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# Reference 3

## WASTE OIL COMBUSTION AT A BATCH ASPHALT PLANT: TRIAL BURN SAMPLING AND ANALYSIS

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## INTRODUCTION

### Statement of the Problem

The Massachusetts Asphalt Pavement Association (MAPA) represents a number of firms operating batch asphalt plants, some of which burn waste oil as fuel. Collectively, these plants consume approximately one half of the estimated quantity of waste oil that is generated each year in Massachusetts.

The Massachusetts Department of Environmental Quality Engineering (DEQE) lists waste oils as hazardous wastes on the basis that the oils typically contain high levels of lead and chlorinated organic solvents and may contain other metals and/or trace contaminants of environmental concern. The DEQE Interim Policy on Use of Waste Oils/Solvents as Fuel recognizes that such use can provide an economic, efficient, and safe means of disposal, if adequate assurance can be given that the environment will not be adversely affected. The Department considers it appropriate to develop regulations/guidelines governing continued use of waste oils as fuels by present and potential users.

DEQE believes that the data previously available relating to possible emissions from combustion sources burning waste oils as fuel are in many cases inadequate to support the development of regulations/guidelines. In particular, DEQE asked MAPA to undertake a trial burn to generate data on destruction efficiency and potential air emissions from batch asphalt plants using waste oil as fuel. It was agreed between MAPA and DEQE that testing to acquire the necessary data be conducted at one representative plant in the fall of 1982. MAPA contracted with Arthur D. Little, Inc. to assist in the development of a specific trial burn plan, to conduct the sampling and analyses, and to report the data in a form suitable for comparison with emission or performance criteria.

### Objectives of the Study

The objective of the trial burn sampling and analysis was to obtain data that address the possible incremental impact of burning waste oil, as an alternative to conventional petroleum fuels, in batch asphalt plants. A comprehensive environmental assessment of batch asphalt plant performance was not part of the scope of this activity. Instead, the tests focused specifically on those elements and potential pollutants suspected to be present as contaminants in waste oil but not in "clean" fuels. The contaminants of particular concern and the approximate levels at which they have commonly been encountered in waste oils are lead and other heavy metals, typically at concentrations of 100-1500 ppm, and chlorinated solvents (such as methylene chloride, Freon 113, 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene) at concentration levels of 200-2000 ppm or higher.

A trial burn plan was designed of designated heavy metals and batch asphalt plant, selected trial burn plan was approved b tests were conducted in accord are noted in this report. The standards that apply specifica plants; this project was esse to support development of fut therefore, a compliance test, based on these test data. As data were generated relevant emission performance standard

### EXPERIMENTAL

In this project a total of th performed at a representative on process operating conditio Samples of the reprocessed o effluents were collected dur to determine the concentrati chromium, lead, trichloroeth and effluent streams. Parti also determined.

### Facility

The representative facility asphalt plant operated by tl shown schematically in Figu process flow are also indic sampled from a recycle line 32' long by 8.7' rotary kil downstream of the fabric fi (baghouse). The stack at t to allow sampling in accord catch was sampled from a ta

### Sampling Procedures

Fuel samples were prepared every 15 minutes during ea headspace in the pre-clean taken during each run were for the several chemical a

Stack gas samples for dete and hydrochloric acid emis sampling train. A 108-min 0.87 ft<sup>3</sup>/min was used to impingers of the train co collection of volatile me collection of hydrochlori during the course of each

A trial burn plan was designed to provide information related to emissions 83-51.1 of designated heavy metals and chlorinated solvents from a representative batch asphalt plant, selected by MAPA and subject to approval by DEQE. The trial burn plan was approved by both MAPA and DEQE prior to testing. The tests were conducted in accordance with the plan with a few exceptions which are noted in this report. There are no existing emission or performance standards that apply specifically to these pollutants from batch asphalt plants; this project was essentially a research and data-gathering effort to support development of future guidelines and standards. This was not, therefore, a compliance test, nor will DEQE undertake enforcement action based on these test data. As part of the overall test program, however, data were generated relevant to compliance with the existing particulate emission performance standards for asphalt plants.

(MAPA) represents a number of which burn waste oil as approximately one half of the used each year in Massachusetts.

Quality Engineering (DEQE) is that the oils typically organic solvents and may contain environmental concern. The DEQE Fuel recognizes that such feasible means of disposal, if comment will not be adversely relate to develop regulations/ is as fuels by present and

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analysis was to obtain data of burning waste oil, as an in batch asphalt plants. A batch asphalt plant performance Instead, the tests focused pollutants suspected to be in "clean" fuels. The approximate levels at which oils are lead and other heavy 00 ppm, and chlorinated 13, 1,1,1-trichloroethane, t concentration levels of

#### EXPERIMENTAL

In this project a total of three complete tests and one partial test were performed at a representative batch asphalt plant. During each test, data on process operating conditions were recorded at 15 minute intervals. Samples of the reprocessed oil feed and of stack gas and baghouse catch effluents were collected during each test. Chemical analysis was conducted to determine the concentrations of selected contaminants--arsenic, cadmium, chromium, lead, trichloroethylene, and polychlorinated biphenyls--in influent and effluent streams. Particulate matter emissions from the stack were also determined.

#### Facility

The representative facility selected for these tests was a 5-ton batch asphalt plant operated by the Simeone Corporation at Wrentham, Massachusetts, shown schematically in Figure 1. The locations of sampling points in the process flow are also indicated in the figure. The waste oil feed was sampled from a recycle line adjacent to the burner. Emissions from the 32' long by 8.7' rotary kiln used for the drying of aggregate were sampled downstream of the fabric filter particulate material control device (baghouse). The stack at the facility was extended for the test in order to allow sampling in accordance with EPA Method 5 criteria. The baghouse catch was sampled from a tap in the first baghouse hopper.

#### Sampling Procedures

Fuel samples were prepared as composites. One liter of fuel was collected every 15 minutes during each test run with care taken to minimize the headspace in the pre-cleaned 1-L borosilicate glass jars. The subsamples taken during each run were mixed and aliquots of appropriate sizes withdrawn for the several chemical analyses performed on the fuel.

Stack gas samples for determination of particulate material, heavy metals, and hydrochloric acid emissions were collected with an EPA Method 5 (1) sampling train. A 108-minute sampling period at an average rate of 0.87 ft<sup>3</sup>/min was used to collect a 90-100 ft<sup>3</sup> sample for each run. The impingers of the train contained, in series, 100 mL 0.1 N nitric acid for collection of volatile metals and 100 mL of 0.1 N sodium carbonate for collection of hydrochloric acid. Grab samples were taken for ORSAT analysis during the course of each Method 5 run.

Stack gas samples for determination of volatile organic chlorine species (RCl) were collected on a sorbent tube, shown schematically in Figure 2. Precalibrated constant flow pumps were used to draw stack gas through 0.25" OD glass probes (in a stainless steel sheath) and into the tubes. Four 0.3 L and two 2 L samples were collected over the course of each Method 5 run.

Baghouse catch samples were collected at 15 minute intervals during each run. The subsamples were composited by cone-and-quartering and aliquots were removed for the several chemical analyses.

#### Analysis Procedures

Metals were determined by inductively coupled plasma emission spectroscopy (Barringer Magenta Laboratories, Ltd.) or atomic absorption spectroscopy. Fuel samples were prepared for analysis by dilution into methyl isobutyl ketone. Stack gas and baghouse particulate samples were subjected to acid digestion prior to analysis.

Chlorinated organic species were determined by gas chromatography/mass spectrometry (GC/MS). Five samples were extracted with tetraglyme, diluted into water, and introduced to the instrument via a purge-and-trap system. Stack gas RCl tubes were analyzed by a direct thermal desorption technique.

Polychlorinated biphenyls in the fuel samples were quantified by a gas chromatography/electron capture detection technique, with GC/MS confirmation.

Hydrochloric acid was determined as chloride by ion chromatography.

#### RESULTS AND CONCLUSIONS

##### Operating Conditions

Table 1 presents average values of the facility operating conditions during these tests. These values are within the normal range of operations for this facility, although the production rate and fuel usage were somewhat lower than the averages for this plant. Short-term variations in process parameters, which are typical of batch operations, were observed. Overall, the process data indicate that the plant was operating normally during the tests; there was no evidence of upset conditions.

##### Feed Characteristics

A blend of approximately equal volumes of reprocessed oil from three local suppliers comprised the proposed test fuel. Before testing was initiated, the fuel was analyzed for the contaminants of interest to determine whether the blend was representative of typical reprocessed oils. Of special interest was the level of volatile chlorinated organic species (RCl's) in the fuel as delivered, as two primary goals of this program were to insure that these compounds were present in sufficient amounts to be detected at the stack and to simulate the highest level type of fuel likely to be burned. Analysis of the fuel as delivered showed only 0.16% by weight of total RCl species. To achieve the desired RCl level and to ensure detectable stack concentrations, trichloroethylene

was added to approximately 1% Removal Efficiency.

Except for the RCl concentration which were similar to the fuel as delivered throughout testing; the metals are presented in Table 2. Excessive metals (arsenic, cadmium, and mercury) are in the range expected for polychlorinated biphenyls (PCBs). The percent sulfur from 0.54-134, 250-141,650 British Thermal Units confirm that the test fuel was burned at this facility.

##### Emissions of Heavy Metals (A)

Table 3 presents a summary of the tests 2-4. The aspects of the concentrations and mass directly to the atmosphere, baghouse collection system.

The mass emission rates for are low, ranging from 0.000C. Correspondingly, concentrations about 0.2  $\mu\text{g}/\text{m}^3$  for arsenic

There are no stack emission which these measured concentrations for the evaluation of these Federal Primary Ambient Air Quality Standards. To achieve this ambient air concentration would require a less than 100% quantitative dispersion model which has a short stack in of this task. However, it to be greater than 20 on each

For arsenic, cadmium, and chromium. As for lead, a 1% effluent would lead to ambient concentrations which are below the quality standards. A reference metals can be generated from 4.2 to correct from a 40 by 100 to introduce an additional non-occupationally exposed are 0.48  $\mu\text{g}/\text{m}^3$  for arsenic, chromium. As for lead, a 1% effluent would lead to ambient concentrations which are below the quality standards.

The removal efficiency calculated the mass feed rate of each fuel to the stack. The removal efficiency for chromium to an average of 85% for chromium to an average of 85% could not be calculated for the other metals because below the analytical limit are consistent with the hypothesis that the particulate phase in the stack is the primary removal efficiency.

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Except for the RCl concentration, the characteristics of the fuel burned were similar to the fuel as delivered and remained consistent with each other throughout testing; the averages of the data from the four tests are presented in Table 2. Except for lead, the concentration of heavy metals (arsenic, cadmium, and chromium) is low; the levels of lead detected are in the range expected for this type of fuel. The concentration of polychlorinated biphenyls (PCBs) ranges from 5-7 ppm for the four tests, the percent sulfur from 0.54-0.60 and the higher heating value from 134,250-141,650 British Thermal Units (Btu) per gallon. These data confirm that the test fuel was representative of the reprocessed oil burned at this facility.

#### Emissions of Heavy Metals (As, Cd, Cr, Pb)

Table 3 presents a summary of the averages of the metals data for tests 2-4. The aspects of these data that are of primary interest are the concentrations and mass emissions in the stack gas, which is discharged directly to the atmosphere, and the removal efficiency achieved by the baghouse collection system.

The mass emission rates for each of the metals determined in this study are low, ranging from 0.00002 lb/hr for arsenic to 0.0031 lb/hr for lead. Correspondingly, concentrations in the stack gas are low, ranging from about 0.2  $\mu\text{g}/\text{m}^3$  for arsenic to about 25  $\mu\text{g}/\text{m}^3$  for lead.

There are no stack emission standards or criteria for these metals to which these measured concentrations can be compared. To provide a context for the evaluation of these results, however, it may be noted that the Federal Primary Ambient Air Quality Standard for lead is 1.5  $\mu\text{g}/\text{m}^3$  (2). To achieve this ambient air level given the measured stack gas concentration would require a less than twenty-fold stack-to-ground dilution. Quantitative dispersion modeling for the Simecne Corporation facility, which has a short stack in its normal configuration was beyond the scope of this task. However, it is reasonable to expect the dilution factor to be greater than 20 on either a 24-hour or an annual average basis.

For arsenic, cadmium, and chromium there are no Federal Ambient Air Quality Standards. A reference point for evaluating emissions of these metals can be generated from the OSHA workplace air standards (3), dividing by 4.2 to correct from a 40-hour work week to a 7 day/24-hour week and by 100 to introduce an additional safety factor for protection of the non-occupationally exposed population. These "adjusted TLV" (4) values are 0.48  $\mu\text{g}/\text{m}^3$  for arsenic, 0.12  $\mu\text{g}/\text{m}^3$  for cadmium and 1.2  $\mu\text{g}/\text{m}^3$  for chromium. As for lead, a less than twenty-fold dilution of the stack effluent would lead to ambient levels below these reference values.

The removal efficiency calculated by comparing the stack emission rate to the mass feed rate of each metal in each test ranges from an average of 85% for chromium to an average of 99.88% for lead. A removal efficiency could not be calculated for arsenic since the feed concentration was below the analytical limit of detection. These high removal efficiencies are consistent with the hypothesis that most of the metals are in the particulate phase in the kiln emissions and controlled by the high particulate removal efficiency of the baghouse.

The observation that the baghouse catch contains an average of 1.4 ppm of lead is not of concern since this catch is totally recycled at the plant studied. This could be a potential concern if the data were disposed of, rather than recycled, in some facilities.

#### Emissions of Trichloroethylene (TCE)

Table 4 outlines the average trichloroethylene (TCE) emissions for the four test runs, representing a concentration range of 205-592 micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ) and "worst-case" Destruction/Removal Efficiencies (DREs) of 99.45-99.92%. The "worst-case" DREs are presented throughout this report because an unknown source of contamination affected observed TCE results in a random manner and prevented the correction of the measured values.

There are no stack emission standards or criteria for TCE; adjustment of the OSHA workplace air standard Threshold Limit Value (TLV) of 538 milligrams per cubic meter ( $\text{mg}/\text{m}^3$ ) would result in a reference point of 1.3  $\text{mg}/\text{m}^3$  or 1300  $\mu\text{g}/\text{m}^3$  which is well above the measured stack emissions. U.S. east coast urban areas report ambient concentrations of TCE ranging from <0.3-47  $\mu\text{g}/\text{m}^3$  with a mean of 1-5  $\mu\text{g}/\text{m}^3$  (5). An average forty-fold stack-to-ground dilution would be required to bring the TCE emissions to an ambient concentration below 1  $\mu\text{g}/\text{m}^3$ .

#### Emissions of Hydrochloric Acid (HCl)

Table 5 outlines the average hydrochloric acid (HCl) emissions from Runs 2, 3, and 4; these represent a concentration range of 27.24-54.77 milligrams per dry standard cubic meter ( $\text{mg}/\text{dscm}$ ). These stack concentrations may be compared to an "adjusted TLV" reference concentration of 17  $\mu\text{g}/\text{m}^3$  in ambient air. A stack-to-ground dilution/dispersion factor of about 2500 would be required in order to reduce the average stack HCl concentration of 41.7  $\text{mg}/\text{m}^3$  to <17  $\mu\text{g}/\text{m}^3$ .

The mass emission rates corresponding to the stack HCl concentration ranged from 3.17-6.06 pounds per hour (lb/hr). As a reference point, one can consider whether these emissions would meet the U.S. EPA RCRA Standard (6), if the facility were a hazardous waste incinerator (which a batch asphalt plant is not). The federal requirement is that stack HCl emissions either be  $\leq 4$  lb/hr or controlled to  $\geq 99\%$  removal efficiency. The lower range of the values observed in these tests would meet such criterion, but the mean HCl emission rate of 4.81 lb/hr is slightly in excess of the reference value. It should be noted, however, that the test fuel, spiked to 1% with trichloroethylene, had a higher total chlorine content than is expected for "as delivered" fuel with more typical HCl concentrations of a few thousand ppm or less. Thus, one of the two generic approaches to control of overall HCl emissions--namely, an upper limit on the total chlorine content (including HCl) of the reprocessed oil--may be a reasonable alternative. The generic approach of controlling HCl emissions by the addition of wet scrubbing equipment would probably be at least equally effective in reducing emission levels, but probably less attractive economically.

#### Particulate Emissions

The particulate emission of 0.025 grains per dry standard cubic meter in all cases, the federal standard for asphalt plants was achieved to meet existing standards for normal steady-state concentrations.

#### SUMMARY

The results of these tests show that waste oil containing sulfur and organic species are summed to give total gas concentrations and are of concern. A stack-to-ground (hydrochloric acid) would be required to bring ambient concentrations to ambient concentrations.

#### ACKNOWLEDGMENT

The work described here was performed under contract to the Massachusetts Department of Environment by Gaffney, Executive Secr firs, the New England Massachusetts Department acknowledged.

#### REFERENCES

1. Title 40, Code of Federal Regulations, Part 61, "Determination of Emissions of Acid Gases from Hazardous Waste Incinerators," (Type 'S' Pitot Tube Method), (1981).
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6. Federal Register, 42, 1000-1005 (1977).
7. Title 40, Code of Federal Regulations, Part 61, "Control of Acid Gases from Hazardous Waste Incinerators," (1981).
8. Title 310, Code of Federal Regulations, Part 61, "Control of Acid Gases from Hazardous Waste Incinerators," (June 1, 1972) and (1981).

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#### Particulate Emissions

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The particulate emissions for Runs 2, 3, and 4 were 0.024, 0.032, and 0.025 grains per dry standard cubic foot (gr/dscf) respectively. In all cases, the federal and state standard of 0.04 gr/dscf (7,8) for batch asphalt plants was achieved. These data indicate that this facility will meet existing standards for particulate emissions when operating under normal steady-state conditions.

#### SUMMARY

The results of these tests at a representative batch asphalt plant burning waste oil containing substantial quantities of lead and of chlorinated organic species are summarized in Table 6, which presents average stack gas concentrations and destruction/removal efficiencies for contaminants of concern. A stack-to-ground dilution factor of 20 (metals) to 2500 (hydrochloric acid) would be sufficient to reduce the stack concentrations to ambient concentrations that are on the order of adjusted TLV criteria.

#### ACKNOWLEDGMENT

The work described here was conducted by Arthur D. Little, Inc. under contract to the Massachusetts Asphalt Pavement Association, Gordon E. Gaffney, Executive Secretary. The cooperation of several MAPA member firms, the New England Reprocessed Oil Dealers Association, and the Massachusetts Department of Environmental Quality Engineering is gratefully acknowledged.

#### REFERENCES

1. Title 40, Code of Federal Regulations, Part 60, Appendix A, Method 2: "Determination of Stack Gas Velocity and Volumetric Flow Rate (Type 'S' Pitot Tube)."
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7. Title 40, Code of Federal Regulations, Part 50, Subpart I (1981).
8. Title 310, Code of Massachusetts Regulations, Regulations 7 (June 1, 1972) and 8 (July 23, 1981).

TABLE 1. Summary of Plant Operating Conditions  
(mean values for Runs 2-4)

Dry Aggregate	173 tph	Production Rate
Finished Product	184 tph	
Fuel Usage Rate	332 gph	
Fuel Temperature	133°F	
Kiln Temperature	365°F	
Baghouse Temperature	269°F	
Baghouse Pressure Drop	7.5" Hg	
Stack Gas Flow	893 dscmm	

8

TABLE 2. Summary of Characteristics of Reprocessed Oil  
Burned during Tests (mean values for Runs 1-4)

		Feed Characteristics
Dry Aggregate		Density
Finished Product		7.5 lb/gal
Fuel Usage Rate		Higher Heating Value
Fuel Temperature		140,400 Btu/gal
Kiln Temperature		Sulfur Content
Baghouse Temperature		0.56%
Baghouse Pressure Drop		Chlorine Content
Stack Gas Flow		0.21%*
		0.94%**
Contaminant Levels:		
	Arsenic	<10 ppm
	Cadmium	1.0 ppm
	Chromium	7 ppm
	Lead	997 ppm
	Trichloroethylene	0.89%**
	PCBs	5-7 ppm

\*base fuel

\*\*spiked fuel

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TABLE 3. Summary of Data for Heavy Metals  
(mean values for Runs 2, 3, 4)

Influent	As	Cd	Cr	Pb
Concentration in reprocessed oil, ppm	<10	1.0	7	997
Mass feed rate, lb/hr	<2.68 x 10 <sup>-2</sup>	2.8 x 10 <sup>-3</sup>	1.78 x 10 <sup>-2</sup>	2.67
Stack Gas Effluent	0.175	0.605	23.1	26.4
Concentration, $\mu\text{g/dscmm}$	$8.82 \times 10^{-5}$	$7.00 \times 10^{-5}$	$2.71 \times 10^{-3}$	$3.08 \times 10^{-3}$

\*base fuel  
\*\*spiked fuel

TABLE 3. Summary of Data for Heavy Metals  
(mean values for Runs 2, 3, 4)

<u>Influent</u>	<u>As</u>	<u>Cd</u>	<u>Cr</u>	<u>Pb</u>
Concentration in reprocessed oil, ppm	<10	1.0	7	997
Mass feed rate, lb/hr	$2.68 \times 10^{-2}$	$2.8 \times 10^{-3}$	$1.78 \times 10^{-2}$	2.67
<u>Stack Gas Effluent</u>				
Concentration, $\mu\text{g/dscm}$	0.175	0.605	23.1	26.4
Mass emission rate, lb/hr	$2.03 \times 10^{-5}$	$7.00 \times 10^{-5}$	$2.71 \times 10^{-3}$	$3.08 \times 10^{-3}$
<u>Baghouse Catch</u>				
Concentration, $\mu\text{g/g}$	0.7	<0.2	4.0	203
<u>Removal Efficiency</u>				
Percent (%)	NA	97.52	85.00	99.88

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TABLE 4. Summary of Data for Trichloroethylene (TCE)  
(mean values for Runs 1, 2, 3, 4)

<u>Influent</u>	<u>Stack Gas Effluent</u>
Concentration in reprocessed oil, %	0.89
Mass feed rate, lb/hr	22.68
<u>Stack Gas Effluent</u>	
Concentration in stack gas, $\mu\text{g}/\text{m}^3$	395
Mass emission rate, lb/hr	0.0473
"Worst Case" Destruction/ Removal Efficiency	
Percent (%)	99.75

TABLE 5. Summary of Data for Hydrochloric Acid (HCl)  
(mean values for Runs 2, 3, 4)

<u>Influent</u>	<u>Stack Gas Effluent</u>
Concentration in stack gas, mg/dscm	41.65
Mass emission rate, lb/hr	4.81
<u>Baghouse Catch</u>	
Concentration in baghouse catch, mg/g (total chloride)	0.500
<u>Removal Efficiency</u>	
Percent (%)	81.9

TABLE 6. Summary of Stack Gas Emissions Data (average of 3-4 test runs)

<u>Metals</u>	<u>Species</u>	<u>Concentration in Stack Gas*</u>	<u>Destruction and/or Removal Efficiency</u>
Lead		26.4 $\mu\text{g}/\text{m}^3$	99.88%
Arsenic		0.17 $\mu\text{g}/\text{m}^3$	—
Cadmium		0.61 $\mu\text{g}/\text{m}^3$	97.52%
Chromium		231.1 $\mu\text{g}/\text{m}^3$	85.00%
	<u>Organics</u>		

TABLE 6. Summary of Stack Gas Emissions Data (average of 3-4 test runs)

<u>Species</u>	<u>Concentration in Stack Gas*</u>	<u>Destruction and/or Removal Efficiency</u>
<u>Metals</u>		
Lead	26.4 $\mu\text{g}/\text{m}^3$	99.88%
Arsenic	0.17 $\mu\text{g}/\text{m}^3$	—
Cadmium	0.61 $\mu\text{g}/\text{m}^3$	97.52%
Chromium	231.1 $\mu\text{g}/\text{m}^3$	85.00%
<u>Organics</u>		
Trichloroethylene	<395 $\mu\text{g}/\text{m}^3$	99.75%
<u>Acids</u>		
Hydrochloric Acid	41.6 $\text{mg}/\text{m}^3$	81.9%
<u>Particulate Material</u>	0.027 gr/DSCF*	99.96%**

\*Dry standard basis

\*\*Based on estimated value of total particulate loading to baghouse.

- Hot Rock Temp. Sensor
- Kiln Static Pressure Tap
- Fuel Flow Meter
- Fuel Temp/Press Gauge
- Baghouse Inlet Temp Sensor
- Baghouse Press. Drop Taps

## ATMOSPHERIC EMISSIONS SAMPLE

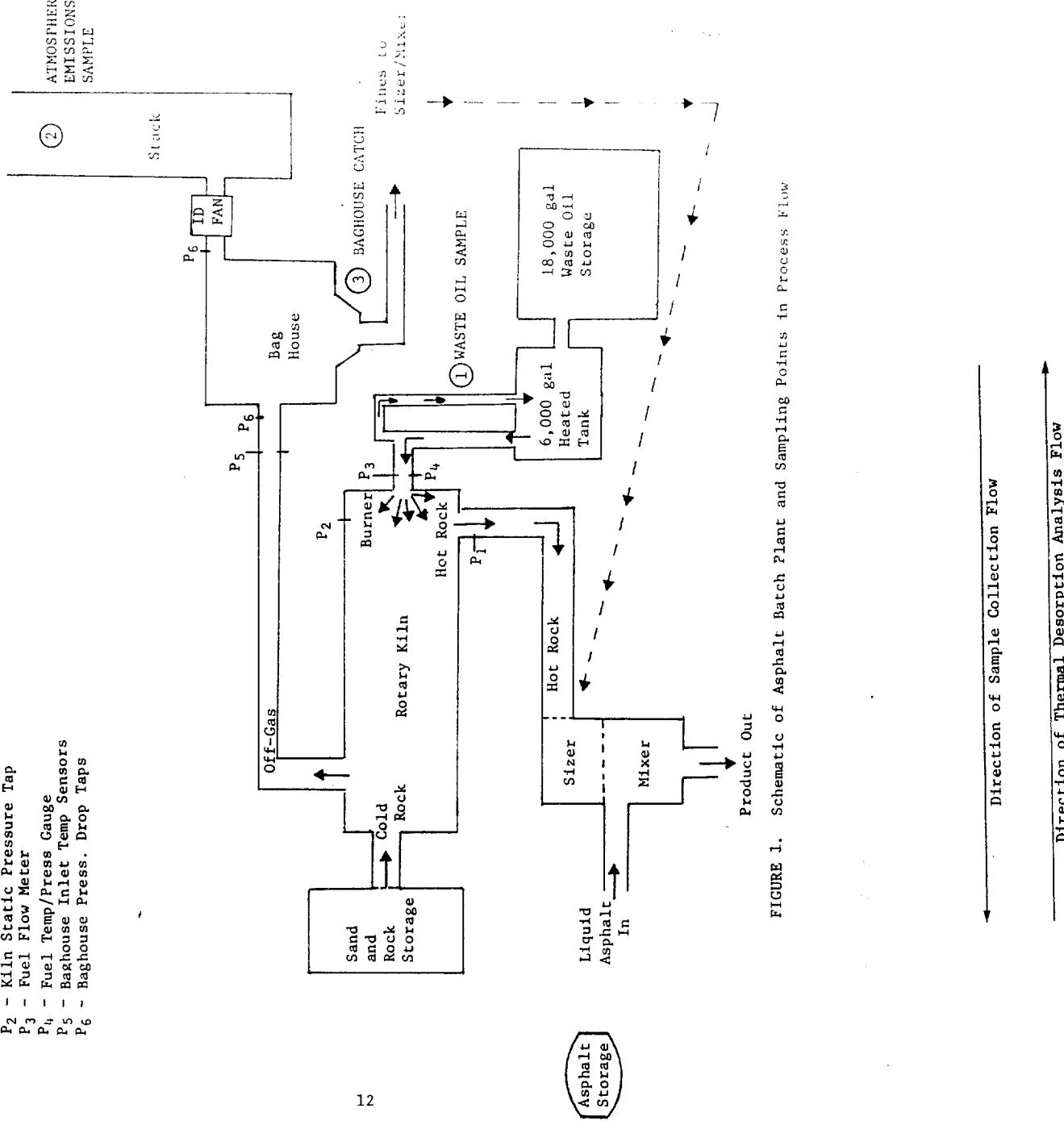


FIGURE 1. Schematic of Asphalt Batch Plant and Sampling Points in Process Flow

83-51.1

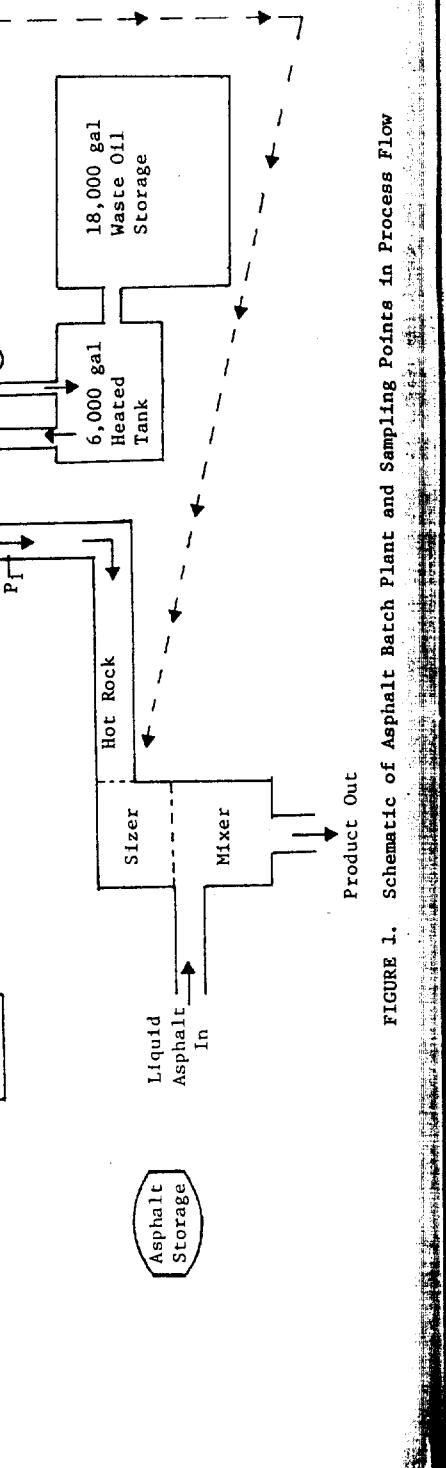
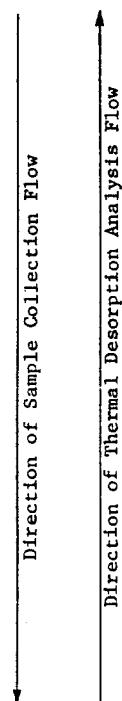


FIGURE 1. Schematic of Asphalt Batch Plant and Sampling Points in Process Flow



83-51.1

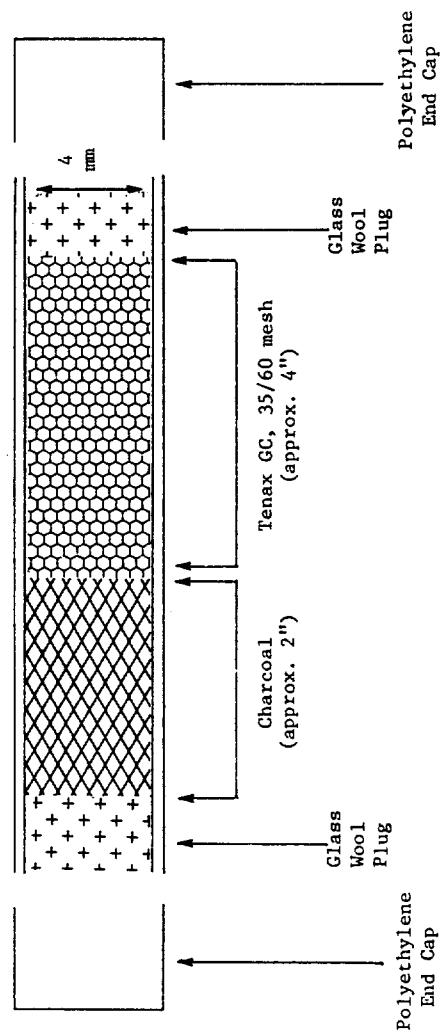


FIGURE 2. Schematic Diagram of RCI Tube