |
| Lead | <0.05 | <0.05 | 0.05 | 5.0 |
| Mercury | <0.01 | <0.01 | 0.01 | 0.2 |
| Selenium | <0.01 | <0.01 | 0.01 | 1.0 |
| Silver | <0.05 | <0.05 | 0.05 | 5.0 |

# ORGANIC COMPONENTS

Attempts were made to detect extractable, organic components of the ash with gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS). Several small pieces of sample A1 were ground to give 15 grams of material which was combined with 10 ml of distilled water. The mixture was allowed to sit for several days and was then filtered several times (to remove all particulates). The filtrate was used for analysis. Samples B1, B2, and B3 were extracted in the same way except for the use of 7.5 grams of material in 20 ml of water. The use of a 0.45 micron filter on the latter samples permitted a single filtration. Extractions were also made with 25 ml of methanol and 30 grams of sample A1 and with 15 ml of methanol and 30 grams of a mixture of B1, B2, and B3. These methanol extractions were made by shaking the mixtures of ground sample and the HPLC-grade solvent several times and then allowing them to sit for 24 hours before filtering.

The gas chromatographic analyses were performed on a Hewlett-Packard HP 5880A gas chromatograph equipped with a flame ionization detector (FID). The GC wall-coated open tubular (WCOT) capillary column had the following characteristics: 12.5 meter length, 0.2 mm ID, 0.33 micron film thickness, cross-linked dimethyl silicone , 150 phase ratio, 1437.5 retention index, 4600 plates/meter, 1.4 acid/base ratio, Hewlett-Packard part number 19091-60312. All peaks and peak areas on the HP 5880A GC were taken from the attached HP 3350 laboratory automation system integrator. Helium was employed as the carrier gas.

The detection limits and uncertainties in quantification of small quantities were determined for the HP5880A GC using 30°C isothermal conditions and a 200:1 split ratio as follows. Chromatographic peak intensity (integrated peak area, A) is proportional to concentration (C) and injection volume (V),

$$A = kCV,$$

where k is a constant of proportionality. Peak areas may be determined from the computerized HP 3350 integrator. The minimum peak integration area measurable above noise is 0.05 (units of 1/8 microvolt-seconds) with an estimated standard deviation of 0.02 (40 percent). With the instrument at its highest sensitivity (attenuation -4), an injection of 100 microliters of methanol vapor at 24 ppm yields an area of 1.20. From this the minimum peak area of 0.05 corresponds to a concentration of 1 ppm. The calculated uncertainties for various concentrations of gaseous methanol and for selected gaseous hydrocarbon standards are shown in Table B8.

TABLE B8. UNCERTAINTY IN QUANTIFICATION OF GASES.

| | Uncertainty, percent | | | |
|---|---|---|---|---|
| Concentration, ppm | methanol | methane | ethane | propanes/butanes |
| 1 | 40. | ---- | ---- | ---- |
| 2 | 20. | 84. | 40. | 23. |
| 4 | ---- | 43. | 22. | 11. |
| 10 | 10. | 14. | 9. | 5. |
| 25 | 1.3 | 10. | 4. | 2. |
| 50 | 0.6 | 6. | 2. | 1. |
| 100 | 0.4 | 5. | 1. | 0.6 |

In many cases, peaks which are too small to be detected by the HP5880A computer can still be detected visually. In this case the peak height (H) in millimeters measured from the graphical output can be used. For small, sharp peaks,

$$H = k'CV.$$

A 1 ppm solution of methanol in water gives peak heights of 6 mm and 11 mm for injection volumes of 0.2 and 0.5 microliters. It is estimated that a peak height of 3 mm could be detected. This indicates that 0.5 ppm of methanol can be detected and quantified. The uncertainty in quantification, however, is rather large. For a peak of 3 mm, the minimum peak height, the standard deviation above noise is estimated at 1 mm (30 percent error).

This work shows that gaseous hydrocarbons and methanol down to 1 ppm can be detected and quantified. Somewhat better detection limits exist for liquid samples and for splitless injection.

Gas chromatography/mass spectrometry was performed with a Finnigan Model 4600 Gas Chromatograph/Mass Spectrometer with computerized spectral matching capabilities. The capillary column characteristics are 30 meter length, 0.2 mm ID, 0.25 micron film thickness, SE-54 phase ("nonpolar"), 94 percent-dimethyl-5 percent-diphenyl-1 percent-vinyl-polysiloxane, J&W Scientific catalog number 112-5432.

The gas chromatography and gas chromatography/mass spectrometry determinations performed on the ash extracts showed only peaks identified as coming from impurities within the solvents or from column bleed. Since high-boiling polycyclic aromatic hydrocarbons (PAHs) are considered the most likely component to be found in the ash residue, the chromatographic analyses were performed with a variable temperature program including an eight-minute final time at 250°C. Again no peaks arising from ash components were detected.

# DISCUSSION

The density of the combustion residue from the first series of tests was approximately one-half that of the residue from the second series. Elemental analyses showed a large amount of carbon, nitrogen, and, to a lesser extent, hydrogen in the residue from the first series of tests and very small amounts of these materials in the residue from the second series. The residue from the first series could be burned further with a significant loss of weight. All of these observations show that the combustion in the Series 1 tests, with the smaller incinerator, was much less complete than that in the Series 2 tests.

The density of the ground material (void spaces presumably eliminated) was about twice that of unground material of the same sample (i.e., including the void spaces). This indicates that about one-half the residual ash is void space.

The ash easily passes the Extraction Procedure Toxicity Test, and since it exhibits none of the other characteristics of a hazardous waste (ignitability, corrosivity, and reactivity) as defined in the Code of Federal Regulations (Reference B3) and is not a listed waste, it is not classifiable as a hazardous waste under RCRA except in those states which classify the foam itself as a hazardous waste. That organic materials down to the 1 ppm level are not detected in water or methanol extracts of the ash samples indicates that there should be no environmentally unacceptable leachates upon disposal in a landfill. Apparently the carbon in the samples is primarily amorphous rather than organic.

# CONCLUSIONS AND RECOMMENDATIONS

The larger CONSUMAT incinerator used in the Series 2 tests gives less ash (better volume reduction) than does the smaller incinerator used for the Series 2 tests. This observation gives no information about emissions, which were separately evaluated. With either incinerator, the ash from combustion of polyurethane fuel cell foam is environmentally acceptable and is not a hazardous waste under RCRA regulations or under regulations of the states of Georgia or Utah. The ash could be landfilled, if desired, in those states. Since ash residues from hazardous wastes are classified as hazardous under RCRA, the ash, unless delisted, would automatically be considered a hazardous waste in most states considering the foam to be a hazardous waste.

# LIST OF REFERENCES

B1. Test Methods for the Evaluation of Solid Wastes, Physical/Chemical Methods, EPA Publication SW-846, 2nd. Ed., 1982, as amended by Update I (April. 1984) and Update II (April, 1985)

B2. Toxicity Characteristic Leaching Procedure, U.S. EPA, Office of Solid Waste, 10 March 1968.

B3. Identification and Listing of Hazardous Waste, Subpart C, "Characteristics of a Hazardous Waste," 40 CFR 261.20 through 40 CFR 261.23.

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# APPENDIX C
# LABORATORY RESULTS AND PATENT EVALUATION

TABLE C-1. HYDROLYSIS.

| SAMPLE | TIME AT WHICH DEGRADATION OCCURRED |
|---|---|
| Red (dry) | 189 Hours |
| Orange (dry) | 189 Hours |
| Yellow (dry) | 189 Hours |
| Light Blue (dry) | 237 Hours (not totally degraded) |
| Dark Blue (dry) | 237 Hours (not totally degraded) |
| Red (immersed in water) | 72 Hours |
| Orange (immersed in water) | 72 Hours |
| Yellow (immersed in water) | 72 Hours |
| Light Blue (immersed in water) | 496 Hours |
| Dark Blue (immersed in water) | 496 Hours |

## TABLE C-2. ULTRAVIOLET DEGRADATION.

| TYPE OF FOAM | DURATION OF TEST (HOURS) | PERCENT WEIGHT LOSS | OBSERVATIONS |
|---|---|---|---|
| Yellow (Polyester) | 125 | 5.34 | Discoloration of foam on the side of the specimen facing the light source. |
| Red (Polyester) | 110 | 1.07 | Discoloration of foam on the side of the specimen facing the light source. |
| Orange (Polyester) | 162 | 9.68 | Same discoloration as above. Slight white residue on flask and a strong odor was present. |
| Light Blue (Polyether) | 117 | 5.37 | Same discoloration as above. Some crumbling and a strong odor were present. |
| Dark Blue (Polyether) | 119 | 17.43 | Same discoloration and strong odor as above. Much of the specimen was brittle and crumbled. |
| Dark Blue (Polyether immersed in water) | 110 | 1.44 | Some white residue on the side of the specimen facing the light source. |
| Dark Blue (Polyether subjected to water vapor) | 110 | 7.41 | Discoloration of foam specimen on the side facing light source. Some crumbling of specimen was observed. |

TABLE C-3. BIODEGRADATION TEST NO. 1.

Duration of Test: 14 Days

| SAMPLE | BACTERIA/MEDIUM | INITIAL WEIGHT (GRAMS) | FINAL WEIGHT (GRAMS) | PERCENT WEIGHT LOSS |
|---|---|---|---|---|
| Dk. Blue No. 1 | SYBRON Chemicals BI-Chem DC-1002 CG/ DC - 1009 - Cy mix | 0.3973 | 0.3966 | 0.18 |
| Dk. Blue No. 2 | Same | 0.3958 | 0.3969 | -0.28 |
| Dk. Blue No. 3 | Same | 0.4019 | 0.4014 | 0.12 |
| Lt. Blue No. 1 | Same | 0.4669 | 0.4695 | -0.56 |
| Lt. Blue No. 2 | Same | 0.4452 | 0.4460 | -0.18 |
| Lt. Blue No. 3 | Same | 0.4550 | 0.4568 | -0.40 |
| Yellow No. 1 | Same | 0.4322 | 0.4257 | 1.5 |
| Yellow No. 2 | Same | 0.4578 | 0.4571 | 0.15 |
| Yellow No. 3 | Same | 0.4856 | 0.4777 | 1.63 |
| Red No. 1 | Same | 0.4683 | 0.4615 | 1.45 |
| Red No. 2 | Same | 0.4348 | 0.4278 | 1.61 |
| Red No. 3 | Same | 0.4396 | 0.4300 | 2.18 |
| Orange No. 1 | Same | 0.6620 | 0.6500 | 1.81 |
| Orange No. 2 | Same | 0.5979 | 0.5864 | 1.92 |
| Orange No. 3 | Same | 0.6026 | 0.5903 | 2.04 |

## TABLE C-4. BIODEGRADATION TEST NO. 2.

Duration of Test: 8 Days

| SAMPLE | BACTERIA/MEDIUM | INITIAL WEIGHT (GRAMS) | FINAL WEIGHT (GRAMS) | PERCENT WEIGHT LOSS |
|---|---|---|---|---|
| Dk. Blue No. 1 | SYBRON Chemicals BI-Chem DC-1002 CG/ DC - 1009 - Cy 0.1 M Phosphate Buffered Ammonia Solution | 0.3729 | 0.3712 | 0.46 |
| Dk. Blue No. 2 | Same | 0.4145 | 0.4140 | 0.12 |
| Dk. Blue No. 3 | Same | 0.3867 | 0.3879 | -0.31 |
| Lt. Blue No. 1 | Same | 0.4432 | 0.4449 | -0.38 |
| Lt. Blue No. 2 | Same | 0.4646 | 0.4643 | 0.06 |
| Lt. Blue No. 3 | Same | 0.4486 | 0.4501 | -0.33 |
| Yellow No. 1 | Same | 0.4312 | 0.4269 | 1.0 |
| Yellow No. 2 | Same | 0.4515 | 0.4437 | 1.74 |
| Yellow No. 3 | Same | 0.4373 | 0.4312 | 1.39 |
| Red No. 1 | Same | 0.4611 | 0.4547 | 1.39 |
| Red No. 2 | Same | 0.4578 | 0.4508 | 1.53 |
| Red No. 3 | Same | 0.4727 | 0.4639 | 1.86 |
| Orange No. 1 | Same | 0.5746 | 0.5662 | 1.46 |
| Orange No. 2 | Same | 0.5800 | 0.5676 | 2.14 |
| Orange No. 3 | Same | 0.6415 | 0.6275 | 2.18 |

## PATENT EVALUATION

| PATENT NO./ DATE | INVENTOR | PROCESS | TIME/TEMP | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|---|---|
| 2,937,151<br>May 17, 1960 | T. Broeck<br>Goodyear Tire | Heating chopped foam in a liquid active-hydrogen containing polymeric material. | 2 hrs/250°C | Simple. | Chemicals undefined. |
| 3,10-9,824<br>Nov. 5, 1963 | H. Heiss<br>Mobay Chemical | Heating scrap in carboxylic acid - tall oil. | 4-8 hrs/<br>150°-200°C | Simple. | Process unrefined, chemicals are messy. |
| 3,117,940<br>Jan. 14, 1964 | W. McElroy<br>Mobay Chemical | Heating scrap in the primary amine and tertiary amine catalyst. | ?/70°C<br>125°-220°C | Product used as plasticizers (moldings and coatings). | Chemicals might not be common and would be hard to locate. |
| 3,123,577<br>Mar. 3, 1964 | H. Heiss<br>Mobay Chemical | Shredding by roller mill and heating in $H_2O$ or an organic fluid w/catalyst. | 5-15 min./<br>150°-225°C | Wide range of chemicals will work. | $H_2O$ will not degrade the foam. Chemicals may make material more hazardous than before. |
| 3,404,103<br>Oct. 1, 1968 | N. Matsudaria<br>Bridgestone Tire<br>Tokyo, Japan | Thermally decomposing scrap in amine and an alkali metal oxide or hydroxide or alkaline earth metal oxide. | 3 hrs/<br>150°-160°C | Product can be used for dyestuff, pesticide, medicine. | Amines hard to locate, NaOH extremely hazardous. |

| PATENT NO./ DATE | INVENTOR | PROCESS | TIME/TEMP | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|---|---|
| 3,441,16<br>Apr. 29, 1969 | L. Pizzini<br>Wyandotte Chemical | Hydroxysis in a $H_2O$/Dimethyl-sulfoxide medium (with a strong base). | 1-10 hrs/<br>110°-150°C | Test is at atmospheric pressure, the extracting process uses gasoline, kerosene and other organic solvents. | The strong bases (NaOH) are extremely hazardous. |
| 3,632,530<br>Jan. 4, 1972 | O. Kinoshita | a) Dissociation in heated alcohol<br>b) Dissociation in heated glycol. | 8 hrs/<br>170°-185°C | Simple;<br>dissociation. | Product separates into two layers. |
| 3,738,946<br>June 12, 1973 | F. Frulla<br>UpJohn Co. | Scrap is ground into fine pieces, and heated in a dihydroxy compound (aliphatic diol and dialkanol-amine). | 3-15 hrs/<br>185°-225°C | Process good for both polyethers and polyesters. | Chemicals could be hard to find and process takes too long. |
| 3,708,440<br>Jan. 2, 1973 | F. Frulla<br>UpJohn Co. | Same as above. | --- | --- | This process is for polyisocyanurate, not polyurethane. |
| 3,954,681<br>May 4, 1976 | R. Castle<br>Whittaker Corp. | Foam is soaked in a keytene (MEK) until brittle (3-16 hrs) and then milled. A devulcanizer is added and the mixture is heated under pressure. | 3-5 min/<br>120°-280°C | Product can be used to make thermoplastics (pot handles), adhesives, or other thermosetting compounds. | Foam does not seem to become brittle in actual tests. |

| PATENT NO./ DATE | INVENTOR | PROCESS | TIME/TEMP | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|---|---|
| 3,983, 087<br>Sept. 28, 1976 | B. Tucker | Scrap is heated in comminuted (chopped up) form with an aliphatic diol. | 2-12 hrs/ 180°-250°C | Extremely simple. | High temperatures, messy product. |
| 4,014,809<br>Mar. 29, 1977 | O. Kondo<br>Bridgestone Tire<br>Tokyo, Japan | Scrap is heated in a mixture of an aliphatic diol and a mon-alkanol-amine. | 45 min-<br>2 hrs/<br>150°-220°C | --- | This process is for rigid polyurethane foam. |
| 4,035,314<br>July 12, 1977 | D. Lohr<br>Firestone Tire and Rubber Co. | Scrap is shredded and hydrolysed in superheated steam (under pressure). | 12-24 hrs/ 175°-300°C | No chemicals involved in the initial process, process is well defined. | High temperatures and pressures (225 psig) are needed. |
| 4,039,568<br>Aug. 2, 1977 | K. Sakai<br>Kyoto, Japan | Scrap is heated with alcoholate, alkalihydroxide, and a decomposition accelerator. | .33-10 hrs/ 50°-180°C | Conducted at atmospheric pressure, low temperatures. | Complicated chemicals and strong bases are involved. |
| 4,110,266<br>Aug. 29, 1978 | M. Sheratte<br>McDonnell Douglas Corp. | Scrap is placed in a steam autoclave with an amine, ammonia, or ammonium hydroxide used as decomposing agents. | 10 sec-<br>1 min,<br>15 min-<br>3 hrs/<br>120°-140°C | Short reaction time. | Steam autoclave and relatively high temperatures. |

| PATENT NO./ DATE | INVENTOR | PROCESS | TIME/TEMP | ADVANTAGES | DISADVANTAGES |
|---|---|---|---|---|---|
| 4,159,972<br>Jul. 3, 1979 | J. Braslaw<br>Ford Motor Co. | Foam is dissolved in low molecular weight aliphatic (diethylene glycol). This mixture is heated. | 40 min-3 hrs/ 180°-200°C | Simple process. | Diols may be hard to locate. |
| 4,316,992<br>Feb. 23, 1982 | J. Gerlock<br>Ford Motor Co. | Foam is reacted in a heated mixture of an alcohol (glycol ether), in a non-oxidizing atmosphere. It is then hydrolysed in super heated steam. A catalyst (alkali metal hydroxide) can be used. | 8 hrs/ 185°-220°C | Drawing of apparatus is given, process is well defined. | Catalysts may be hazardous. |
| 4,317,939<br>Mar. 2, 1982 | J. Gerlock<br>Ford Motor Co. | Same process as above, except with a simpler apparatus. | Same as above. | Same as above. | Same as above. |

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# APPENDIX D

# INCINERATOR COMPANY CONTACTS AND INSTALLATION/OPERATION PERMITS

# INCINERATOR COMPANY CONTACTS

1. Advanced Combustion Systems, Inc.
   Mike Milnes
   2183 E. Bakerview
   Bellingham, Washington 98226
   Phone (206) 676-6005

2. Alpine Products
   Paul Heffron
   3235 Vassar N.E.
   Albuquerque, New Mexico 87107
   Phone (505) 884-1193

3. Consumat Systems, Inc.
   Dan Tuszynski
   P.O. Box 9379
   Richmond, Virginia 23227
   Phone (804) 746-4120

4. Incinerators International, Inc.
   Dick Dunham
   2702 N. Main
   P.O. Box 8617
   Houston, Texas 77249
   Phone (713) 227-1466

5. Hi Temp Tech Corporation
   Steve Parker
   P.O. Box 903
   Flemington, New Jersey 08822
   Phone (210) 788-6999

6. Industrial Waste Industries
   Mehrdad Etemad
   1777 Walton Road
   Blue Bell, Pennsylvania 19422
   Phone (215) 643-2100

7. Omega Conversion, Inc.
   Ken Hladin
   1137 N. Woodvine Avenue
   Narberthe, Pennsylvania 19072
   Phone (215) 664-6554

8. Southeastern Waste Control
Paul Scarberry
P.O. Box 278
Charleston, South Carolina 29402
Phone (803) 723-6240

9. Trane Thermal
Frank Romano
Brook Road
Conshohocken, Pennsylvania 19428
Phone (215) 828-5400

10. Thermal Reduction Co.
Brian Stephen
1321 King Street
Bellingham, Washington 98226
Phone (206) 676-0660

**APPLICATION FOR AN AIR QUALITY PERMIT TO CONSTRUCT, MODIFY OR OPERATE AN INCINERATOR**

Complete and return two copies to:

AIR QUALITY CONTROL SECTION
ENVIRONMENTAL PROTECTION DIVISION
DEPARTMENT OF NATURAL RESOURCES
270 Washington Street, S.W., Rm. 816
Atlanta, Georgia 30334

DO NOT WRITE IN THIS SPACE
Permit No.: ____________
Date Approved: ____________
Date Disapproved: ____________
Reviewer: ____________

I THIS APPLICATION IS FOR: New Installation____ Extensive Modification____

GIVE BEST ESTIMATED DATE TO:

Begin Installation____________ Start up Equipment____________

Has the incinerator been previously permitted? ____________

If yes, give date____________and permit number____________

II ____________________________________
NAME OF FIRM, INSTITUTION OR ESTABLISHMENT:

____________________________________
MAILING ADDRESS OF CENTRAL OFFICE (street/P.O. Box, city, state, zip code)

____________________________________
INCINERATOR LOCATION (street, city, county, zip code)

____________________________________
PERSON TO CONTACT REGARDING THIS APPLICATION (name and title) TELEPHONE

III ____________________________________
NAME OF CONSULTING FIRM

____________________________________
ADDRESS (street, or P.O. Box, city, state, zip code) TELEPHONE

IV ADDITIONAL INFORMATION REQUIRED:

(1) Include detailed drawings of the unit along with pertinent specifications and combustion calculations, showing location and size of all burners, timers, air inlets, dampers, volumes and construction materials. These drawings must show the unit to be installed, not a general description. Detailed drawings of any type control equipment used in conjunction with this unit should be included. If a permit for modification is desired, drawings must show the unit before and after the proposed modification.

(2) A plot plan and/or location map should be included showing incinerator location with respect to surrounding buildings, roads and residential areas.

V TECHNICAL DATA ON INCINERATOR:

(A) INCINERATOR MAKE AND MODEL NUMBER ____________

RATED CAPACITY FOR I.I.A. TYPE WASTE ____________ lbs/hr

(B) MANUFACTURERS CERTIFICATION OF EMISSIONS AT NORMAL RATED CONDITIONS:
(1) Particulate Corrected to 12% $CO_2$ ______ Grains/dscf
(2) Opacity of Visible Emissions ______ %

(C) STACK: Height ____ ft Dia ____ ft Temp ____ °F Flow Rate ______ SCFM

(D) DRAFT: ______ CFM; Natural( ), Induced( ), Forced( ), Excess Air ______ %

(E) FOR STARVED AND CONTROLLED AIR INCINERATORS:
Number of Chambers; 1 ( ), 2 ( ), 3 ( ) (If 3, complete section "F")
Primary Chamber Volume ______ $ft^3$ Secondary Chamber Volume ______ $ft^3$

(F) FOR MULTI AND THREE CHAMBERED STARVED OR CONTROLLED AIR INCINERATORS:
(1) Primary Chamber Volume __________ $ft^3$
(2) Flame Port Area __________ $ft^2$
(3) Settling Chamber Area __________ $ft^2$
(4) Settling Chamber Length __________ ft
(5) Hearth Area __________ $ft^2$
(6) Effective Grate Area __________ $ft^2$

(G) BURNERS: Primary; number __________, Size __________ BTU/HR
Secondary; number __________, Size __________ BTU/HR

(H) FUEL: Type __________ Estimated Annual Consumption __________

(I) OPERATING SCHEDULE ______ lb/waste/hr, ____ hr/day, ______ day/wk, ____ wk/yr

(J) TYPE WASTE: Give expected lb/hr of each and BTU/lb if #5 or #6 waste
(0) ________ (1) ________ (2) ________ (3) ________ (4) ________
(5) ________ lb/hr ________ BTU/lb (6) ________ lb/hr ________ BTU/lb

Infectious (Give breakdown) ____________

VI THIS APPLICATION FOR AN AIR QUALITY PERMIT IS SUBMITTED IN ACCORDANCE WITH THE PROVISIONS OF THE GEORGIA AIR QUALITY RULES AND REGULATIONS, AND TO THE BEST OF MY KNOWLEDGE IS TRUE AND CORRECT.

NAME OF OWNER OR AUTHORIZED OFFICIAL ____________ TITLE ____________

SIGNATURE ____________ DATE ____________

# COUNTY OF SACRAMENTO
## AIR POLLUTION CONTROL DISTRICT

NORM COVELL
AIR POLLUTION CONTROL OFFICER
9323 Tech Center Drive, Suite 800
Sacramento, California 95826
(916) 366-2107

## APPLICATION FOR AUTHORITY TO CONSTRUCT AND PERMIT TO OPERATE

**INSTRUCTIONS**

A. This application form must be filled out completely

B. The appropriate filing fee must be submitted with the application

1. Business License Name of organization that is to receive the permit: ______________________

2. Mailing Address: ______________________ (NUMBER, STREET, CITY, ZIP CODE, TEL. NO.)

3. Pursuant to the provisions of the Health & Safety Code of the State of California and the Rules & Regulations, Sacramento County Air Pollution Control District, application is hereby made for Authority to Construct and Permit to Operate the following:
______________________
______________________

4. Above equipment to be operated at: ______________________ (NUMBER, STREET, CITY OR COMMUNITY)

5. Estimated Starting Date: ____________ Estimated Completion Date: ____________

6. If change of ownership give date of transfer: ____________

7. Signature of responsible officer, partner, or proprietor of firm ______________________ Date ____________

8. Type or print name and title of above officer: ______________________ (NAME, TITLE)

DO NOT WRITE BELOW (A.P.C.D. USE ONLY)

| | | | |
|---|---|---|---|
| DATE STAMP | APPLICATION AND PERMIT NUMBER | A/C FEE | A/C RECEIPT |
| | DATE P/O ISSUED | P/O FEE | P/O RECEIPT |
| | ZONE | MAP PAGE | PREVIOUS P/O |

Further information or clarification concerning permits can be obtained by writing or calling (916) 366-2107