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AIR POLLUTIONAL DISCHARGES FROM TEN SEWAGE SLUDGE INCINERATORS

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ABSTRACT

Reports from Japan indicated that the particulate fraction from sludge incinerators contained much higher concentrations of heavy metals, particularly cadmium and lead, than were present in the feed (on a volatiles-free basis). Ten sludge incinerators were investigated in the United States to verify this finding, and to determine its nature.

Results obtained with U. S. sludge incinerators indicated that the effect does indeed take place. For example, cadmium levels in the particles leaving the incinerator averaged 15 times higher than in the feed (volatiles-free basis) and lead averaged 5 times higher. In addition, the heavy metals were concentrated in the finer portion of the particulates. Since scrubbers are less efficient for fine particles, a further concentration of about 10-fold took place across the scrubbers for cadmium and lead.

Despite the concentration that takes place for cadmium and lead, overall losses of these metals were relatively low. Median calculated ground level concentration for lead was 1.7 percent of the standard of 1500 ng/m^3 and for cadmium was 1.0 percent of the suggested standard of 100 ng/m^3.

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INTRODUCTION

In October of 1970, The Council on Environmental Quality recommended that ocean dumping be phased out as an ultimate disposal process for municipal wastewater sludge. One of the obvious alternatives to ocean dumping is incineration, which inevitably produces some air pollution. Consequently, the U. S. Environmental Protection Agency set up a task force in 1971 to determine if sludge incineration is an environmentally acceptable disposal method. After a series of air pollution tests conducted on several well-controlled incinerators, the task force concluded that properly operated incinerators produce acceptable stack emissions of particulate matter, nitrogen oxide, sulfur oxides, and odor (1).

Based in part on this work, New Source Performance Standard (Subpart O) was proposed in 1973 by EPA's Office of Air Quality Planning and Standards and became final in 1974 (2). The standards in Subpart O apply to any facility built or modified after November 10, 1977. This standard and other Federal standards applicable to sewage sludge incineration are presented in Table 1. Note that there are no standards in Subpart O for NO_x and SO_2. Data available at the time Subpart O was prepared indicated that concentrations of these gases (or amounts discharged) were not sufficiently high to warrant regulation.

TABLE 1. Federal Standards Applicable to Sewage Sludge Incineration

POLLUTANT	STANDARD	REFERENCE
Particulates	0.65 g/kg Dry Sludge Fed	(2)
Opacity	20%	(2)
Beryllium	10 g/24 hr.	(3)
Mercury	3200 g/24 hr.	(4)
Lead	Ambient air standard is 1500 ng/m^3	(5)
Cadmium	No standard but a 100 ng/m^3 in ambient air is being discussed as a possible future standard	(6)

The Incineration Task Force also attempted to determine whether the more volatile heavy metals appeared in disproportionate amounts in the particulate fraction. It was established that mercury was essentially driven off from the incinerator--there was no mercury in the bottom ash or the particulate fraction, although some might have been collected by the water scrubbers used for air pollution control. Fortunately, sludges are low in mercury, generally under 5 µg/g of dry sludge. The standard for mercury (see Table 1) is so high, 3200 g/day, that only the largest plants need to be concerned about mercury losses in incinerator stack gases.

The Task Force results indicated that two of the volatile metals, cadmium and lead, showed higher concentrations in the particulates leaving the discharge stack than in the sludge (on a volatiles-free basis) or in the ash. The concentration factor was small and no further investigation appeared to be warranted at the time. However, Japanese data on sludge incinerators, which became available in 1978 (7), indicated much greater concentration factors than were obtained in the Task Force investigation. This information indicated the need to undertake more extensive studies of the heavy metal discharges from sludge incinerators.

The objective of the present investigation has been to determine whether any unusual classification of heavy metals into the particulate fraction discharged from the stacks occur in U. S. sludge incinerators, assess the environmental implications if this is the case, determine the causes and suggest remedies. It was planned to determine the quantities and compositions of the uncontrolled emissions before the particle removal devices as well as from the stacks, so that performance of the pollution control devices could be evaluated. Particle size distributions and composition of the various particle size fractions were to be determined because of the importance of particle size in performance of air pollution control equipment and in health effects.

Air pollution testing is expensive because of the need to send skilled crews to each site where they must carry out tests for periods averaging two days. The large numbers of samples collected must be dissolved and then analyzed by sophisticated methods. Consequently, only a limited number of incinerators could be evaluated. A total of ten incinerators were selected. Factors involved in test site selection were: nature of the sludge being incinerated (a range from high to low heavy metals concentrations was desired), type of incinerator used, capacity (a wide range was desired), willingness of the plant personnel to allow testing, the ability of the personnel to keep the plant operating, and the distance from the principal contractor's home office (Monsanto Research Corporation, Dayton, Ohio).

A portion of this work has been reported previously (8,9). The present report contains all material included in these earlier presentations.

EXPERIMENTAL PROCEDURES

1. Incinerator Sampling. Ten sludge incinerators operated at sewage treatment plants were selected for the investigation. Eight had multiple hearth furnaces and two utilized fluidized bed furnaces. All the furnace outlets were equipped with some type of a water scrubbing device which served to remove particulate matter, cool the off-gases, and remove some SO_2 and NO_x. Generally, the off-gases were cooled ("quenched") by a water spray before they entered the scrubber.

The incinerator stacks were sampled at the inlet to the off-gas scrubbing device and at its outlet, which is the normal stack sampling location. The water quench was upstream from the inlet sampling point. Composite samples of sludge bottom ash and water into and out of the scrubbers were obtained by combining grab samples taken periodically during the period of stack sampling. There was only one particulate sampling device and one sampling team available at the time these tests were made, so samples at the inlet and outlet of scrubber had to be taken at different times, usually within a day of each other.

Before sampling could start, a multiple hearth furnace had to be stabilized by four days' operation, then it had to operate stably for an hour, maintaining uniform feed rate and constant temperatures within the furnace. It was then considered to be in steady state operation and sampling could be started. A fluidized bed furnace, starting at holding temperature with no sludge input, had to be operated for twelve hours before it was considered stabilized. After one hour at constant temperature it was considered to be in steady state operation and samples could be taken. Normally it took at least a day to set up the test equipment, so there was ample time to get the furnaces under control for the tests.

Normally, it took about five hours to complete sampling on the scrubber outlet and about three hours to complete the sampling on the scrubber inlet. The length of time was determined by the particulate loading in the sample stream. If a large amount of fines was present, pressure drop across the sampler built up relatively quickly, and it became necessary to change the "pancake" filter (see below) more times than normal; consequently, it took more time to get the mass of sample necessary for analysis. About 10 mi of each size range were required for analysis.

The tests were normally performed at one incinerator location on one day, then the equipment was relocated that evening or early the next day and the test performed at the next incinerator location as soon as possible after that. In all cases, only one set of samples was taken because of the extra costs required for taking and analyzing the samples.

Samples of the sludge cake charged to the furnaces were taken by compositing grab samples taken from the conveyor belt leading to the furnace throughout the run. Enough sample was taken at hourly intervals so that total sample size was between 0.5 and 1 liter.

2. Particle Sampling Apparatus. An Autotherm* High Volume Source Assessment Sampling System (SASS) train was used for sampling the gas streams to determine particle loading and particle size distribution. The equipment is illustrated in Figure 1. In the SASS train, the gas stream sample is drawn through a series of small cyclone dust collectors which segregate the particles into the three aerodynamic size fractions: greater than 10 μm, 10 to 3.5 μm, and 3.5 to 1 μm. Following the cyclones there is a 0.1 μm filter which recovers the 1 to 0.1 μm particles.

*Trade name. Use of a trade name does not indicate EPA endorsement.

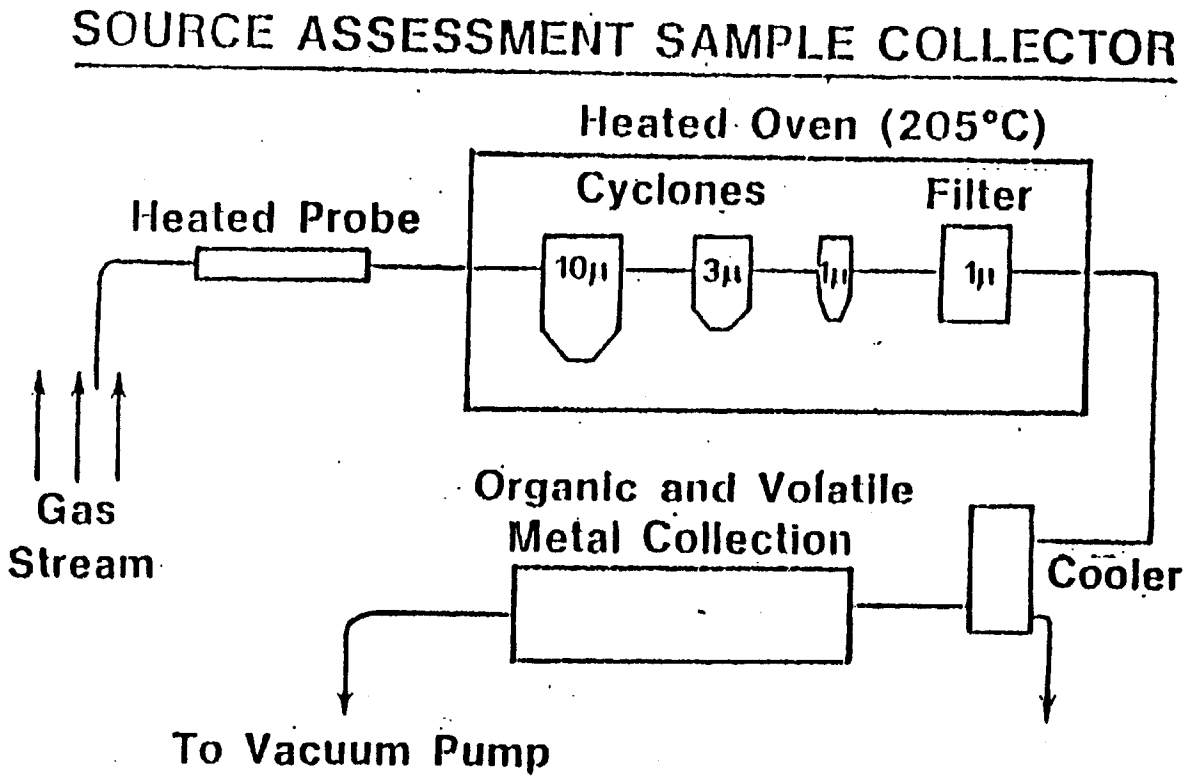


FIGURE 1: SOURCE ASSESSMENT SAMPLE COLLECTION AND SEPARATION TRAIN

The SASS train is described in detail by Harris et al. (10). The section following the heated oven (see Figure 1) consists of a cooler and a series of impingers in an ice bath. The stack gases are cooled in a condenser and scrubbed in the series of impingers to remove residual water vapor, organics, ionized metals, metal vapors, and particles smaller than 0.1 μm. The impingers were filled with distilled water at the start of all of these incineration tests. The quantity of material collected in the impingers other than condensed water is generally minor relative to the amount of material collected on the cyclone and in the filter. An important function of the back section is to protect the gas meter and the vacuum pump from condensed water.

The particle samples are taken under isokinetic conditions, following EPA Methods 1 and 2 in the Code of Federal Regulations (11). The gas velocity profile in the duct is determined, average velocity calculated, and the sampling probe is located at a point where actual velocity equals average velocity. Gas is drawn through the sampler so that the velocity in the sample probe matches the average velocity and is maintained at this velocity throughout the run. In this way, kinetic effects that may affect the representative nature of the sample are avoided.

3. Chemical Analysis of Samples. The particle size fractions collected in each size range at the front end of the SASS train were separately digested and analyzed for the following 11 metals: silver (Ag), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe) mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), zinc (Zn), and arsenic (As). The fractions were dissolved using standard methods (12) and filtered. Then metal analyses were performed using a Jarrell Ash* (13) spectrophotometer system with inductively coupled argon plasma (ICAP) source for all of the elements except arsenic and mercury. Arsenic and mercury were analyzed by conventional cold vapor atomic absorption techniques (14).

The sludge and incinerator ash samples were dried at 100 °C to determine the moisture content (total residue). The sludge samples were heated to 600 °C for 30 minutes to determine the volatile solids content (12). After drying, the ash was heated to 1000 °C to determine if the sludge had been completely burned to ash in the furnace. The resulting sludge ash and incinerator ash were digested in nitric and perchloric acid according to the procedures of Dolezal (15) and Gorsuch (16). These solutions were then analyzed by atomic absorption spectrophotometric techniques (17).

The impinger contents were evaporated to dryness and weighed in beakers by the contractor. Later these beakers were shipped to the U. S. EPA's Andrew W. Breidenbach Environmental Research Center in Cincinnati. In order to consolidate the sample into one beaker, it was necessary to remove the material from some beakers by washing them with acetone because the solids were partly in the form of organic tars. The solids were put into solution using nitric and perchloric acid in accordance with the procedures of Dolezal (15) and Gorsuch (16). The resulting solutions were analyzed by atomic absorption spectrometric techniques (17).

* Trade name. Use of a trade name does not indicate EPA endorsement.

4. Sulfur Dioxide. The procedure outlined in Method 6, 40 CFR (11) was used to determine sulfur dioxide content of the off-gases. To check the accuracy of the results, the contractor participated in the "round robin" for determining accuracy sponsored by the Quality Assurance Branch of U. S. EPA, Research Triangle Park, North Carolina 27711.

Equations 6-1 and 6-2 in Method 6 were used to compute the results.

5. Nitrogen Oxides. The analytical method used by the contractor to determine the nitrogen oxides (NO_x) is described in Method 7, 40 CFR (11). Quality control samples from the U. S. EPA's Quality Assurance Branch at Research Triangle Park, N. C., were tested along with the field samples to check the accuracy of the NO_x results.

Equations 7-2, 7-3, and 7-4 of Method 7 were used to determine the NO_x concentrations.

RESULTS AND DISCUSSION

A. Total Particulate Emissions

The primary objective of the test program was to collect data on the composition and size distribution of the particulates immediately after leaving the sludge incinerators, and after leaving the air pollution control devices. In the process of obtaining these data, sufficient information was obtained to permit calculation of total particulate emission rates and estimation of scrubber efficiences.

When the incinerators were being tested, the plant operators were aware that these were not official emissions tests to determine conformance with standards. Consequently, the incinerator-scrubber systems were not "tuned up" for optimum performance, nor were input rates adjusted to design conditions. As noted in the preceding section, care was exercised in arriving at a steady state.

Total emissions per unit of input of dry sludge solids, along with estimated scrubber efficiencies, are reported in summary form in Table 2. Scrubber efficiencies are discussed in a later section. The emissions data are arranged in the order of increasing emissions. Run H is not shown because results indicated extremely high emissions, which was not consistent with observations made at the site during the test.

TABLE 2. Summary of Particulate Emission Results

Site	Incinerator Type	Relative Emission (g/kg)	Scrubber Type	Scrubber Δ P (cm H_2O)	Loading* (g/kg)	% CO_2 in Exhaust (water-free)	Scrubber Efficiency
J	FB	0.036	V+I	41	9.5	12.8	99.6
E	MH	0.13	V+I	51	2.4	8.5	94.7
B	MH	0.40	I	48	5.1	16.9	92.0
G	FB	0.54	V+I	--	769	10.9	99.9
F	MH	0.59	V+I	51	5.6	3.6	89.5
		0.65					
C	MH	0.67	I	42	8.7	3.2	92.3
A	MH	0.72	I	25	40.2	2.9	98.2
D	MH	1.73	I	15	~~225~~ very poorly operated.	6.3	99.2
K	MH	33.6	WC	--	226	7.0	85.1

Do not consider

Symbols
- FB - fluidized bed furnace
- MH - multiple hearth furnace
- I - impingement type scrubber
- V+I - two stage scrubber (venturi + impingement)
- WC - willed wall cyclone

* Loading has been adjusted for the different feed rates in scrubber output runs. See Table A-1 for procedure.

The results indicate reasonably good performance when the relative emissions are compared with EPA's standard of 0.65 g of particulate emissions per kilogram of dry sludge charged. Incinerator K should not be seriously considered because of the obvious inadequacy of the collection device. Of the remainder, only Incinerator D seriously exceeded the standard. Examination of the loadings show that this incinerator was losing 225 g of particulates per kg of dry sludge fed. This was a major portion of the inert material in the entering sludge in this run and indicates that about half of the ash was being blown out of the incinerator and had to be removed by the scrubber. If this scrubber loading were in a more normal range of perhaps 20 g/kg, it is possible that Incinerator D also would be close to meeting the standard.

D.

The emissions obtained with the incinerators tested are slightly higher than obtained with new incinerators built under NSPS standards. Data drawn from Helfand's Table 5-1 (18) show that, of ten MH and FB incinerators equipped with scrubbers with 46 cm of water or greater pressure drops, the median was 0.49 g/kg, and two out of ten, or 20 percent, slightly exceeded the 0.65 g/kg standard. Excluding Incinerator K, the median of the 8 incinerators in this investigation is 0.56 g/kg and three out of eight, or 38 percent, exceeded the standard.

NSPS

Attention must be drawn to peculiarities associated with the two fluid bed incinerator runs, G and J. In fluid bed incinerators, all of the ash is removed overhead and goes to the scrubber. Since sludges frequently contain about 30 percent ash, there should thus be a scrubber loading of about 300 g/kg of dry sludge fed. Observation of the data in Table 2 shows that Incinerator J lost only 9.5 g/kg to the scrubber whereas Incinerator G lost 769 g/kg. Incinerator J was evidently accumulating ash, but G was losing ash and sand from the bed faster than inerts were being added through the feed. At equivalent scrubber loadings, these two incinerators might show a nearly equivalent performance. The peculiar behavior of the fluidized bed incinerators G and J requires that conclusions drawn about fluidized bed units throughout this report be considered tentative.

FBC

An important contributing factor to system performance, which is not in Table 2, is the specific design and operation of the incinerator-scrubber system. Each of these incinerators is a custom design, and differences between the systems are more frequent than similarities. In proper operation, such as leaving an observation port open at the ash drop (where ash leaves the MHF) can cause suspension of virtually all the fines in the ash by the ensuing current of air drawn into the furnace, which creates an overload on the scrubber system.

The data in Table 2 show superior performance for incinerators equipped with both venturi (V) and impingement (I) scrubbers. All of the incinerators so equipped show lower emissions than the standard. It is important not to generalize this conclusion, however reasonable it may appear, without close examination. Drawing conclusions based only on input and output without any consideration to mechanism is a completely empirical approach, which can lead to erroneous conclusions unless great quantities of data are available. A rational look at the problem indicates that the losses from an incinerator depend on the particle density in the gas arriving at the scrubber, the particle size distribution (because scrubber efficiencies depend on particle size), and the efficiency of the scrubbers for each particle size. Fortunately, enough data were obtained so that a rational examination is possible.

It can be observed from Table 2, looking only at the MHF data, that relative emissions increase steadily with the loading to the scrubber. (Percent CO_2, which correlates in an inverse way with excess air and may thus correlate with particle density, shows a correlation with relative emissions but not as positive as the correlation with loading to the scrubber.) Later sections of the report examine the individual factors that contribute to relative emissions, and the conclusion is reached that, for the incinerators tested, loading was the most important manageable factor affecting performance.

B. Scrubber Efficiencies

Because emissions were measured upstream and downstream of the collection device, it is possible to obtain information on unabated discharges and also to calculate scrubber efficiencies.

As noted earlier, emissions upstream and downstream from the scrubber were not collected during the same run. Thus the input to the scrubber and the output from the scrubber do not exactly correspond. Mass flow rates to the incinerator and air flow within the incinerator were different during the two tests. A correction for the difference in dry solids mass flow rate has been made by adjusting the scrubber input flow rate in direct proportion to the mass flow of dry solids into the incinerator (see Table A-1). This adjustment is necessarily an approximation. No other adjustment was attempted.

Calculated scrubber efficiencies, along with parameters that might influence them, are presented in Table 3 in order of decreasing efficiency. These efficiencies are referred to herein as "total particle efficiencies" (tpE), and are calculated from input and output particle flow rates. Excluding Plant K, which uses a wet cyclone, efficiencies ranged from 89.5 to 99.9 percent.

Examination of the parameters presented in Table 3 indicates that tpE correlates exceptionally well with the percent fines (the 0.1-1.0 um fraction) in the particles entering the scrubbers. Pressure drop, type of scrubber, and percent CO_2 (related to % excess air) do not show any trends as efficiency decreases down through the table. For the MHF incinerators, loading to the scrubber (g/kg) correlates with tpE.

The fluidized bed plants show the best scrubber efficiencies (tpE) and the lowest percent fines. The low percent fines is to be expected because all of the particulates are removed overhead, whereas only the finer particles are carried overhead in MHF incinerators. This low percentage of fines seems to explain satisfactorily the high tpE of the fluidized bed scrubber systems. The high efficiencies of the scrubbers for Plants D and A are probably related to the high loadings and to relatively low proportion of fines in the particles entering the scrubber. The relatively poor performance of Incinerator E's scrubber is probably due to the high percentage of fines.

Only one incinerator appears to show anomalous behavior. Plant F uses a high pressure drop V and I system and has a low percentage of fines in the particles arriving at the scrubber; however, the scrubber system has a low tpE.

TABLE 3. Scrubber Efficiencies and Possible Significant Variables

Site	Incinerator Type	Scrubber Efficiency(%)	Type	Scrubber Δ P (cm H_2O)	Loading (g/kg)	Percent CO_2 in Exhaust (water-free basis)*	Percent Fines** (0.1-1.0 μm)
G	FB	99.9	V+I	-- ?	769	10.9	0.2
J	FB	99.6	V+I	41 16.1	9.5	12.8	0.3
④ D	MH	99.2	I	15	225	6.3	1.9
① A	MH	98.2	I	25	40.2	2.9	9.8
⑤ E	MH	94.7	V+I	51 20	2.4	8.5	15.4
③ C	MH	92.3	I	42	8.7	3.2	24.8
② B	MH	92.0	I	48	5.1	16.9	-
⑥ F	MH	89.5	V+I	51 20	5.6	3.6	5.4
⑦ K	MH	85.1	WC	--	226	7.0	4.4

* Percent CO_2 is related to excess air. A low value indicates a high percent excess air. For a given sludge input rate, high percent excess air means higher gas velocity and probably higher entrainment of solids.

** Percent fines in the particles entering the scrubber

The low percentage of fines for fluid bed plant G is expected because losses into the scrubber were very high. However, Plant J showed a low loss rate and still had a low percentage of fines. It may be that this is a characteristic of fluid bed incinerators as contrasted to MHF incinerators. A single observation is insufficient basis for a firm conclusion. However, further investigation is warranted.

The data show that it is misleading to judge the performance of the scrubber system by the total particle efficiency (tpE). The spectacular performance of Plant G and J scrubbers is attributable to the low proportion of fines. A better procedure would be to compare efficiency of the removal of the various particulate fractions. These individual fraction efficiencies (ifE) can be calculated from the tpE's from Table 3 and the particle size distributions (Tble A-2). Results are presented in Table 4. Runs are listed in order of decreasing efficiency of removal of the fines fraction (0.1-1.0 μm).

The results in Table 4 show that the removal efficiency for the fines fraction is poor for all systems. There is no discernible difference between I and V-I systems. For Plant F, the scrubber system is apparently not operating at anywhere near its potential. The cause could be faulty design or operation or failure of an internal part.

The results of this portion of the investigation support well-established concepts of scrubber operation. The total particle efficiency (tpE) of a scrubber depends on particle size. For a given particle size range, the ifE is relatively independent of particle density so the mass of material that escapes will be proportional to the mass of material that enters the scrubber.

In the practical operation of an incinerator-scrubber system, it is desired to minimize the final discharge per unit of mass fed to the incinerator. To accomplish this, loading to the scrubber should be decreased and, if possible, particle size increased. Reduction in rabble arm speed in MHF incinerators may increase average particle size. Reduction in gas velocity in the furnace will reduce scrubber loadings; however, particle size will also decrease. These effects work in opposite directions--the former decreases losses and the latter allows higher losses. The data for the MHF incinerators (see above) strongly indicate that the overall effect of lower loadings is a reduction in losses per unit of sludge fed. Reduction of off-gas rate, accomplished by reducing percent excess air or total sludge feed rate, appears to be a desirable action to take when emissions for a given furnace are excessive.

C. Material Balances

It was not possible in any of the tests to properly sample scrubber water or to determine its rate of flow. Consequently, for the tests in which the particles at the scrubber outlet were collected, it was not possible to calculate material balances. However, for those runs in which particles were collected at the scrubber inlet, a material balance could be calculated.

TABLE 4. Comparison of the Removal Efficiency of the Various Particle Size Fractions

Plant	Furnace Type	Scrubber Type	Δ P (cm H_2O)	Percent Removal Efficiency Particle Size Fraction (μm) 0.1-1.0	1.0-3.5	3.5-10	> 10
A	MH	I	25	90.4	98.8	98.6	99.2
E	MH	V+I	51	83.4	90.4	92.5	97.0
G	FB	V+I	--	72.3	88.6	99.8	99.9
C	MH	I	42	71.6	98.7	99.8	99.2
D	MH	I	15	61.7	99.7	99.9	99.9
J	FB	V+I	41	47.1	99.4	99.5	99.9
F	MH	V+I	51	-6	79.5	96.0	94.8

The only mass flows determined were the total mass of flow rate of sludge cake entering the furnace, and the gas and particle discharge rate at the entrance to the scrubber. Mass flows of ash were not measured independently but were calculated by difference. Determination of individual metals concentrations were carried out on these three streams. Consequently, individual mass balances could be calculated for each of these metals.

The results of the material balance calculations for each metal for the runs in which scrubber input rates (subscript 1) were measured are presented in the appendix in Table A-3. Plant G has not been included in the tabulation because analyses of the particle fractions collected appear to be seriously in error. A few other data points were excluded (see Table A-3) because the departure from the mean was extreme.

A summary of the material balance calculations is presented in Table 5. The average of the ratio of output to input (O/I ratio) for each metal (across plants) is itself averaged (vertical column in Table 5) and equals 1.18. This average should equal unity. The deviation from unity indicates a consistent error of some kind. Possible candidates are gas flow rate in the measurement of particle discharge rate, and particle composition (analytical method was different from ash and sludge analysis). The data were normalized (made to average 1.00) by dividing the O/I ratio for each metal by the average value for a run. The "normalized" results in Table 5 thus show a mean for all metals of 1.00. The means for each metal (across runs) show considerably less variation in the normalized data. The normalized means range from 0.79 to 1.24. Considering the short-term nature of the tests and the poor control possible under plant-scale conditions, this variation is about as good as can be expected.

Although carbon dioxide content of the stack gases was determined, no material balance was made for carbon because amount of fuel and percent carbon in the sludge were unknown. In future investigations, such a balance should be attempted because it provides an independent check on flow rate of stack gases.

An important finding of the tests is that cadmium and lead show material balances consistent with the other metals. There has been concern that these two metals might vaporize in combustion and then either solidify (as metal or oxide) in an extremely fine form or subcool and not solidify, possibly thus escaping not only collection devices such as scrubbers but also the particle sampling devices. The evidence of these experiments indicates that lead and cadmium are collected as efficiently by the analytical sampling devices as the other metals.

TABLE 5. Averages of Material Balances (Output/Input) for Individual Metals

Metal	Runs Excluded	Number Included	Unadjusted Results		Normalized Results			
			Mean($\bar{x}$)	Std.Dev.(s)	Mean($\bar{x}$)	Std.Dev.	Std.error of $\bar{x}$	95% confidence limits of $\bar{x}$
			($\bar{x}$)	(s)	($\bar{x}$)	(s)		
Cadmium	G,K	7	1.42	1.08	1.15	0.57	0.215	± 0.51
Iron	G,H	7	1.22	0.41	0.99	0.21	0.079	± 0.19
Nickel	G	8	0.98	0.33	0.84	0.23	0.081	± 0.19
Lead	D,G	7	1.03	0.64	0.88	0.33	0.125	± 0.30
Silver	G	8	1.14	0.42	0.98	0.32	0.113	± 0.26
Chromium	G	8	0.95	0.47	0.79	0.29	0.103	± 0.24
Copper	G	8	1.22	0.39	1.02	0.24	0.085	± 0.20
Manganese	G	8	1.34	0.28	1.24	0.58	0.205	± 0.47
Zinc	E,G	7	1.30	0.47	1.09	0.33	0.125	± 0.30
Average of $\bar{x}$'s			1.18		1.00			
Std. Dev. (s)			0.16		0.15			

D. Heavy Metal Emissions

1. Emissions from the Incinerator. A major objective of the investigation was to determine the extent of the elevated emissions of certain heavy metals from sludge incineration and establish whether the cause of the high concentration was poor collection efficiency in the scrubber for these substances or high concentrations leaving the furnace. Consequently, mass flow rate of emissions and composition were measured at the inlet and outlet of the pollution control devices.

(a) Emissions from the Furnace. The information obtained on the particle flows at the inlet to the scrubbers allowed direct calculation of losses from the furnaces. However, the plants tested varied in excess air used, furnace design, temperature level, and type of sludge. Unless a correlation is found, the results do little more than establish a "population" of discharge rates. In order to increase the value gained from the study, two correlation approaches were attempted with considerable success.

Approach 1. The mass of metal A carried off in the air stream (at a given temperature and gas flow rate) is assumed to be proportional to the average concentration of the metal in the burning mass:

$$P_A = k_1 C_{B-A} \qquad (1)$$

where P_A = particle emission rate of metal A (g/sec)*
C_{B-A} = concentration of metal A in the bed (mg/kg)
k_1 = proportionality constant

Similarly the mass of other substances carried off (materials other than A) is assumed to be proportional to the concentration of these materials in the bed:

$$P_{NON\ A} = k_2 C_{B-NON\ A} \qquad (2)$$

where $P_{NON\ A}$ = emission rate of materials other than A (g/sec)
$C_{B-NON\ A}$ = concentration of materials other than A (mg/kg)
k_2 = proportionality constant

Dividing Equation 1 by Equation 2,

$$\frac{P_A}{P_{NON\ A}} = k_3 \frac{C_{B-A}}{C_{B\ NON\ A}} \qquad (3)$$

or

$$\frac{C_{P-A}}{C_{P-NON\ A}} = k_3 \frac{C_{B-A}}{C_{B-NON\ A}} \qquad (4)$$

where C_{P-A} = concentration of metal A in the particles (mg/kg)
$C_{P-NON\ A}$ = concentration of NON A in the particles (mg/kg)

This equation has the same form as the expression for relative volatility for miscible liquids. It assumes that all NON A substances act in the same manner. Concentrations of A and NON A material are difficult to establish because the formulas for the chemical compounds in which A and NON A are found are not known. A good application of Equation 4, which avoids this difficulty, is comparing two different metals (e.g., cadmium versus lead). The concentration of the second metal is used in place of NON A in Equation 4.

Equation 4 can also be used when C_{P-A} and C_{B-A} are small so that $C_{P-NON\ A}$ and $C_{B-NON\ A}$ are approximately unity. Equation 4 is rewritten below for this case:

$$C_{P-A} = k_4\ C_{B-A} \qquad (5)$$

If this equation is used for high concentrations of C_{B-A} and C_{P-A}, the constant k_4 will vary with concentration.

The proper bed concentration to use for Equation 4 or 5 depends on the design of the incineration device. In a fluidized bed, which typically has a single, well-mixed bed, the concentration in the ash is probably the appropriate concentration to use. In a multiple hearth incinerator, which has more than one actively burning beds, some average between ash and feed concentration is probably appropriate. Concentrations should be on a volatile solids-free basis.

Approach 2. Consider the case where C_{P-A} and C_{B-A} are small and C_{B-A} can be selected as the composition of Metal A in the incoming feed. Express the concentrations in terms of mass flow rates:

$$C_{P-A} = P_A/P_T \qquad (6a)$$

and $$C_{B-A} = F_A/F_T \qquad (6b)$$

where P = particle flow rate (g/sec)
F = feed flow rate (volatiles-free basis) (g/sec)
subscripts A & T = Metal A, and total dry solids (volatiles-free)

Equation 5 becomes

$$P_A/P_T = k_4\ F_A/F_T \qquad (7)$$

Rearranging this equation,

$$P_A/F_A = k_5\ P_T/F_T \qquad (8)$$

The designation of the constant has been changed to k_5 to identify it with Equation 8.

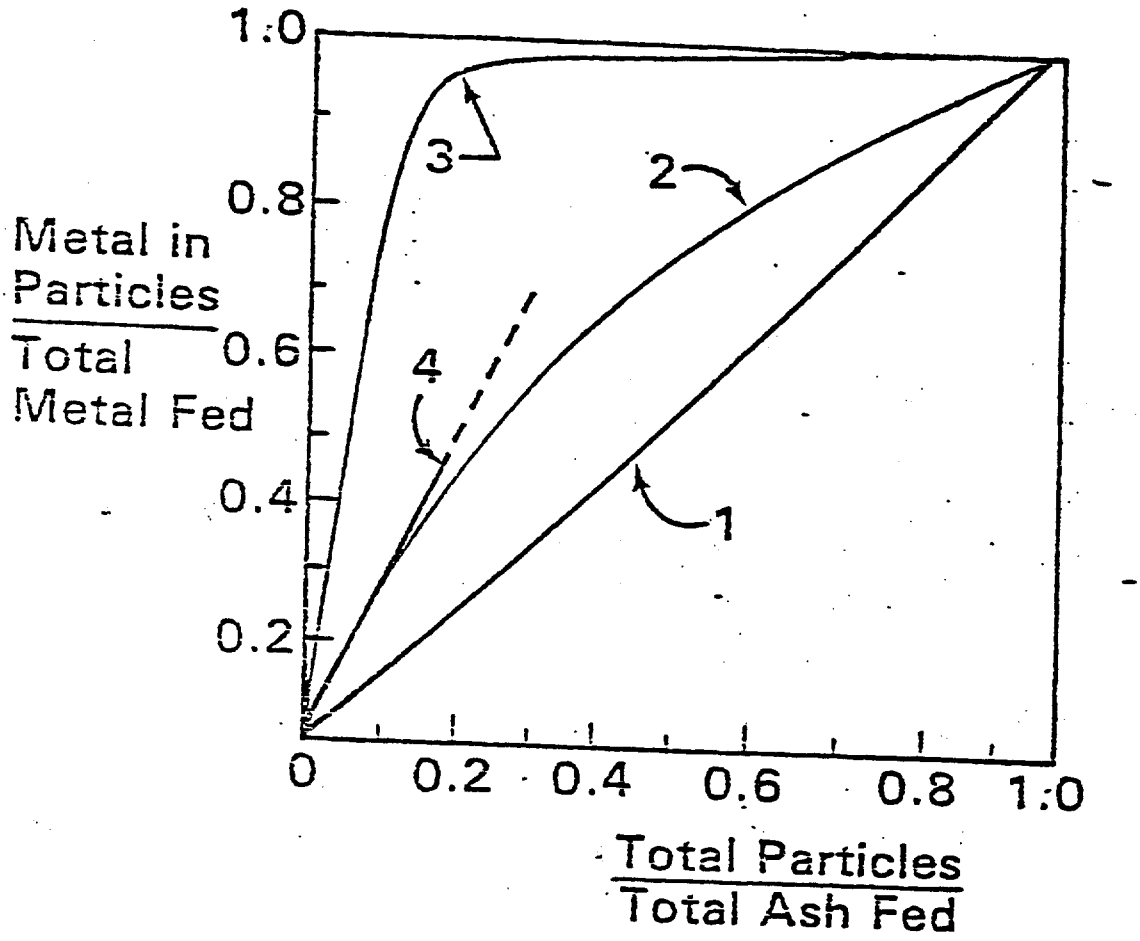
Equation 8 states that the fraction of Metal A fed to the furnace that is lost in the particulates (P_A/F_A) is proportional to the fraction of the total feed (volatiles-free basis) that is lost as particulates. Consideration of the relationship between P_A/F_A and P_T/F_T indicates that it must take the form shown in Figure 2. Curve 1 is for a metal that does not disproportionate into the particulate fraction; that is, k_5 is unity. Curve 2 is for a metal that, for some reason, appears in higher concentration in the particulate fraction. It is clear that k_5 cannot be a constant. At the top end of the curve (1000 g/kg), the total mass is discharged as particles and it is obvious that the total mass of any metal must be discharged as particles, so k_5 must be unity for all cases. When carryover is low, the relationship can be expressed as a straight line (see dotted line). If the disproportionation into the particles is great, the departure from a direct proportion (k_5 = constant) occurs at a low value of P_T/F_T.

It is interesting to observe that Equation 5 and Equation 8 have the same constant, even though the variables are different.

The graphical method demonstrated in Figure 2 did not prove convenient for presenting the data, chiefly because the range of the data required logarithmic coordinates. Consequently, k was plotted against P_T/F_T. The shape expected when k_5 is plotted against P_T/F_T is shown in Figure 3.

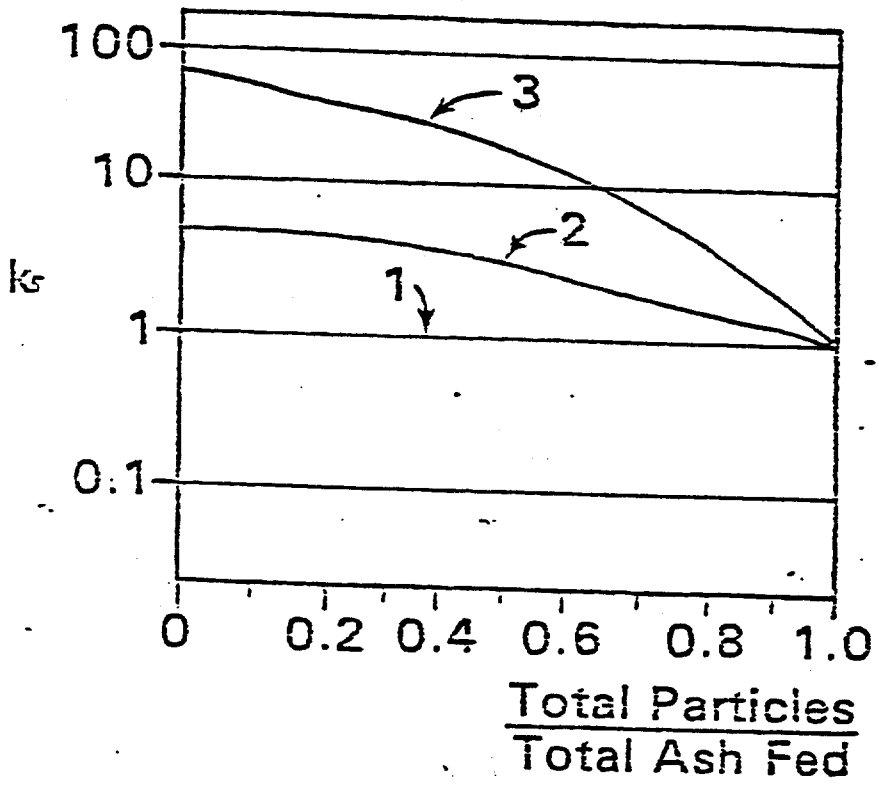
Approach 1 vs. Approach 2. Approach 1 has the advantage of having a rational basis. It is flexible and can be based on ash or feed composition or some intermediate composition. It can be used to compare results with various metals (see, for example, the column for Cd/Pb in Table 6). Approach 1 also illustrates that Approach 2 has a rational basis. The major advantage of Approach 2 is that its final form, Equation 8, is so easy to understand. The fact that k_5 must equal 1 when P_T/F_T equals 1 is easily appreciated, and it gives a check on reliability of results.

The data correlated by Approach 1 (Equation 5) are presented in Table 6. The ratio of the concentration of each metal to its concentration in the ash (k_4) is presented in the table. The plants are arranged in the order of increasing relative emissions from the furnace so that the table can be scanned to see if there is a trend in k_4 with increasing relative particle loss. The only metal for which a trend is clearly evident is cadmium, for which k_4 decreases as the fraction of the feed lost as particulates (P_T/F_T) increases. These results are presented in Figure 4, along with results for chromium. The chromium data show substantial scatter. A trend to lower values of k_4 at higher values of P_T/F_T is discernible.



1: No classification into particles
2: Moderate classification
3: High classification
4: Dotted line is suitable at low particle loss

FIGURE 2: FORM OF CORRELATION EXPECTED WHEN FRACTION OF INPUT METAL LOST IN THE PARTICLES IS PLOTTED AGAINST FRACTION OF INPUT NON-VOLATILE SOLIDS LOST IN THE PARTICLES



$$k_5 = \frac{\text{Metal in Particles/Total Metal Fed}}{\text{Total Particles/Total Ash Fed}}$$

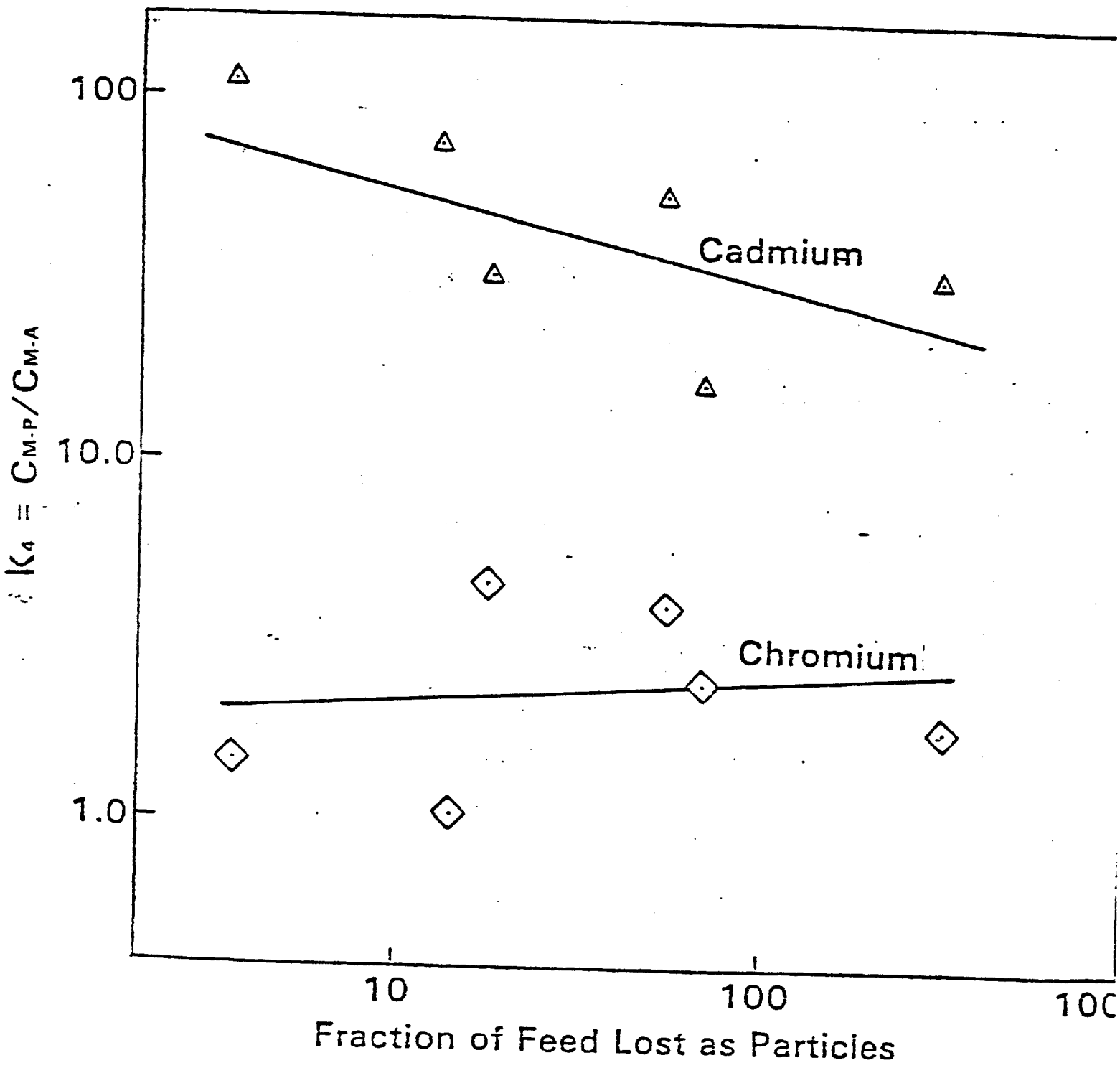
1: No classification into particles
2: Moderate classification
3: High classification

FIGURE 3: EXPECTED RELATION BETWEEN K5 AND THE FRACTION OF INPUT NON-VOLATILE SOLIDS LOST IN THE PARTICLES

TABLE 6. Concentration of Metal in Particles Leaving Furnace Relative to Concentration in the Ash

Plant	Furnace Type	Particle/Feed[1] (g/kg)	Metal										
			Ag	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	As	Cd/Pb
E	MHF	3.64	2.7	121	1.5	0.58	0.22	0.27	0.56	27	--	--	4.5
F	MHF	14.1	1.7	76	1.0	0.90	0.03[3]	0.33	0.70	8.3	0.99	0.71	9.2
C	MHF	17.9	18[3]	33	4.6	9.2	2.7	133[2]	3.2	6.5	4.4	8.8	5.1
H	MHF	55.3	2.2	54	3.9	0.62	0.40	0.50	1.1	24	4.7	2.9	2.3
A	MHF	69.7	2.1	16	2.5	1.4	1.3	1.3	2.0	2.3	1.6	6.0	7.0
D	MHF	319	1.0	33	1.8	2.2	1.3	1.6	2.3	26	3.8	7.6	1.3
K	MHF	745	---------- No ash analysis was obtained ----------										
J	FB	41.5	2.6	1.6	4.3	1.5	1.2	1.4	2.9	0.32	1.6	>4.5	
G[5]	FB	2370	9.7	2.6	0.038	0.032	0.030	0.046	0.091	0.108	--	-	
Geometric Mean[4]			1.84	45.3	2.22	1.44	.83	.62	1.36	11.3	2.62		
Standard deviation factor			1.46	2.04	1.79	2.82	2.74	2.23	2.00	2.71	2.00		

1 Feed is on volatiles-free basis
2 Analytical error
3 Outliers. Not included in average
4 Data for Plant J not included in the averages
5 Data are not included in the average. Results are consistent with MHF runs but s's are very low. It is likely that particles from sludge are diluted with carryover of sand from the fluid bed.



Effect of Increase in Fraction of Feed Lost as Particulates (P/F) on the Ratio of Metal Concentration in Particles to Concentration in the *Ash*.

FIGURE 4

The tabulated results show a distinct classification for cadmium, lead, and arsenic. There may be some classification of zinc but it is not conclusively established and, if it exists, it is much smaller than for lead and cadmium. Silver, chromium, copper, iron, manganese, and nickel do not show evidence of classification into the particulate fraction.

Comparisons of two metals (Cd vs. Cr, Cd vs. Fe, and Cd vs. Pb) were attempted using Equation 4 but the correlation was poorer than using Equation 5 for the individual metals for the first two comparisons. Better results were obtained for Cd vs. Pb (see last column in Table 6).

The data are presented in a different form (Approach 2) in Table 7. Here Equation 8 is used to calculate the value of k_5. (Note that Equation 5 would give the same k's if C_{B-A} was chosen as the feed composition.) The data are presented in the table in the order of increasing relative particulate emission rate. The expected decreasing trend of k_5 with increase in P_T/F_T is clearly evident for cadmium. The effects are seen more clearly by graphical presentation. Results for cadmium and chromium are plotted against P_T/F_T in Figure 5, and for lead and iron in Figure 6. The k_5 values for cadmium and lead show a decreasing trend with increasing fractional loss. Chromium (Cu, Fe, Mn, Ni, and Zn as well) shows a slight upward trend. If these materials tend to classify into the ash rather than the particles, an upward trend is to be expected. All of the curves extrapolate to an ordinate of about 2.0. This ratio should extrapolate to unity. The fact that most of the metals extrapolate to about the same point indicates some kind of a constant error. A likely candidate is gas velocity at the stack outlet, or total particulate concentration in the stack gases.

As before, the results indicate high classification of cadmium and lead into the particulates. The arsenic data are now mixed, and a conclusion cannot be drawn from this table. The metals silver and zinc may classify slightly into the particulates. Chromium, copper, iron, manganese, and nickel do not classify into the particulates and in fact may end up in reduced proportion in the particulates.

Curves such as shown in Figure 5 and 6 may be quite useful in predicting emission rates. If the fractional loss as particulate of the feed (volatiles-free basis) is known, the fractional loss of a metal in the particulates can be determined. In using these curves, it is probably wise to make an adjustment for the evidently incorrect terminal point. All of the data in Table 7 should be shifted downward by dividing by 2.0. Then the terminal point will be approximately unity. The curves should not be extrapolated linearly to lower P_T/F_T values. At low P_T/F_T, the P_A/F_A values should be essentially constant.

TABLE 7. Concentration of Metal in Particles Relative to Concentration in the Feed (Volatiles-free Basis)

Plant	Furnace Type	Particle/Feed (g/kg)	Metal									
			Ag	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	As
E	MHF	3.64	2.7	54	1.94	0.61	0.24	0.34	0.63	18.7	1.86	-
F	MHF	14.1	1.6	60	0.74	1.22	0.042*	0.46	0.50	5.6	1.27	0.90
C	MHF	17.9	8.6*	15.9	2.42	4.3	1.22	70.2**	1.81	3.5	2.02	1.01
H	MHF	55.3	1.85	11.3	1.94	0.84	0.58	0.71	1.04	6.1	5.7	-
A	MHF	69.7	3.3	7.2	1.40	1.32	1.29	1.27	2.01	1.59	1.61	8.3
D	MHF	319	0.94	10.4	1.79	2.75	1.68	1.93	1.83	11.9	3.89	>6.2
K	MHF	745	2.38	5.5	2.29	1.21	1.57	0.92	1.70	3.0	1.56	3.8
J***	FB	41.5	1.10	1.32	1.99	2.24	1.90	1.97	1.27	1.73	2.29	--
G****	FB	2370	----------analytical error----------									
Geometric Mean			1.97	15.7	1.68	1.42	0.91	.901	1.21	5.36	2.21	
Standard deviation factor			1.56	2.56	1.50	1.95	2.13	1.96	1.76	2.31	1.72	

* Outliers. Not included in averages

** Analytical error likely. Not included in averages

*** Plant J. Not included in averages

**** Plant G. Not included in average (see footnote to Table 5)

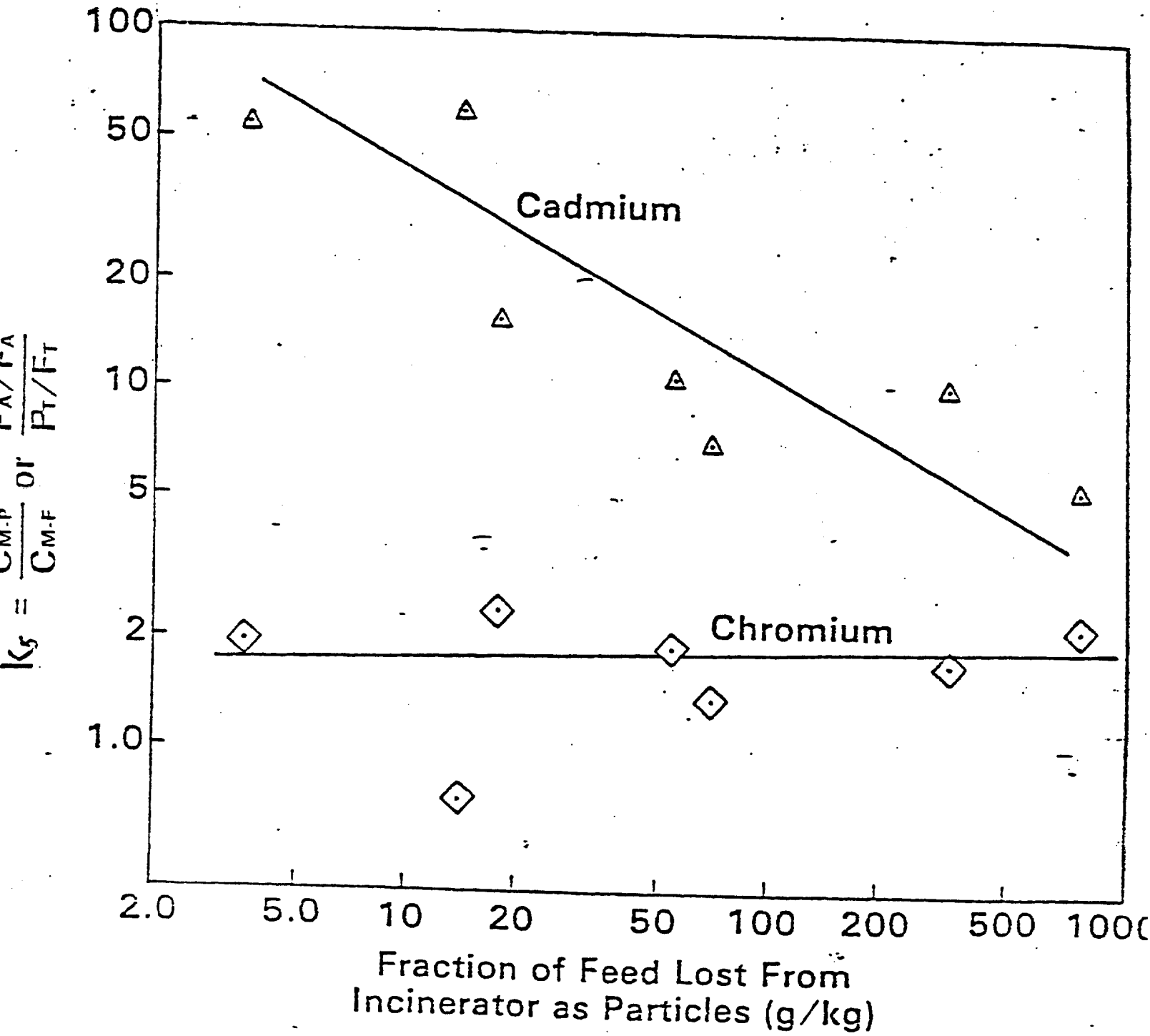


FIGURE 5: EFFECT OF THE FRACTION OF FEED LOST AS PARTICULATES ON THE CLASSIFICATION FACTOR, K_5 (CADMIUM AND CHROMIUM)

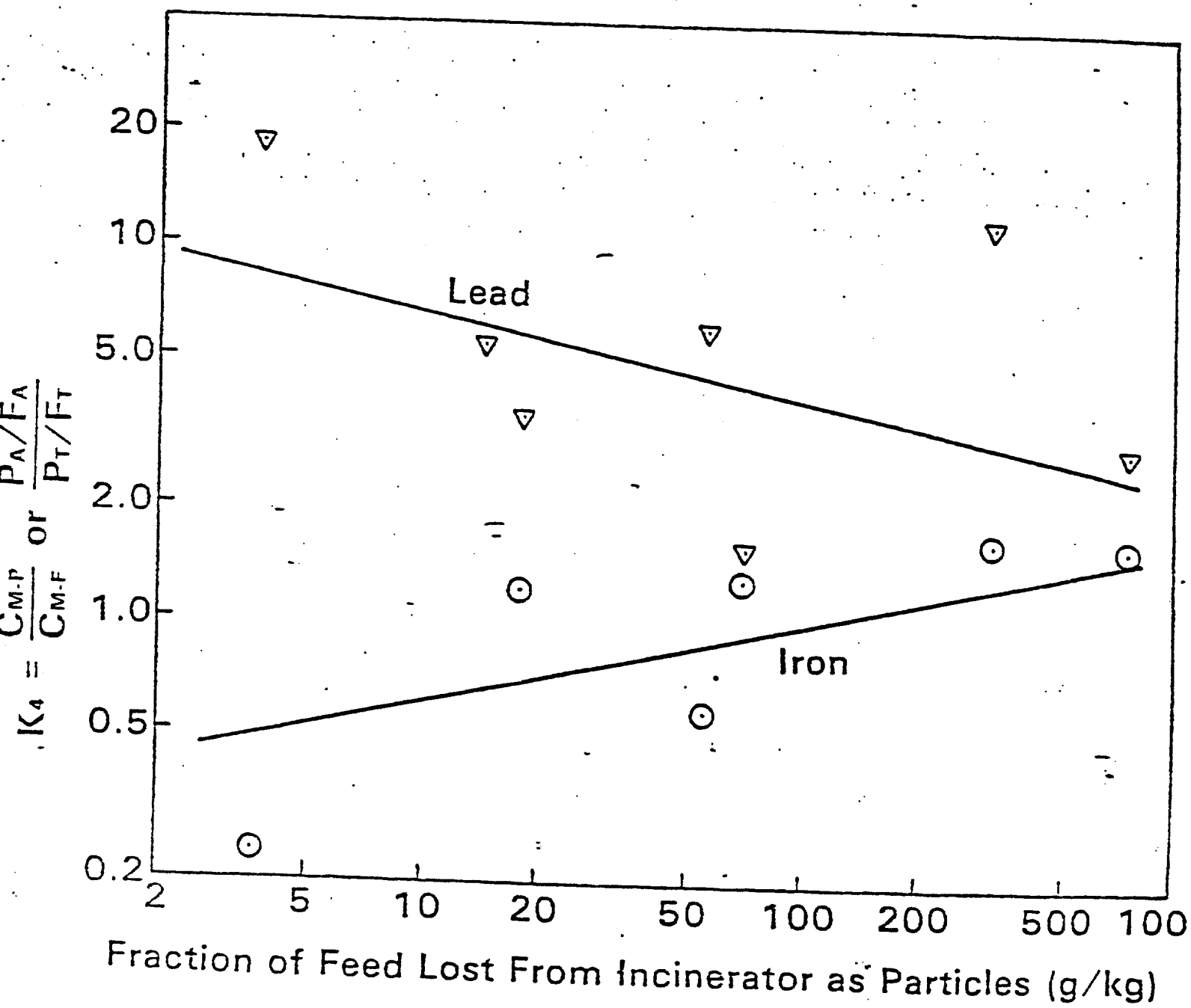


FIGURE 6: EFFECT OF THE FRACTION OF FEED LOST AS PARTICULATES ON THE CLASSIFICATION FACTOR, K_5 (LEAD AND IRON)

2. Effect of Industrial Input. In the initial developments of the work scope for this study, concern was expressed that, when incinerated, sludges with a high metals content might release amounts of metals greater even than might be expected from their higher concentrations in the sludge. For this reason, some sites were selected where the sludges were low in metals, reflecting a domestic origin, and some were selected where the sludges were high in metals, reflecting a high contribution from metal finishing industries.

Chemical analyses of the feed and ash for the various runs are presented in Table A-4. Data are summarized in Table 8 for cadmium and lead, where k_5 (see Equation 8--k_5 also equals the concentration of the metal in the particles divided by the concentration of the metal in the feed) is compared with the concentration of the metal in the feed (on a volatiles-free basis). The runs are listed in the order of increasing concentration for each metal.

No correlation between k_5 and concentration is evident from examination of Table 8. It would indeed be surprising to find a correlation, because the effect of the fraction of feed lost as particles has not been considered and the results reported above indicate there is an important effect.

The effect of the fraction of feed lost as particles on k_5 has been considered by replotting Figure 5 but with the metals concentration shown alongside of the appropriate points (Figure 7). For cadmium, no convincing trend is evident although there is an indication that higher cadmium levels in the feed may contribute to a lower enrichment of cadmium in the particles. The effect for lead is shown in Figure 8. No trend of any kind is discernible for lead.

The results thus indicate that the mere fact that cadmium or lead are present in high concentrations does not contribute to any disproportionate losses above that indicated by the correlations shown in Figures 5 and 6. These figures indicate that absolute quantities of these metals lost are directly proportional to the mass or concentrations in the feed and depend on the nature of the metal.

If no independent effect of concentration on the enrichment of metals is observed at the incinerator outlet, no effect is anticipated at the scrubber outlet. The enrichment that occurs as the particles pass through the scrubber is related to aerodynamic size and should show no independent influence of concentration.

TABLE 8. Comparison of k_5* Values with Metal Concentration in Feed (Volatiles-free basis) for Cadmium and Lead**

Cd			Pb		
Plant	Cd Concn. (mg/kg)	k_5	Plant	Pb Concn. (mg/kg)	k_5
D-1	12.7	10.4	D-1	330	11.9
E-1	17.9	54	E-1	1162	18.7
F-1	21.6	60	H-1	1340	6.1
K-1	30.0	5.5	C-1	1491	3.5
A-1	74.4	7.2	F-1	2255	5.6
C-1	257	15.9	K-1	3102	3.0
H-1	574	11	A-1	4637	1.59

* $k_5 = P_A/F_A \div \bar{F}_A/\bar{F}_T$ (see Equation 8)

** This comparison does not consider the effect of the fraction of feed lost as particles in k_5.

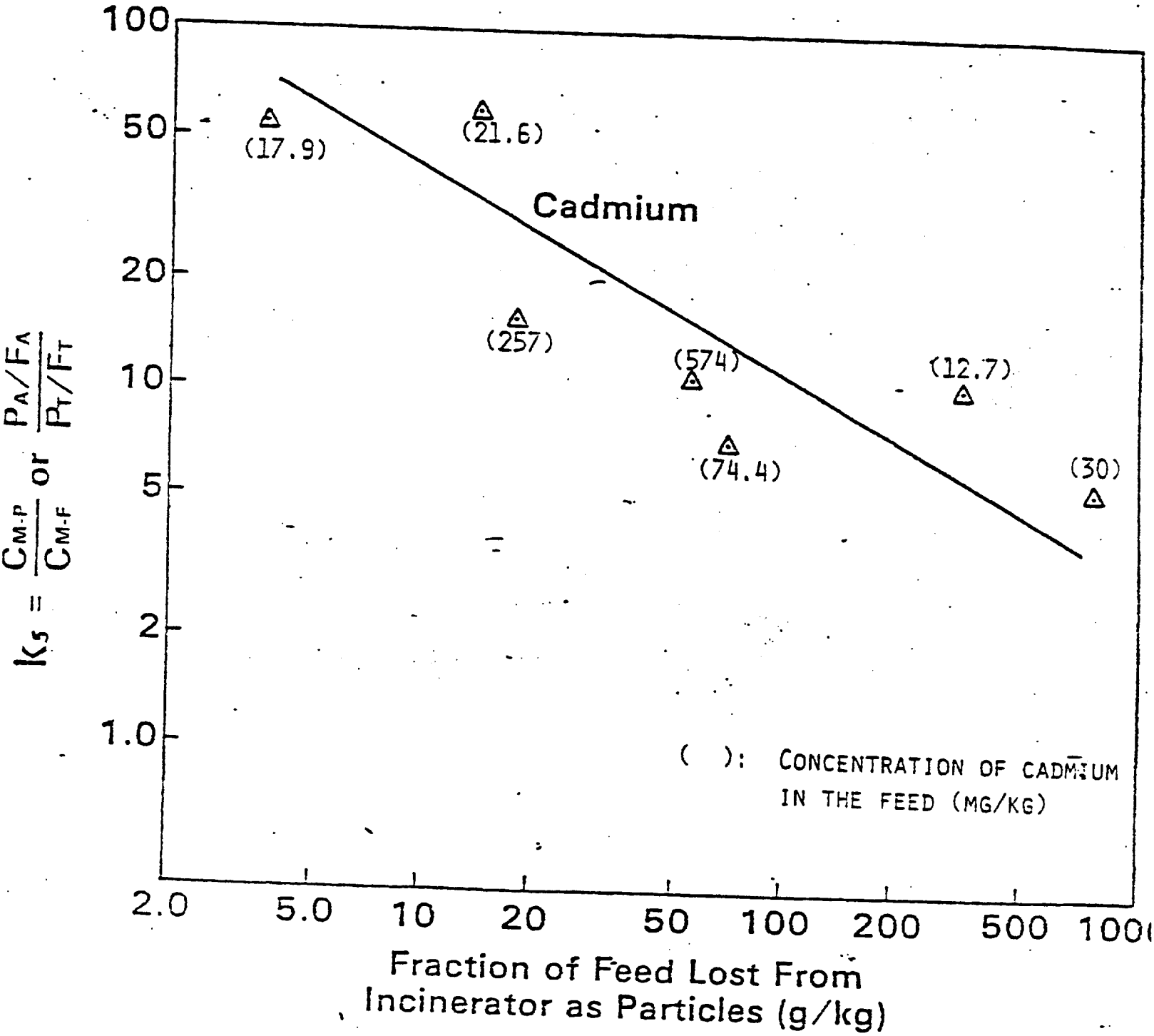


FIGURE 7: EXAMINATION OF THE CORRELATION OF K5 WITH FRACTION OF FEED LOST AS PARTICLES FOR THE INFLUENCE OF CONCENTRATION OF CADMIUM IN THE FEED

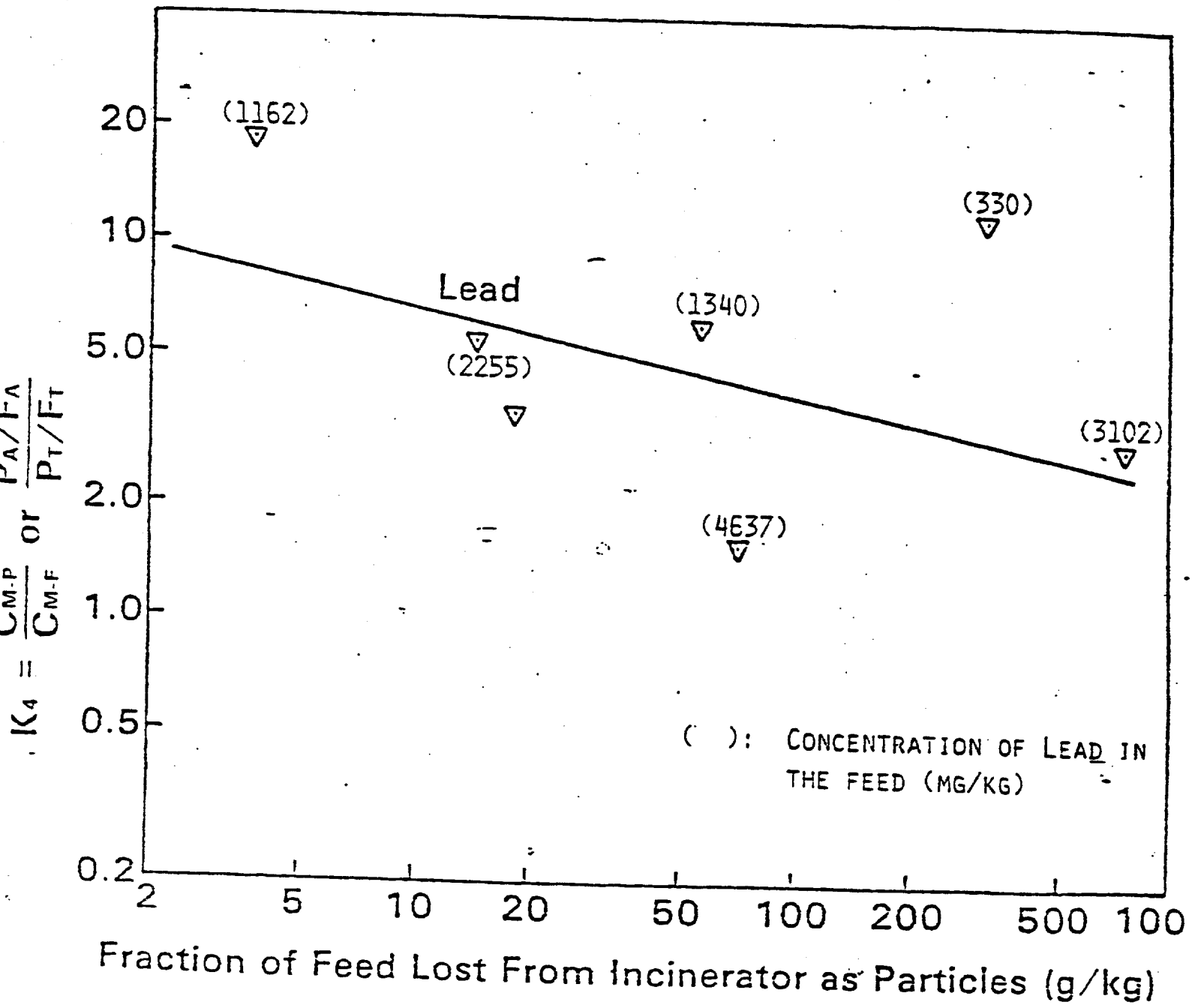


FIGURE 8: EXAMINATION OF THE CORRELATION OF K5 WITH FRACTION OF FEED LOST AS PARTICLES FOR THE INFLUENCE OF CONCENTRATION OF LEAD IN THE FEED

3. Emissions from the Scrubber. The particulate emissions that leave the scrubber have passed through two classification operations. As seen above, there is a classification that occurs in the incineration stage, which is a function of physical properties such as melting point and vapor pressure of the metal, chemical reactivity, and possibly of the chemical form in which the metal is present in the sludge. A second classification occurs in the scrubber, which appears to depend (see following section) on the aerodynamic particulate size range in which the metal is found when it leaves the incinerator. When there is inadequate information on compositions and flow rates between the incinerator and the scrubber, a rational basis for interpreting results cannot be developed. The data have to be interpreted on a completely empirical basis.

The results obtained for the plants tested are presented in Table 9. The ratio of concentration in the particles to the concentration in the feed (volatiles-free basis) is presented for each metal. As noted above, this is also equal to the ratio of the fraction of metal fed that is lost in the particles to the fraction of total feed (volatiles-free basis) that is lost in the particles.

The average k_5 values for the five multiple hearth incinerators that have reasonable emission rates leaving the scrubber compared to the standard of 0.65 g/kg of dry sludge solids are also shown in the table. They are compared below with the average k_5 values across the incinerator only.

	k_5 Incinerator only (I)	k_5 Incinerator and scrubber	$\frac{k_5(I+S)}{k_5 (I \text{ only})}$
Ag	1.97	16.3	8.3
Cd	15.7	161	10
Cr	1.68	2.6	1.5
Cu	1.42	4.6	3.2
Fe	0.91	0.45	0.50
Mn	0.90	0.46	0.51
Ni	1.21	1.46	1.21
Pb	5.36	59	11
Zn	2.21	11.1	5.0

Arsenic is not listed because data are too scant. Qualitatively, it is evident that arsenic parallels the effects noted with lead and cadmium, but the magnitude is not established.

The data show that a further classification occurs in the scrubbing device, which appears to depend on the metal. Silver, cadmium, lead, and zinc show an additional classification factor of 5- to 10-fold whereas chromium, copper, iron, manganese, and nickel show little classification. Silver and zinc showed no substantial classification in the incinerator but evidently particle size and density are such that classification occurs in the scrubbers (Results in the following section verify this conclusion).

TABLE 9. Concentration of Metal in Particles Leaving the Scrubber, Relative to Concentration in the Feed (Volatiles-free Basis)

Plant	Furnace Type	Relative Emissions (g/kg)	Metal									
			Ag	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	As
E	MH	0.13	19	290	1.8	2.5	0.09**	0.19	0.65	200	15	
F	MH	0.59	24.5	54	4.0	5.9	0.36	0.50	1.24	49	5.5	1.01
C	MH	0.67	10.8	270	3.2	4.8	0.21	0.49	1.02	27	12.1	410
A	MH	0.72	21.0	178	1.6	4.0	1.29	0.95	2.43	24	4.4	18
D	MH	1.73	10.8	144	3.2	7.6	0.41	5.4**	3.3	110	38	--
K*	MH	33.6	8.5	17.8	3.3	2.3	0.50	0.18	1.94	19.6	3.7	8.5
G*	FB	0.67	----------errors in analytical work----------									
J*	FB	0.036	2.0	4.7	5.8	0.55	1.51	0.26	8.0	1.8	1.9	--
Geometric Mean			16.3	161	2.60	4.64	0.447	0.459	1.458	58.7	11.1	
Standard deviation factor			1.47	1.96	1.49	1.52	2.14	1.94	1.93	2.49	2.36	

* Runs K, G, and J were not included in the calculation of the mean

** These points were rejected as outliers.

E. Concentration of Metals in the Various Particle Size Fractions

In the SASS train particle collection system, the sample is collected in four particle size ranges. The individual particle size fractions were then analyzed, so the particle size range where each metal concentrated could be determined.

1. Emissions from the Incinerator. The complete tabulation for each plant of mass of particle catch, mass of each metal and distribution of each metal in the various particle size ranges is given in Table A-5 in the appendix. A portion of this information is presented in Table 10 in which the percentage of the mass of a given metal in the total particulate catch that is found in the 0.1-1.0 μm fraction (the "fines" fraction) is given for each plant.

Examination of Table 10 shows there is little consistency in the percentages for a given metal for the runs at the different plants. However, certain metals consistently have a higher percentage in the "fines" fraction than other metals. To arrive at a semi-quantitative number, the metals were "ranked" in order of decreasin percentage in the fines for each plant and the ranks were averaged. A low number consequently indicates that a higher proportion of a given metal was consistently found in the fine fraction than the other metals. The average ranking for the metals from the results for eight plants is given below:

Ranking According to Particle Size Entering Scrubber		Enrichment Across the Scrubber	
	Average rank	$\frac{k_5\ (I+S)}{k_4\ (I\ only)}$	
Pb	2.1	Pb	11
Cd	2.1	Cd	10
Ag	3.4	Ag	8.3
Zn	3.6	Zn	5.0
Cu	5.7	Cu	3.2
As	6.0	As	--
Cr	7.1	Cr	1.5
Ni	7.3	Ni	1.2
Fe	8.4	Mn	0.51
Ni	9.0	Fe	0.50

The second column is taken from the preceding section which compared the "enrichment" in each metal that occurs across the scrubber. The results are remarkably consistent. The presence of a high concentration of metals in the fine fraction in the scrubber is reflected by a proportionate enrichment in that metal across the scrubber.

TABLE 10. Fraction of the Total Mass of a Given Metal in the Particulates Leaving the Incinerator That is Found in the 0.1-1.0 μm Size Range

Plant	Furnace Type	Total Discharge (%)	Metal									
			Ag	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	As
A	MH	9.8	51.1	34.7	18.0	18.5	12.7	13.1	18.6	23.1	19.0	13.6
C	MH	24.8	18.7	84.9	38.3	17.7	25.0	98.7*	36.6	45.2	43.0	16.6
D	MH	1.91	23.8	17.0	0.5	9.1	0.7	3.6	1.4	17.0	4.0	2.5
E	MH	15.4	45.5	80.7	11.4	44.3	4.7	5.7	18.3	94.4	69.9	42.1
F	MH	5.3	59.6	97.0	4.7	33.1	8.5	1.6	1.7	66.7	29.2	9.8
G	FB***	0.20	98.7	82.7	1.4	9.0	0	18.2	98.1	87.4	0.1	18.3
H	MH	26.5	54.1	68.4	25.5	29.1	5.0	2.4	9.9	67.6	70.1	61.7
J	FB**	0.32	0	0	0	0	0	0	0	0	0	0.8
K	MH	4.5	23.2	21.8	8.0	7.0	4.2	1.8	114	34.4	23.5	24.9

* Analytical error

** Analytical error in the metal determinations for the 0.1-1 μm fraction for Plant J is suspected. However, this fraction was only 0.3 wt. % of the particle catch, so mass balances and other results are not significantly affected.

***Percent total discharge is low, probably because of carryover of sand from the fluid bed.

2. Emissions from the Scrubber. A complete tabulation for each plant of mass of particle catch, mass of each metal, and distribution of each metal in the various particle size ranges is given in Table A-6 in the appendix. A portion of the information is presented in Table 11, which gives the percentage of the mass of each metal in the total particulate catch that is found in the 0.1-1.0 μm particle size range.

The tabulation shows that except for iron, manganese, and nickel, all of the metals are concentrated into the fines fraction for the multiple hearth furnaces. Except for Plant H, the results show that generally more than half of the mass of particles leaving the scrubbers is found in 0.1-1.0 μm fraction. The metals that are classified into the particulates in the furnace (Cd, Pb, and possibly As--Section D-1 above) and the metals that leave the furnace in a fine form (Pb, Cd, Ag, Zn) are concentrated into the fines to an even greater degree; generally over 90 percent of the mass of these metals leaving the scrubbers is in the 0.1-1.0 μm fraction.

F. Calculated Ground Level Concentrations of Heavy Metals

The information presented in the preceding Section D allows an estimate to be made of the emissions of heavy metals from multiple hearth incinerators. Of equal importance to absolute emission rates are the ground level concentrations that develop. These concentrations can be calculated from plume models. These models predict the ground level concentrations of particulates from a knowledge of the nature, quantity, and temperature of the discharge. Other conditions of discharge such as the exit velocity of gas, stack height, wind speed and direction, and air turbulence are also used in the plume model to determine atmospheric calculations. The dispersion of a plume is illustrated in Figure 9. Plume dispersion models given approximate results because of the intrinsic difficulty of the problem as well as the fluctuations in ambient conditions that occur in nature. Nevertheless, they are useful in predicting the approximate magnitude of particulate concentrations in the atmosphere.

Plume models are available that can calculate concentrations for a wide variety of circumstances and conditions. A previously presented paper (8) utilized a program (10) in which different atmospheric conditions were selected and the emissions data from a test were used to determine the maximum ground level concentration of the emissions and the distance from the stack at which they occurred. This was an instantaneous maximum condition and gives a "worst-case" estimate of any environmental impact. Plume models are available that utilize actual meteorological data and calculate various time-averaged estimates of ground level concentrations. This is a much better procedure than merely making worst-case estimates. Fortunately, meteorological data were available for all of the cities where the test incinerators were located, so this procedure was utilized to calculate realistic maximum annual average ground level concentrations.

TABLE 11. Fraction of the Total Mass of a Given Metal in the Particulates Leaving the Scrubber That Is Found in the 0.1-1.0 μm Size Range

Plant	Furnace Type	Total Discharge	Ag	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	As
A	MH	46.1	90.8	82.5	19.7	96.3	15.3	22.5	49.3	93.4	87.2	49.9
C	MH	90.3	94.3	99.3	94.1	97.8	83.5	48.8	90.1	99.0	98.8	99.9
D	MH	83.1	93.2	89.3	38.4	84.8	31.1	92.2	46.9	90.4	87.9	88.7
E	MH	48.4	58.0	80.3	38.6	79.5	45.3	37.1	60.6	90.7	81.5	79.6
F	MH	53.0	91.3	71.9	7.9	87.1	11.3	25.9	5.9	93.2	80.7	39.5
G	FB	55.4	100 *	99.1	29.1	--	--	90.7	99.8	99.9	49.6	89.7
H	MH	3.8	93.1	96.8	19.3	75.9	18.9	14.2	17.5	94.5	97.9	78.4
J	FB	42.4	29.2	1.2	5.8	19.9	0.9	9.5	3.0	6.6	32.6	69.4
K	MH	62.8	72.6	86.6	27.0	84.5	42.0	39.4	4.5	92.8	91.2	88.0

* Concentration appears to be in error

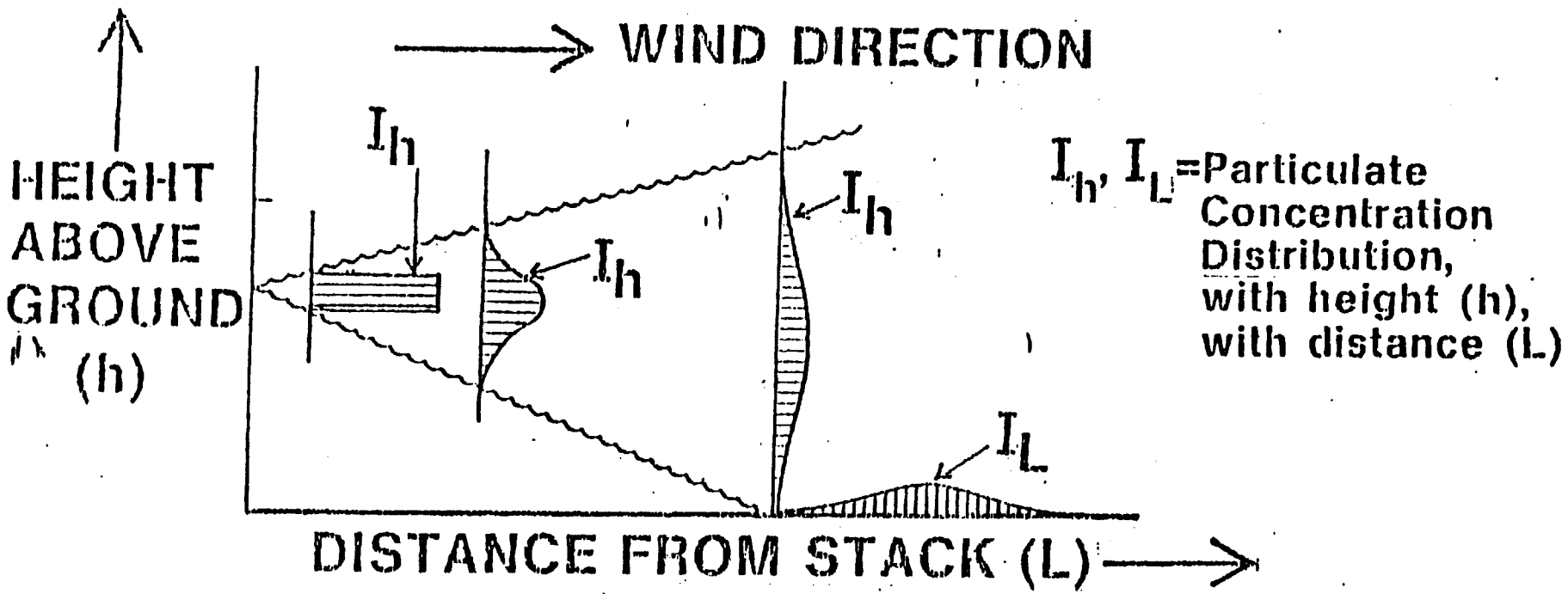


FIGURE 9: EFFECT OF PLUME DISPERSION ON PARTICULATE CONCENTRATIONS IN AIR AND AT GROUND LEVEL

The calculations of ground level concentrations were made using EPA's CRSTER model (20). The program utilizes the emissions data and a compilation of hourly meteorological data for an entire year to calculate various averaged concentrations at the test site location. The model calculates hourly average concentrations at 180 points around the stack (see Figure 10 for the spatial arrangement). From the hourly concentrations, annual average concentrations are calculated. The program then selects the maximum annual average concentration. Selection of the proper distance between rings (see Figure 10) is important. If distance is improperly selected, the array may not include the maximum. Figure 11 shows a plot of the annual average concentrations in the prevailing wind direction for cadmium for several of the plant locations, which indicate that the maximum was located.

The results of the CRSTER calculations of the maximum annual average concentrations are presented in Table 12 for seven metals (cadmium, iron, nickel, lead, chromium, copper, and manganese). Also shown in this table are the average yearly ambient levels of these metals in the atmosphere for the cities where the plants are located as determined by EPA's National Air Surveillance Network (21) for the years 1970-74. Cadmium is the only metal that shows calculated ground level concentrations consistently close to ambient levels. The median calculated ground level concentration for lead is 25.8 ng/m^3 which is only 2 percent of the average actual ambient concentration and 1.7 percent of EPA's standard. For all the other metals noted above, except cadmium, CRSTER-calculated concentrations are far below the actual ambient concentrations.

Although calculated cadmium ground level concentrations approach ambient levels, it should be appreciated that both the calculated concentrations and the ambient levels are very low. Compared to a suggested EPA standard of 100 ng/m^3 (22), median calculated ground level concentration is 1.5 ng/m^3. This is only 1.0 percent of the suggested standard and appears to be of little significance.

Arsenic, silver, and zinc are not listed in Table 12 because average ambient levels were not available for comparison. If it is desired to obtain CRSTER ground level concentrations for these metals, it is only necessary to adjust the CRSTER value for one of the metals in Table 12 by the ratio of the concentration of the metals in the discharged particulates. For example,

For Plant A-0, concentration in particles at stack outlet,

Cd: 13,570 mg/kg (from Table A-6)

As: 157 mg/kg (from Table A-6)

From Table 10, CRSTER-calculated ground level concentration for Cd = 3.47 ng/m^3

$$As = 3.47 \times \frac{157}{13,570} = 0.040 \text{ ng/m}^3$$

Figure 10

EXAMPLE OF RECEPTOR NETWORK USED IN THE SINGLE SOURCE (CRSTER) MODEL FOR A SOUTH WIND AND FOR EACH STABILITY CLASS

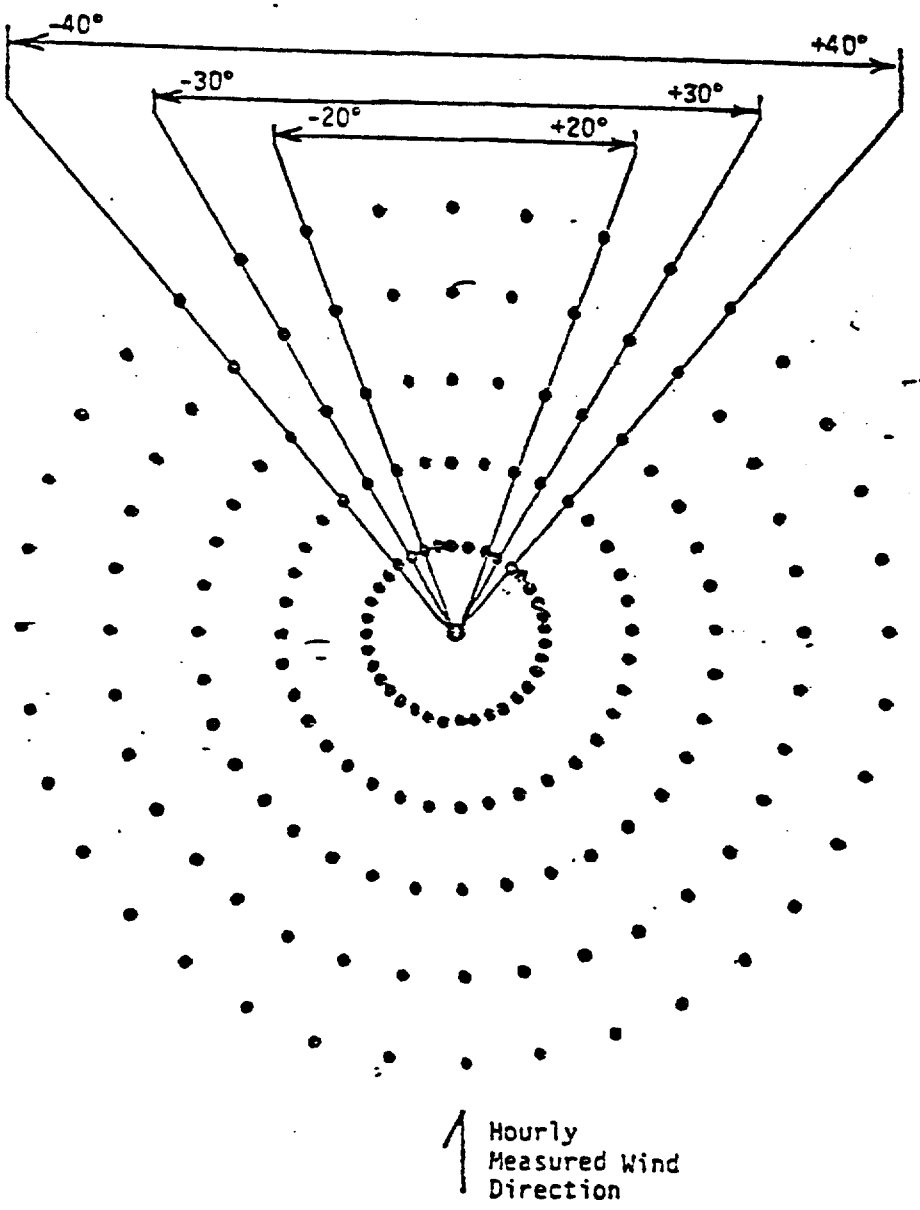


FIGURE 11

AVERAGE ANNUAL CONCENTRATION OF CADMIUM
IN RADIAL DIRECTION IN VACINITY AT MAXIMUM

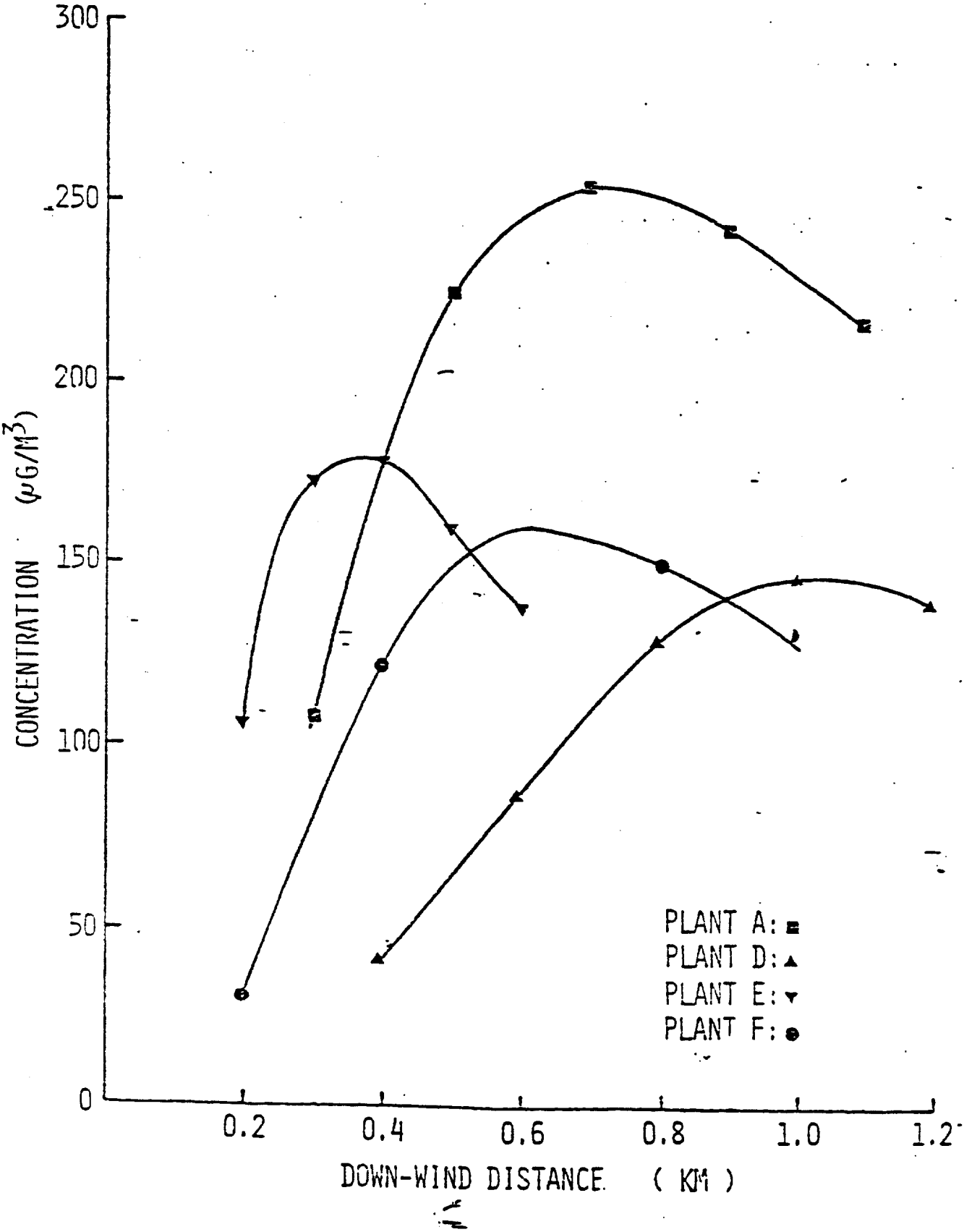


TABLE 12. Comparison of CRSTER Calculated Heavy Metals Concentrations and Ambient Concentrations for 7 Heavy Metals

Plant	Source	Year[1]	Total	Metal Concentration (ng/m^3) Cd	Fe	Mn	Pb	Cr	Cu	Hg
A	CRSTER	1977	255.5	3.47	9.36	1.11	25.8	1.32	4.62	0.20
A	AMBIENT			3.73	2,660	0.21	1,573	15.52	400.3	173.3
A	% AMBIENT			93.0	0.35	13.5	1.6	8.5	1.1	0.16
C	CRSTER	1977	124.4	9.66	3.65	3.62	4.98	0.73	1.22	0.07
C	AMBIENT			1.77	2,543	15.25	1,323	13.03	75.00	105.7
C	% AMBIENT			545.8	0.14	23.7	0.38	5.6	1.6	0.07
D	CRSTER	1977	148.5	0.25	1.99	0.23	6.76	0.32	1.43	0.41[2]
D	AMBIENT			0.26	1,018	2.59	579.8	3.73	51.47	30.54
D	% AMBIENT			96.2	0.2	8.9	1.2	8.6	2.8	1.3
E	CRSTER	1977	177.7	0.84	2.20[3]	0.15	39.3	0.22	0.95	0.07
E	AMBIENT			1.77	2,543	15.25	1,323	13.03	75.00	105.7
E	% AMBIENT			47.5	0.09	0.98	2.97	1.69	1.27	0.07
F	CRSTER	1977	160.0	0.12	6.65	0.05	3.30	0.23	0.55	0.05
F	AMBIENT			0.26	1,220	2.24	872.7	6.86	67.33	37.73
F	% AMBIENT			46.2	0.5	2.2	0.4	3.4	0.8	0.1
G	CRSTER	1977	329.1	1.92	3.90	82.21[2]	117.7	0.38	0.53	1.51
G	AMBIENT			1.77	2,543	15.25	1,323	13.03	75.00	105.7
G	% AMBIENT			108.5	0.2	539.1	8.9	2.9	0.7	1.4
H	CRSTER	1964	22,885	3.16	11.81	0.49	30.02	1.79	6.36	0.37
H	AMBIENT			12.38	1,192	29.47	1,403	13.68	845.7	29.4
H	% AMBIENT			25.5	1.0	1.7	2.7	13.1	0.8	1.3
J	CRSTER	1964	161.9	0.04	10.19	0.55	0.46	0.34	0.27	0.19
J	AMBIENT			12.38	1,192	29.47	1,403	13.68	845.7	29.4
J	% AMBIENT			0.3	0.9	1.9	0.03	2.5	0.03	0.6
K	CRSTER	1964	2,205	1.49	29.98	1.62	109.2	5.44	10.85	0.74
K	AMBIENT			5.36	1,364	33.36	1,297	30.10	151.4	29.0
K	% AMBIENT			27.8	212	4.9	8.4	18.1	7.2	2.6
	CRSTER TOTAL			20.95	76.53	7.02	345.52	10.77	26.78	3.28
	CRSTER AVERAGE (ng/m^3)			2.33	9.57	0.87	38.39	1.20	2.98	0.41
	AMBIENT TOTAL			39.68	16,283	151.09	11,090	122.66	2,595	646.47
	AMBIENT AVERAGE (ng/m^3)			4.41	1,809	16.79	1,233	13.63	288.32	71.83
	% AMBIENT			52.8	0.53	5.2	3.1	8.8	1.0	0.57

1. Source year for meteorological data on wind velocity, etc.
2. Appears to be an erroneous analytical determination. Not included in average.
3. The concentration on which these figures was based was an outliers. Not included in averages.

G. Loss of Metal to Impingers

After passing through the 0.1 um filter of the SASS train, the stack gases pass through a condenser and then through a series of bubblers. The adsorbent in the condenser, described by Harris et al. (10), was not used, and distilled water was used in the bubblers instead of the suggested reagents. Because there was some concern that volatile metals might pass through the 0.1 µm filter, a check was made to see if any substantial amount of metals were collected downstream from the filter. The water from the bubblers was evaporated down, weighed, and analyzed for metals. The water from the condenser was not analyzed.

Results obtained are presented in Table 13. The mass of metals collected from the bubblers has been compared to the mass of metals collected in the particulate catch. For lead and cadmium, the amount of material collected is seen to be a small fraction of the particle catch, indicating no loss of ultrafine material through the filter. For several other metals, such as chromium, nickel, manganese, and silver, the results indicate a catch in the bubblers as high as the catch in the particulates. This anomalous result is hardly believable and is attributed to an unknown source of error. No blank run was made. It is conceivable that a blank would have indicated a high concentration of the metals that show excessive recoveries in the bubblers.

H. Gaseous Emissions

Analyses were carried out for NO_x, SO_2, and unburned hydrocarbons on a few of the incinerators tested. The data on NO_x and SO_2 are summarized in Tables 14 and 15.

If Plant H is excluded, the multiple hearth data show reasonably uniform NO_x concentrations. When production is based on sludge input, results are less regular. Plant G, the only fluid bed furnace, shows a substantially higher NO_x concentration. Data are not sufficient to draw a firm conclusion above differences between fluid bed and multiple hearth furnaces. Calculated ground level concentrations are a small fraction of ambient air quality standards in all cases.

The data for SO_2 concentrations are also reasonably uniform if Plant H is excluded (there is a basis for uncertainty about Plant H scrubber output readings. Particulate data were also inconsistent and had to be rejected). Calculated ground level concentrations are a miniscule percentage of the ambient air quality standard for SO_2.

Results on total unburned hydrocarbons at the scrubber outlets are summarized below:

Plant	Furnace	Concentration (ppm)	CRSTER Ground Level Concn. (ppm)
E	MH	15.7	0.21 x 10-3
F	MH	9.0	0.47 x 10-4
G	FB	0.5	0.85 x 10-5

TABLE 13. Quantity of Metals in Impingers Compared to Amount Collected in Front End (upstream from 0.1 μm filter) of the SASS Train

	Plant	Ag	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	As
A	Front	8.33	109	41.6	145	295	8.89	34.8	811	182	1.26
	Impingers	17.5	63	35.0	12.3	14.9	17.5	43.8	35.0	52.6	0.64
	Ratio: Im/F	2.1	0.058	0.84	0.084	0.051	1.97	1.26	0.043	0.29	0.51
C	Front	13.0	1110	83.7	140	419	7.94	41.6	572	1400	224
	Impingers	17.5	17.5	78.8	17.5	96.4	17.5	61.3	26.3	140	1.75
	Ratio: Im/F	1.3	0.015	0.94	0.12	0.23	2.20	1.47	0.94	0.10	0.0078
D	Front	17.4	30.1	38.8	170	238	48.6	28.0	808	650	2.16
	Impingers	7.01	1.8	17.5	2.6	8.8	14.0	26.3	5.3	26.3	0.26
	Ratio: Im/F	0.40	0.60	0.45	0.015	0.037	0.29	0.94	0.0066	0.040	0.12
G	Front	54.5	2.55	0.502	0.703	5.19	2.01	109	157	2.07	0.10
	Impingers	--	.021	1.05	0.57	--	--	1.30	0.56	2.4	0.057
	Ratio: Im/F	--	0.008	2.09	0.81	--	--	0.011	0.0036	1.15	0.57
K	Front	6.95	14.5	53.0	106	292	7.18	15.8	1060	649	7.99
	Impingers	--	0.037	1.83	10.0	--	--	3.77	4.2	40.3	0.76
	Ratio: Im/F	--	0.0026	0.034	0.094	--	--	0.24	0.0040	0.062	0.095

TABLE 14. Comparison of CRSTER Max. Annual Concentration With NAAQS Limits for NO_x (As NO_2)

Plant	Furnace Type	Average NO_x Concn. at Stack g/m^3	CRSTER Average NO_x Concn. ng/m^3	NO_x NAAQS* ng/m^3	Percent of NAAQS	NO_x Flow g/hr	Dry Sludge kg/hr	g NO_x kg Sludge
E-Outlet	MH	0.059	772.0	100,000	0.77	889.8	1,596	0.558
F-Outlet	MH	0.14	738.1	100,000	0.74	2,561	936	2,736
G-Outlet	FB	0.41	6,958	100,000	6.96	5,221	93	56,140
H-Outlet	MH	0.38**	7,893**	100,000	7.89**	5,085**	640	7.945**
J-Outlet	FB		--	--	--	--	--	--
K-Outlet	MH	0.071	809.7	100,000	0.81	1,680	73	23,014

* NAAQS based on annual arithmetic mean (NAAQS = National Ambient Air Quality Standard)

** High uncertainty arithmetic average based on three measurements, one of which was very high

TABLE 15. Comparison of CRSTER Maximum Annual Concentrations With NAAQS Limits for SO_x (As SO_2)$_2$)

Plant	Furnace Type	Average SO_x Concn. at Stack g/m^3	CRSTER Average SO_x Concn. ng/m^3	SO_x NAAQS* ng/m^3	Percent of NAAQS	SO_x Flow g/hr	Dry Sludge	g SO_x kg sludge
E-Outlet	MH	--	--	80,000	--	--	--	--
F-Outlet	MH	0.0030	1.56	80,000	0.002	5.40	936	0.0058
G-Outlet	FB	--	--	80,000	--	--	--	--
H-Outlet	MH	0.0160	338.17	80,000	0.423	217.8	640	0.3403
J-Outlet	FB	0.0044	72.62	80,000	0.091	21.96	1,340	0.0164
K-Outlet	MH	0.0068	78.79	80,000	0.098	163.44	73	2.2389

* Based on annual arithmetic mean (NAAQS = National Ambient Air Quality Standard)

The paucity of data makes any conclusion regarding unburned hydrocarbons tentative. However, the low total unburned hydrocarbons for the fluidized bed incinerator is in accord with expectations. The National Ambient Air Quality Standard for hydrocarbons is 0.24 ppm (23). The CRSTER ground level concentrations are well below the standard. However, individual states and municipalities have rules that may make afterburning necessary, particularly for MH incinerators.

The limited amount of data and the variability in results make it desirable to obtain more information. However, the low ground level concentrations relative to standards indicate that no serious problems exist.

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CONCLUSIONS

1. Five out of eight sewage sludge incinerators met EPA's new source performance standard of 0.65 g of particulates per kg of dry sludge solids feed. Of the remaining three, only one significantly exceeded the standard. None of these incinerators when constructed had to meet new source performance standards although most of them had undergone some upgrading of their particle removal devices. This is an encouraging result and indicates no extreme hardship created by the standard.

2. Overall efficiencies of the scrubbers varied widely and no correlations were evident. When efficiencies for removal of various particle size fractions were compared, differences in overall efficiency could be explained. All scrubbers showed good removals for size fractions larger than 1.0 μm. However, efficiencies ranged from about 50 to 90 percent for the 0.1 to 1.0 μm fraction. No significant improvements in performance by use of higher pressure drops or use of a venturi scrubber downstream from an impingement scrubber were evident. This is not unexpected because the scrubbing systems for the plants were totally unrelated.

3. The use of percent removal efficiency for the various fractions appears to be a satisfactory expression of the performance of the scrubber systems. Thus, for a given particle size fraction, the mass per unit time that escapes collection is directly proportional to the mass per unit time of that fraction approaching the scrubber.

4. When operating conditions are adjusted to give reduced loadings to the scrubber, the average particle size falls. Scrubber efficiency is reduced, allowing a higher percentage of particles to escape. However, this increase does not compensate for the reduction caused by the reduction in loadings, so an overall reduction in emissions occurs.

5. Material balances around the incinerators (not including the scrubbers) for cadmium and lead show results consistent with the other metals. These metals evidently are being collected by the particle collection apparatus as efficiently as other metals.

6. Heavy metal emissions from the incinerator (upstream from the scrubber) can be correlated by plotting fraction of the metal fed that leaves as particulates versus fraction of the inerts in the feed that leave as particulates. Cadmium, lead, and probably arsenic show substantial concentration in the particles leaving the incinerator. If the fraction of feed (volatiles-free basis) that leaves as particulates is known, then the amount of loss of various metals can be estimated.

7. Silver and zinc are not concentrated into the particulates by the intineration process. However, those particles that are carried overhead are fine and concentrate in the fines fraction. Consequently, since the scrubbing systems are less efficient for fine particles, they are not recovered as efficiently as the bulk of the particles. Consequently, their concentration in the particle catch at the scrubber exit is substantially higher than at the inlet.

8. Cadmium and lead, probably by virtue of the chemical transformations that cause them to be concentrated into the particulate fraction leaving the incinerator, are fine and are concentrated in the fines fraction. Consequently, their concentration in the particle catch at the scrubber exit is substantialy higher than at the inlet. Arsenic probably behaves in the same way as cadmium and lead.

9. The enrichment of Cd, Pb, probably As, Ag, and Zn that occurs across the scrubber is directly related to the presence of these metals in high proportion in the 0.1-1.0 μm fraction leaving the incinerator.

10. Generally over 90 percent of the Cd, Pb, probably As, Ag, and Zn that leave the scrubber as particulates are found in the 0.1 to 1.0 μm fraction.

11. The median of ground level concentrations for lead, calculated from plume models, averaged 25.8 ng/m^3, which is only 2 percent of the actual ambient concentrations in the cities where the incinerators are located and 1.7 percent of EPA's standard of 1500 ng/m^3.

12. For cadmium, the median of the calculated ground level concentrations averaged 1.5 ng/m^3. This level approaches actual ground level concentrations but is only 1.0 percent of a suggested standard of 100 ng/m^3.

13. The low concentrations of lead and cadmium relative to concentrations of health significance indicate that sludge incineration creates little or no threat to health from these metals.

14. The comparable material balances of lead and cadmium when compared to other metals indicate good collection of these metals by the SASS train and its 0.1 μm filter. If desired, use of a filter downstream from the scrubbing system would assure virtually complete collection of metals except mercury.

15. Sulfur dioxide and nitrogen oxides levels are very low compared to ambient standards and to other sources of these pollutants.

RECOMMENDATIONS

1. Investigations should be conducted under controllable conditions to determine the effects of factors, such as temperature, oxygen partial pressure, and agitation of the burning bed on the loss of certain heavy metals into the particulate stream.

2. More information should be collected on fluidized bed incineration. Data reported here are too scant. The possibility exists that particulates are larger in size and may be easier to remove.

3. For multiple hearth incinerators, an increased loading of particles arriving at the scrubber produces a related increase in particulate losses. A measuring device should be found (or developed) for indicating particulate loading, and used as a control device to prevent excessive particulate emissions from multiple hearth incinerators.

4. Scrubbers have reduced efficiencies for removal of fine particles, the fraction in which lead and cadmium are concentrated. Increasing pressure drop across scrubbers requires large increases in power without commensurate increase in efficiency. Alternative particle collection devices, such as electrostatic precipitates or fabric filters, alone or in combinations that could include low intensity scrubbers, may be more efficient for lead and cadmium removal and more cost effective than combinations of impingement and venturi scrubbers. Investigations of the utility of alternative approaches to particle collection should be instituted.

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TABLE A-1

CALCULATION OF SCRUBBER EFFICIENCIES *

Run	Sludge Feed Rate (Dry Solids) kg/hr	Emission Rate kg/hr	Adjusted Emission Rate kg/hr	Scrubber Efficiency
A-0	1281	0.918	0.918	
A-I	1735	69.86	51.58	98.2
B-0	1397	0.561	0.561	
B-I	1045	5.32	7.11	92.0
C-0	2441	1.63	1.63	
C-I	1998	17.35	21.20	92.3
D-0	1173	2.03	2.03	
D-I	720	162.3	264.4	99.2
E-0	1596	0.205	0.205	
E-I	1347	3.28	3.89	94.7
F-0	936	0.555	0.555	
F-I	1587	8.95	5.28	89.5
G-0	93	0.050	0.050	
G-I	160	123.1	71.6	99.9
J-0	1340	0.049	0.049	
J-I	1746	16.65	12.78	99.6
K-0	73	2.45	2.45	
K-I	89	20.14	16.52	85.1

* Emissions from the furnaces were assumed to be proportional to sludge feed rate. Emissions for scrubber input runs (- I runs) were adjusted to correspond to the feed rates in the scrubber output runs (- O runs).

TABLE A-2.

DISTRIBUTION OF MASS IN VARIOUS PARTICLE SIZE FRACTIONS AT SCRUBBER INLET AND OUTLET IN SLUDGE INCINERATOR TEST (Weight Percents)*

Run	Size Fractions (μm)				Wt. Percent of Scrubber Input That Left at Outlet
	> 10	3.5-10	1.0-3.5	0.1-10	
A-I	68.42	9.19	12.18	10.21	
A-O	30.06	7.20	8.41	54.33	1.8
C-I	34.93	31.48	8.06	25.53	
C-O	3.81	0.61	1.36	94.22	7.7
D-I	72.61	19.25	6.22	1.92	
D-O	3.98	1.88	2.28	91.86	0.8
E-I	80.77	1.86	1.92	15.45	
E-O	45.83	2.63	3.13	48.40	5.3
F-I	49.61	41.65	3.39	5.35	
F-O	24.53	15.81	6.63	53.03	10.5
G-I	98.28	1.39	0.13	0.20	
G-O	27.13	2.68	14.84	55.35	0.1
J-I	67.88	26.09	5.71	0.32	
J-O	16.26	33.36	8.03	42.35	0.4
K-I	39.46	34.86	21.23	4.45	
K-O	35.13	0.06	2.04	62.77	14.9

* Mass in probe wash not included.

TABLE A-3

RESULTS OF MATERIAL BALANCE CALCULATIONS FOR EACH METAL FOR SLUDGE INCINERATOR RUNS

Run	Ratio of Output Mass/Input Mass										
	Cd	Fe	Ni	Pb	Ag	Cr	Cu	Mn	Zn	As	Mean for all metals
A-I	0.95	1.04	1.10	0.76	1.70	0.62	0.97	1.02	1.05	1.78	1.023
C-I	0.75	0.46	0.58	0.57	0.62	0.55	0.53	1.77	0.48	0.13	0.701
D-I	3.32	1.38	1.17	4.19*	1.15	1.25	1.73	1.42	1.96	2.83	1.801
E-I	0.63	1.07	1.11	0.75	1.01	1.32	1.06	1.25	--	--	1.025
F-I	2.64	1.28	0.82	0.69	1.10	0.76	1.44	1.43	1.36	1.32	1.28
H-I	0.79	14.20*	0.92	0.71	0.89	0.57	1.33	1.37	1.44	--	1.002
J-I	0.91	1.57	0.58	1.38	0.85	0.68	1.61	1.55	1.63	--	1.196
K-I	4.12*	1.71	1.58	2.35	1.83	1.85	1.06	0.88	1.17	--	1.553

* Outliers -- not included in the averages

TABLE A-4

CHEMICAL ANALYSIS OF SLUDGE FEED AND ASH RESIDUE DURING INCINERATOR TESTS (Dry Solids Basis-mg/kg)

Plant[1]	Sample	Volatile Solids(%)	Loss on Ignition(%)	Ag	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
A-I	Sludge	42.2		25	43	1,737	2,327	15,900	780	567	2,600	2,880
A-I	Ash		3.69	67	33	1,700	3,787	28,200	1,353	1,013	3,253	4,987
A-0	Sludge	55.5		22	34	1,416	2,013	12,593	520	793	1,880	2,300
A-0	Ash		1.65	89	16	1,987	4,153	31,153	1,213	1,506	3,907	4,993
B-I	Sludge	56.9		18	301	1,529	385	60,800	333	127	553	3,548
B-I	Ash		1.88	49	410	2,153	1,137	144,800	1,114	293	1,540	9,953
B-0	Sludge	63.0		19	299	1,507	421	57,667	333	105	560	3,693
B-0	Ash		1.39	37	473	2,853	989	131,733	1,019	233	1,213	9,133
C-I	Sludge	51.7		43	124	1,020	1,000	73,600	609	1,293	720	4,133
C-I	Ash		0.73	43	125	1,107	967	69,533	665	1,513	793	3,927
C-0	Sludge	50.2		42	142	913	1,020	69,100	567	1,413	733	4,007
C-0	Ash		0.86	73	87	1,500	1,890	138,400	1,291	2,987	1,390	6,633
D-I	Sludge	29.4		77	9	551	655	20,413	336	286	233	523
D-I	Ash		9.07	99	4	753	1,173	36,267	557	327	153	767
D-0	Sludge	40.6		54	7	410	747	19,287	301	282	247	579
D-0	Ash		7.63	95	6	660	1,351	37,667	576	307	167	787
E-I	Sludge	32.9		25	12	501	1,240	92,100	1,133	780	1,150	4,246
E-I	Ash		0.45	38	8	984	1,954	147,000	2,110	1,290	1,180	--
E-0	Sludge	33.0		23	11	460	1,439	91,100	1,262	860	750	4,413
E-0	Ash		1.0	39	10	818	2,350	148,100	2,490	1,490	820	--
F-I	Sludge	49.0		21	11	231	316	51,600	359	133	213	973
F-I	Ash		2.86	39	17	327	844	125,867	977	187	260	2,463
F-0	Sludge	49.3		20	7	183	297	50,267	345	121	213	867
F-0	Ash		2.01	28	< 4	324	832	127,600	949	160	213	2,272
G-I	Sludge	66.9		23	17	1,100	2,987	6,607	497	150	425	2,587
G-I	Ash		3.54	15	3	1,664	5,267	25,240	716	347	907	--
G-0	Sludge	56.2		20	--	1,108	2,667	6,169	524	158	375	2,653
G-0	Ash		3.86	15	3	1,457	5,560	26,267	799	347	893	--
H-I	Sludge	76.5		83	17	135	744	10,573	561	132	315	1,009
H-I	Ash		1.55	303	15	285	4,320	66,400	3,373	520	347	5,573
H-0	Sludge	77.0		68	19	128	673	9,880	349	141	259	1,129
H-0	Ash		3.95	189	17	312	3,405	59,600	2,053	520	427	4,853
J-I	Sludge	77.0		75	15	77	644	9,253	1,032	109	363	705
J-I	Ash		1.0	139	55	155	4,173	62,133	6,133	208	1,920	5,027
J-0	Sludge	76.2		77	11	85	709	9,880	1,075	107	360	836
J-0	Ash		1.65	359	73	201	5,333	70,933	6,533	284	2,453	6,827
K-I	Sludge	66.7		13	10	279	973	8,500	568	144	1,033	4,547
K-I	Ash		1.7	--	--	--	--	--	--	--	--	--
K-0	Sludge	65.7		13	13	255	747	9,256	631	130	867	2,027
K-0	Ash		1.4	17	2	521	2,213	68,933	1,716	507	1,293	--

[1] The designations I and 0 after the letter indicating the plant site refer to scrubber input (I) and scrubber output (0) runs.

TABLE A-5

Sludge Incinerator Emission Tests, Sampled at Incinerator Outlet (Scrubber Inlet)

Explanatory Comment

1. For each run, the sample weight distribution of the total sample in the various fractions is given at the top of the table for each run.

2. There is no information for Run B. Although the particle sample was collected, the samples were lost before chemical analyses were determined.

3. For each metal, the amount of metal in each fraction is given. If desired, the concentration of the metal can be calculated. For example, for Plant A-INLET, Silver,

In the 0.1-1.0 μm fraction, 0.8222 mg Ag
1111.2 mg total particles

$$\text{concentration of Ag (mg/kg)} = \frac{0.8222}{1111.2} \times 10^6 = 740$$

In the total particle catch, 1.609 mg Ag
11336 mg total particles

$$\text{concentration of Ag (mg/kg)} = \frac{1.609}{11336} \times 10^6 = 141.9 \text{ mg/kg}$$

This checks the concentration shown in the table.

PLANT J-INLET DATE OF COMPUTER RUN: 4/30/79 PARTICULATE FLOW (KG/HR): 16.65000

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG)	20256.20	10059.50	2374.70	132.80	0.00	41623.20
<SILVER>						
SIZE FRACTIONS (MG)	11.141420	3.566260	0.311561	0.000000	0.000000	15.019241
SIZE DISTRIBUTION	74.2 PERCENT	23.7 PERCENT	2.1 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.001237909	0.000396260	0.000034619	0.000000000	0.000000000	0.001668077
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0003608382			
<CADMIUM>						
SIZE FRACTIONS (MG)	2.630652	0.764509	0.225359	0.000000	0.000000	3.620520
SIZE DISTRIBUTION	72.7 PERCENT	21.1 PERCENT	6.2 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000292307	0.000084949	0.000025041	0.000000000	0.000000000	0.000402297
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0000869032			
<CHROMIUM>						
SIZE FRACTIONS (MG)	22.039833	4.405697	1.258353	0.000000	0.000000	27.703006
SIZE DISTRIBUTION	79.6 PERCENT	15.9 PERCENT	4.5 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.002448976	0.000489543	0.000139823	0.000000000	0.000000000	0.003078343
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0006655876			
<COPPER>						
SIZE FRACTIONS (MG)	205.891632	44.310017	11.672548	0.000000	0.000000	261.094196
SIZE DISTRIBUTION	78.6 PERCENT	16.9 PERCENT	4.5 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.022877038	0.004923548	0.001299228	0.000000000	0.000000000	0.029100614
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0062920246			
<IRON>						
SIZE FRACTIONS (MG)	2576.699707	507.770290	99.355782	0.000004	0.000000	3183.833740
SIZE DISTRIBUTION	80.9 PERCENT	15.9 PERCENT	3.1 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.286312342	0.056422252	0.011040009	0.000000000	0.000000000	0.353774637
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0764918104			
<MANGANESE>						
SIZE FRACTIONS (MG)	290.976685	62.369366	15.054886	0.000001	0.000000	368.400940
SIZE DISTRIBUTION	79.0 PERCENT	16.9 PERCENT	4.1 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.032332141	0.006930229	0.001672837	0.000000000	0.000000000	0.040935207
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0080500558			
<NICKEL>						
SIZE FRACTIONS (MG)	19.697397	4.427418	0.939669	0.000000	0.000000	25.064484
SIZE DISTRIBUTION	78.6 PERCENT	17.7 PERCENT	3.7 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.002188694	0.000491957	0.000104412	0.000000000	0.000000000	0.002785063
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0006021758			
<LEAD>						
SIZE FRACTIONS (MG)	86.952005	21.281361	5.822102	0.000000	0.000000	113.056270
SIZE DISTRIBUTION	76.4 PERCENT	18.7 PERCENT	4.9 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.009661040	0.002364690	0.000624705	0.000000000	0.000000000	0.012651244
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0027354041			
<ZINC>						
SIZE FRACTIONS (MG)	251.867279	57.870277	15.019538	0.000001	0.000000	325.557098
SIZE DISTRIBUTION	77.4 PERCENT	17.8 PERCENT	4.9 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.027986463	0.006430309	0.001757803	0.000000000	0.000000000	0.036174577
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0078215301			
<ARSENIC>						
SIZE FRACTIONS (MG)	1.093515	0.322527	0.087051	0.011500	0.000000	1.516594
SIZE DISTRIBUTION	72.1 PERCENT	21.3 PERCENT	5.9 PERCENT	0.8 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000121507	0.000035830	0.000009855	0.000001278	0.000000000	0.000168518
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0000364363			
<MERCURY>						
SIZE FRACTIONS (MG)	0.026292	0.007774	0.002137	0.005206	0.000000	0.073408
SIZE DISTRIBUTION	11.7 PERCENT	10.5 PERCENT	2.3 PERCENT	5.6 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000002922	0.000001016	0.000000237	0.000000578	0.000000000	0.000010179
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0000027441			

PLANT K-10LET DATE OF COMPUTER RUN: 4/30/79 PARTICULATE FLOW (KG/HR): 22.11600

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG):	506.90	447.00	272.00	57.20	0.00	1284.70
<SILVER>						
SIZE FRACTIONS (MG):	0.031004	0.044198	0.015413	0.027599	0.000000	0.119094
SIZE DISTRIBUTION:	26.0 PERCENT	37.1 PERCENT	12.9 PERCENT	23.2 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000152467	0.000211351	0.000073705	0.000131976	0.000000000	0.000569490
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000927019			
<CADMIUM>						
SIZE FRACTIONS (MG):	0.050690	0.076619	0.038192	0.046097	0.000000	0.211598
SIZE DISTRIBUTION:	24.0 PERCENT	36.2 PERCENT	18.0 PERCENT	21.8 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000242396	0.000366304	0.000182631	0.000220435	0.000000000	0.001011845
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0001647062			
<CHROMIUM>						
SIZE FRACTIONS (MG):	0.891384	0.946022	0.420896	0.197203	0.000000	2.463505
SIZE DISTRIBUTION:	36.2 PERCENT	38.4 PERCENT	17.1 PERCENT	8.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.004262526	0.004523083	0.002050947	0.000943008	0.000000000	0.011780205
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0019175721			
<COPPER>						
SIZE FRACTIONS (MG):	1.100379	2.299990	0.830291	0.320103	0.000000	4.550766
SIZE DISTRIBUTION:	24.2 PERCENT	50.5 PERCENT	18.2 PERCENT	7.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.005261923	0.010998370	0.003970400	0.001530705	0.000000000	0.021761401
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0035422789			
<IRON>						
SIZE FRACTIONS (MG):	23.357395	13.855603	12.660293	2.161903	0.000000	52.035194
SIZE DISTRIBUTION:	44.9 PERCENT	26.6 PERCENT	24.3 PERCENT	4.2 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.111693218	0.068256396	0.060540516	0.010338048	0.000000000	0.240828108
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0405037738			
<MANGANESE>						
SIZE FRACTIONS (MG):	0.672301	1.026716	0.275992	0.036499	0.000000	2.011508
SIZE DISTRIBUTION:	33.4 PERCENT	51.0 PERCENT	13.7 PERCENT	1.8 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.003214892	0.004909674	0.001319771	0.000174537	0.000000000	0.009618875
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0015657418			
<NICKEL>						
SIZE FRACTIONS (MG):	0.299781	0.390079	0.149194	0.107502	0.000000	0.946555
SIZE DISTRIBUTION:	31.7 PERCENT	41.2 PERCENT	15.8 PERCENT	11.4 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.001433527	0.001865325	0.000713435	0.000514065	0.000000000	0.004526353
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0007367909			
<LEAD>						
SIZE FRACTIONS (MG):	1.900320	3.940208	2.030198	4.133590	0.000000	12.020525
SIZE DISTRIBUTION:	15.8 PERCENT	32.8 PERCENT	17.0 PERCENT	34.4 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.009088136	0.018880017	0.009746500	0.019766539	0.000000000	0.057481203
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0093566794			
<ZINC>						
SIZE FRACTIONS (MG):	5.669770	10.872897	4.453407	6.432003	0.000000	27.428165
SIZE DISTRIBUTION:	20.7 PERCENT	39.6 PERCENT	16.2 PERCENT	23.5 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.027112428	0.051993329	0.021296224	0.030757328	0.000000000	0.131159306
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0213490604			
<ARSENIC>						
SIZE FRACTIONS (MG):	0.024585	0.057104	0.028208	0.036499	0.000000	0.146476
SIZE DISTRIBUTION:	16.8 PERCENT	39.0 PERCENT	19.3 PERCENT	24.9 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000117562	0.000273450	0.000134806	0.000174537	0.000000000	0.000700434
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0001140154			
<MERCURY>						
SIZE FRACTIONS (MG):	0.000600	0.000090	0.000191	0.003798	0.000000	0.004687
SIZE DISTRIBUTION:	13.0 PERCENT	1.9 PERCENT	4.1 PERCENT	81.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000002909	0.000000438	0.000000913	0.000018162	0.000000000	0.000022412
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000016402			

TABLE A-6

Sludge Incinerator Emission Tests, Sampled at Scrubber Outlet

Explanatory Comment

1. See comments for Table A-5.

2. Runs are designated by the plant letter followed by 0, e.g., Plant A-0. The 0 indicates that the sample was taken at the scrubber outlet.

PLANT 6 UNIT 1 — DATE OF COMPUTER RUN: 4/30/79 — PARTICULATE FLOW (KG/HR): 67.05100

	10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG)	7443.60	1000.00	1324.70	1111.20	457.00	11336.50
<SILVER>						
SIZE FRACTIONS (MG)	0.521052	0.125000	0.039741	0.022200	0.100540	1.808521
SIZE DISTRIBUTION	28.8 PERCENT	6.9 PERCENT	2.2 PERCENT	1.2 PERCENT	5.6 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000021937	0.000013975	0.000030029	0.001407593	0.000172104	0.002753639
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.000141075			
<CADMIUM>						
SIZE FRACTIONS (MG)	2.233080	0.200000	0.953704	2.089056	0.539260	6.015180
SIZE DISTRIBUTION	37.1 PERCENT	3.3 PERCENT	15.9 PERCENT	34.7 PERCENT	9.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000302589	0.000342360	0.001632680	0.003576040	0.000923106	0.010296792
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.000530029			
<CHROMIUM>						
SIZE FRACTIONS (MG)	30.221016	1.740000	5.775692	0.545120	1.320730	47.603566
SIZE DISTRIBUTION	63.5 PERCENT	3.7 PERCENT	12.1 PERCENT	18.0 PERCENT	2.8 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.051732359	0.002770534	0.009006836	0.014627550	0.002260827	0.081406121
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0041990527			
<COPPER>						
SIZE FRACTIONS (MG)	36.622513	2.465000	8.464832	11.112000	1.343580	60.007923
SIZE DISTRIBUTION	61.0 PERCENT	4.1 PERCENT	14.1 PERCENT	18.5 PERCENT	2.2 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.062690459	0.004219589	0.014490109	0.019021533	0.002299942	0.102721624
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0052933372			
<IRON>						
SIZE FRACTIONS (MG)	279.879333	14.265000	50.471068	51.281879	8.248050	404.146149
SIZE DISTRIBUTION	69.3 PERCENT	3.5 PERCENT	12.5 PERCENT	12.7 PERCENT	2.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.479097724	0.024418844	0.086396426	0.087784372	0.014120390	0.691817760
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0356499808			
<MANGANESE>						
SIZE FRACTIONS (MG)	13.249608	0.650000	2.569918	3.555760	0.400990	19.814277
SIZE DISTRIBUTION	67.9 PERCENT	3.3 PERCENT	13.2 PERCENT	18.1 PERCENT	2.5 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.022680692	0.001112671	0.004399180	0.006374952	0.000687054	0.033404559
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0017213660			
<NICKEL>						
SIZE FRACTIONS (MG)	14.142039	0.860000	2.775117	4.178112	0.479850	22.455919
SIZE DISTRIBUTION	63.0 PERCENT	3.8 PERCENT	12.4 PERCENT	18.6 PERCENT	2.1 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.024209720	0.001472149	0.004784604	0.007152097	0.000821408	0.038440064
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0019800509			
<LEAD>						
SIZE FRACTIONS (MG)	45.100215	3.010000	12.226979	19.334029	4.021600	83.701668
SIZE DISTRIBUTION	53.9 PERCENT	3.6 PERCENT	14.6 PERCENT	23.1 PERCENT	4.8 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.077216290	0.005152521	0.020930156	0.033097468	0.006884180	0.143200610
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0073833778			
<ZINC>						
SIZE FRACTIONS (MG)	54.338200	3.385000	13.247000	17.279160	2.897300	91.146812
SIZE DISTRIBUTION	59.6 PERCENT	3.7 PERCENT	14.5 PERCENT	19.0 PERCENT	3.2 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.093016326	0.005794446	0.022676229	0.029570403	0.004959738	0.156025216
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0000401190			
<ARSENIC>						
SIZE FRACTIONS (MG)	0.595490	0.030000	0.052998	0.111120	0.027420	0.817016
SIZE DISTRIBUTION	72.9 PERCENT	3.7 PERCENT	6.5 PERCENT	13.6 PERCENT	3.4 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.001019357	0.000051354	0.000090705	0.000190215	0.000046938	0.001398569
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0000720695			
<MERCURY>						
SIZE FRACTIONS (MG)	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
SIZE DISTRIBUTION	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT
FLOW RATE (G/SEC)	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.000000000			

PLANT C-INLET DATE OF COMPUTER RUN: 4/30/79 PARTICULATE FLOW (KG/HR): 17.35300

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG):	3329.40	3000.00	760.40	2433.10	297.70	9820.60
SILVER						
SIZE FRACTIONS (MG):	0.233050	5.760000	0.107576	1.411190	0.023816	7.535640
SIZE DISTRIBUTION:	3.1 PERCENT	76.4 PERCENT	1.4 PERCENT	18.7 PERCENT	0.3 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000114300	0.002824099	0.000052759	0.000692097	0.000011680	0.003695736
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0007667061			
CADMIUM						
SIZE FRACTIONS (MG):	2.397168	1.290000	1.736584	34.063404	0.640986	40.136143
SIZE DISTRIBUTION:	6.0 PERCENT	3.2 PERCENT	4.3 PERCENT	84.9 PERCENT	1.6 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.001175552	0.000632660	0.000851679	0.016705045	0.000310205	0.019604119
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0040036069			
CHROMIUM						
SIZE FRACTIONS (MG):	17.146410	9.225000	4.341460	19.270153	0.315562	50.298580
SIZE DISTRIBUTION:	34.1 PERCENT	18.3 PERCENT	8.6 PERCENT	38.3 PERCENT	0.6 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.008409179	0.004524252	0.002129199	0.009450735	0.000154762	0.024660127
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0051175738			
COPPER						
SIZE FRACTIONS (MG):	9.921612	59.174999	2.812344	15.523179	0.294723	87.726860
SIZE DISTRIBUTION:	11.3 PERCENT	67.5 PERCENT	3.2 PERCENT	17.7 PERCENT	0.3 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.004865094	0.029021418	0.001379269	0.007613091	0.000144542	0.043024216
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0089256717			
IRON						
SIZE FRACTIONS (MG):	812.373535	424.800018	136.006790	459.855096	8.085532	1841.121948
SIZE DISTRIBUTION:	44.1 PERCENT	23.1 PERCENT	7.4 PERCENT	25.0 PERCENT	0.4 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.398415416	0.208336279	0.066702321	0.225520866	0.003965418	0.902940300
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.1873220997			
MANGANESE						
SIZE FRACTIONS (MG):	6.225978	3.420000	1.313964	858.004338	0.220298	870.064575
SIZE DISTRIBUTION:	0.7 PERCENT	0.4 PERCENT	0.2 PERCENT	98.7 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.003053430	0.001677204	0.000644412	0.421225076	0.000108042	0.426709006
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0885237530			
NICKEL						
SIZE FRACTIONS (MG):	16.646999	9.180000	3.972628	17.420996	0.333424	47.554047
SIZE DISTRIBUTION:	35.0 PERCENT	19.3 PERCENT	8.4 PERCENT	36.6 PERCENT	0.7 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.008164250	0.004502102	0.001940311	0.008543044	0.000163522	0.023322111
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0048303335			
LEAD						
SIZE FRACTIONS (MG):	10.054700	13.075000	3.749792	23.114450	0.309608	51.103642
SIZE DISTRIBUTION:	19.7 PERCENT	27.2 PERCENT	7.3 PERCENT	45.2 PERCENT	0.6 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.004931207	0.006004769	0.001839025	0.011336107	0.000151842	0.025062952
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0051994831			
ZINC						
SIZE FRACTIONS (MG):	40.285740	44.070000	11.210640	73.236313	1.425903	170.236679
SIZE DISTRIBUTION:	23.7 PERCENT	25.9 PERCENT	6.6 PERCENT	43.0 PERCENT	0.8 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.019757407	0.021613417	0.005502000	0.035917562	0.000699350	0.083409820
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0173205417			
ARSENIC						
SIZE FRACTIONS (MG):	0.16470	0.090000	0.092209	0.072993	0.017862	0.439533
SIZE DISTRIBUTION:	37.9 PERCENT	20.5 PERCENT	21.0 PERCENT	16.6 PERCENT	4.1 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000081643	0.000044139	0.000045722	0.000035798	0.000008760	0.000215562
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000447198			
MERCURY						
SIZE FRACTIONS (MG):	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
SIZE DISTRIBUTION:	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT
FLOW RATE (G/SEC):	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000000000			

PLANT D-INLET DATE OF COMPUTER RUN 4/30/79 PARTICULATE FLOW (KG/HR)= 162.31500

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG)	33623.20	8650.00	2794.40	862.60	202.10	45132.30
<SILVER>						
SIZE FRACTIONS (MG)	1.304920	1.946250	0.139720	1.104120	0.141470	4.636496
SIZE DISTRIBUTION	28.1 PERCENT	42.0 PERCENT	3.0 PERCENT	23.8 PERCENT	3.1 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.001303633	0.001944318	0.000139501	0.001103032	0.000141330	0.004631074
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0001027312			
<CADMIUM>						
SIZE FRACTIONS (MG)	3.262320	1.384000	0.279440	1.017060	0.030399	5.982027
SIZE DISTRIBUTION	54.5 PERCENT	23.1 PERCENT	4.7 PERCENT	17.0 PERCENT	0.6 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.003259002	0.001382626	0.000279163	0.001016058	0.000030361	0.005976089
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0001325443			
<CHROMIUM>						
SIZE FRACTIONS (MG)	47.956104	12.110000	2.291408	0.345040	0.297087	62.999641
SIZE DISTRIBUTION	76.1 PERCENT	19.2 PERCENT	3.6 PERCENT	0.5 PERCENT	0.5 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.047900500	0.012097900	0.002289134	0.000344698	0.000296792	0.062937103
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0013950880			
<COPPER>						
SIZE FRACTIONS (MG)	84.020313	14.229250	5.057864	10.480590	0.466851	115.054863
SIZE DISTRIBUTION	73.7 PERCENT	12.4 PERCENT	4.4 PERCENT	9.1 PERCENT	0.4 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.084736118	0.014215126	0.005052843	0.010470187	0.000466300	0.114940651
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0025492797			
<IRON>						
SIZE FRACTIONS (MG)	1686.619385	439.852509	50.299190	15.052370	5.345545	2197.169189
SIZE DISTRIBUTION	76.8 PERCENT	20.0 PERCENT	2.3 PERCENT	0.7 PERCENT	0.2 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	1.684945107	0.439415902	0.050249271	0.015037429	0.005340239	2.194988251
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0406828536			
<MANGANESE>						
SIZE FRACTIONS (MG)	26.751024	5.665750	5.253472	1.500924	2.202890	41.374058
SIZE DISTRIBUTION	64.7 PERCENT	13.7 PERCENT	12.7 PERCENT	3.6 PERCENT	5.3 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.026724471	0.005660126	0.005248257	0.001499434	0.002200703	0.041332986
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0009167203			
<NICKEL>						
SIZE FRACTIONS (MG)	18.248991	12.542500	1.872248	0.457178	0.311234	33.452148
SIZE DISTRIBUTION	54.6 PERCENT	37.5 PERCENT	5.6 PERCENT	1.4 PERCENT	0.9 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.018250058	0.012530050	0.001870390	0.000456724	0.000310925	0.033418942
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0007412019			
<LEAD>						
SIZE FRACTIONS (MG)	115.812363	21.625000	8.019927	30.234129	1.887404	177.550823
SIZE DISTRIBUTION	65.2 PERCENT	12.2 PERCENT	4.5 PERCENT	17.0 PERCENT	1.1 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.115697406	0.021603536	0.008011968	0.030204119	0.001885550	0.177302573
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0039341050			
<ZINC>						
SIZE FRACTIONS (MG)	94.607285	24.695749	5.001976	5.261860	0.604279	130.171143
SIZE DISTRIBUTION	72.7 PERCENT	19.0 PERCENT	3.8 PERCENT	4.0 PERCENT	0.5 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.094513372	0.024671236	0.004997010	0.005256637	0.000603679	0.130041927
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0020842124			
<ARSENIC>						
SIZE FRACTIONS (MG)	0.326232	0.216250	1.816360	0.060382	0.014147	2.433371
SIZE DISTRIBUTION	13.4 PERCENT	8.9 PERCENT	74.6 PERCENT	2.5 PERCENT	0.6 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000325909	0.000216035	0.001814557	0.000060322	0.000014133	0.002430955
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0000539164			
<MERCURY>						
SIZE FRACTIONS (MG)	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
SIZE DISTRIBUTION	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT
FLOW RATE (G/SEC)	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0000000000			

PLANT E-INLET DATE OF COMPUTER RUN: 4/30/79 PARTICULATE FLOW (KG/HR): 3.20100

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG):	2096.40	48.30	42.90	401.10	0.00	2595.70
<SILVER>						
SIZE FRACTIONS (MG):	0.125704	0.006699	0.010098	0.117608	0.000000	0.263070
SIZE DISTRIBUTION:	47.8 PERCENT	2.5 PERCENT	4.1 PERCENT	45.5 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000044165	0.000002352	0.000003027	0.000042024	0.000000000	0.000092368
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.000101340 2			
<CADMIUM>						
SIZE FRACTIONS (MG):	0.457054	0.000902	0.010398	2.027601	0.000000	2.512035
SIZE DISTRIBUTION:	18.2 PERCENT	0.4 PERCENT	0.7 PERCENT	80.7 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000160759	0.000003126	0.000006460	0.000711949	0.000000000	0.000882294
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.000960759			
<CHROMIUM>						
SIZE FRACTIONS (MG):	3.176256	0.114601	0.057699	0.428896	0.000000	3.777453
SIZE DISTRIBUTION:	84.1 PERCENT	3.0 PERCENT	1.5 PERCENT	11.4 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.001115231	0.000040230	0.000020259	0.000150592	0.000000000	0.001326320
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0014552732			
<COPPER>						
SIZE FRACTIONS (MG):	1.580233	0.034000	0.021602	1.310313	0.000000	2.934748
SIZE DISTRIBUTION:	53.7 PERCENT	1.2 PERCENT	0.7 PERCENT	44.3 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000557652	0.000012219	0.000007505	0.000460071	0.000000000	0.001037526
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0011384012			
<IRON>						
SIZE FRACTIONS (MG):	78.755875	1.562302	0.501001	3.902602	0.000000	84.801781
SIZE DISTRIBUTION:	92.9 PERCENT	1.8 PERCENT	0.6 PERCENT	4.7 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.027652359	0.000548547	0.000175909	0.001370351	0.000000000	0.029725169
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0326701030			
<MANGANESE>						
SIZE FRACTIONS (MG):	1.367691	0.027304	0.014800	0.085314	0.000000	1.495110
SIZE DISTRIBUTION:	91.5 PERCENT	1.8 PERCENT	1.0 PERCENT	5.7 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000480217	0.000009582	0.000005197	0.000029955	0.000000000	0.000524955
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0005759940			
<NICKEL>						
SIZE FRACTIONS (MG):	1.484251	0.030598	0.031402	0.346791	0.000000	1.893042
SIZE DISTRIBUTION:	78.4 PERCENT	1.6 PERCENT	1.7 PERCENT	18.3 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000521143	0.000010743	0.000011026	0.000121764	0.000000000	0.000664675
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0007292994			
<LEAD>						
SIZE FRACTIONS (MG):	4.449609	0.001898	0.243502	70.665092	0.000000	83.360100
SIZE DISTRIBUTION:	5.3 PERCENT	0.0 PERCENT	0.3 PERCENT	94.4 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.001562324	0.000000666	0.000085497	0.027620485	0.000000000	0.029268973
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0321146920			
<ZINC>						
SIZE FRACTIONS (MG):	8.950546	0.148102	0.140098	21.446697	0.000000	30.701445
SIZE DISTRIBUTION:	29.2 PERCENT	0.5 PERCENT	0.5 PERCENT	69.9 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.003145479	0.000052001	0.000051999	0.007530255	0.000000000	0.010779734
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0118270897			
<ARSENIC>						
SIZE FRACTIONS (MG):	0.137524	0.002101	0.001602	0.102481	0.000000	0.243708
SIZE DISTRIBUTION:	56.4 PERCENT	0.9 PERCENT	0.7 PERCENT	42.1 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000048207	0.000000738	0.000000562	0.000035983	0.000000000	0.000085569
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000930870			
<MERCURY>						
SIZE FRACTIONS (MG):	0.000210	0.000170	0.000200	0.000401	0.000000	0.001009
SIZE DISTRIBUTION:	19.3 PERCENT	18.2 PERCENT	18.3 PERCENT	44.2 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000000074	0.000000070	0.000000079	0.000000169	0.000000000	0.000000382
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000004154			

PLANT F-INLET DATE OF COMPUTER RUN: 4/30/79 PARTICULATE FLOW (KG/HR): 11.43000

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG):	8115.70	4812.90	554.00	874.60	0.00	14358.00
<SILVER>						
SIZE FRACTIONS (MG):	0.183415	0.203024	0.050020	0.645192	0.000000	1.082451
SIZE DISTRIBUTION:	16.9 PERCENT	18.8 PERCENT	4.7 PERCENT	59.6 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000035625	0.000039434	0.000009071	0.000125316	0.000000000	0.000210245
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000651726			
<CADMIUM>						
SIZE FRACTIONS (MG):	0.305150	0.183940	0.155209	20.628570	0.000000	21.272964
SIZE DISTRIBUTION:	1.4 PERCENT	0.9 PERCENT	0.7 PERCENT	97.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000059269	0.000035720	0.000030162	0.004006699	0.000000000	0.004131850
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0013004624			
<CHROMIUM>						
SIZE FRACTIONS (MG):	2.969535	1.577068	0.699492	0.261505	0.000000	5.508400
SIZE DISTRIBUTION:	53.9 PERCENT	28.6 PERCENT	12.7 PERCENT	4.7 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000576724	0.000306470	0.000135063	0.000050792	0.000000000	0.001069049
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0003367404			
<COPPER>						
SIZE FRACTIONS (MG):	4.319175	2.960806	1.013120	4.097676	0.000000	12.390859
SIZE DISTRIBUTION:	34.9 PERCENT	23.9 PERCENT	8.2 PERCENT	33.1 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000838915	0.000575094	0.000196779	0.000795894	0.000000000	0.002406682
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0007574800			
<IRON>						
SIZE FRACTIONS (MG):	28.173658	17.456911	17.477200	5.866901	0.000000	68.973770
SIZE DISTRIBUTION:	40.8 PERCENT	25.3 PERCENT	25.3 PERCENT	8.5 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.005472102	0.003390489	0.003394605	0.001139531	0.000000000	0.013396808
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0042165159			
<MANGANESE>						
SIZE FRACTIONS (MG):	3.213817	1.772717	0.281284	0.086323	0.000000	5.354140
SIZE DISTRIBUTION:	60.0 PERCENT	33.1 PERCENT	5.3 PERCENT	1.6 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000624221	0.000344316	0.000054634	0.000016767	0.000000000	0.001039937
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0003273102			
<NICKEL>						
SIZE FRACTIONS (MG):	1.290396	0.630369	0.209492	0.036821	0.000000	2.175078
SIZE DISTRIBUTION:	59.3 PERCENT	29.3 PERCENT	9.6 PERCENT	1.7 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000250634	0.000123991	0.000040690	0.000007152	0.000000000	0.000422466
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0001329672			
<LEAD>						
SIZE FRACTIONS (MG):	4.531806	3.031575	4.310297	25.425495	0.000000	38.099174
SIZE DISTRIBUTION:	11.9 PERCENT	10.1 PERCENT	11.3 PERCENT	66.7 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000880215	0.000744209	0.000837191	0.004930406	0.000000000	0.007400021
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0023290850			
<ZINC>						
SIZE FRACTIONS (MG):	12.567162	11.735220	3.051009	11.586176	0.000000	39.739647
SIZE DISTRIBUTION:	31.6 PERCENT	29.5 PERCENT	9.7 PERCENT	29.2 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.002440926	0.002279337	0.000747999	0.002250388	0.000000000	0.007718651
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0024293708			
<ARSENIC>						
SIZE FRACTIONS (MG):	0.191531	0.226180	0.070422	0.056062	0.000000	0.572202
SIZE DISTRIBUTION:	33.5 PERCENT	39.5 PERCENT	17.2 PERCENT	9.8 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000037201	0.000043933	0.000019116	0.000010809	0.000000000	0.000111139
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000349000			
<MERCURY>						
SIZE FRACTIONS (MG):	0.000496	0.002735	0.000277	0.000707	0.000000	0.004193
SIZE DISTRIBUTION:	9.7 PERCENT	65.0 PERCENT	6.6 PERCENT	10.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000000079	0.000000525	0.000000054	0.000000153	0.000000000	0.000000811
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000002765			

PLANT 0-INLET DATE OF COMPUTER RUN: 4/30/79 PARTICULATE FLOW (KG/HR): 125.54000

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG):	119696.00	1690.20	150.71	240.30	0.00	121801.21
<SILVER>						
SIZE FRACTIONS (MG):	0.095757	0.113440	0.027695	17.613211	0.000000	17.850101
SIZE DISTRIBUTION:	0.5 PERCENT	0.6 PERCENT	0.2 PERCENT	98.7 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000027416	0.000032470	0.000007929	0.005042740	0.000000000	0.005110563
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0001465511			
<CADMIUM>						
SIZE FRACTIONS (MG):	0.003707	0.071834	0.009999	0.791506	0.000000	0.957126
SIZE DISTRIBUTION:	8.0 PERCENT	7.5 PERCENT	1.0 PERCENT	82.7 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000023589	0.000020566	0.000002863	0.000226612	0.000000000	0.000274029
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000078501			
<CHROMIUM>						
SIZE FRACTIONS (MG):	4.871627	2.553244	0.314897	0.112306	0.000000	7.852073
SIZE DISTRIBUTION:	62.0 PERCENT	32.5 PERCENT	4.0 PERCENT	1.4 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.001394768	0.000731005	0.000090158	0.000032154	0.000000000	0.002248003
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000644663			
<COPPER>						
SIZE FRACTIONS (MG):	11.061874	8.304220	0.739001	1.073101	0.000000	20.778204
SIZE DISTRIBUTION:	57.1 PERCENT	30.3 PERCENT	3.6 PERCENT	9.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.003396107	0.001804928	0.000211579	0.000536277	0.000000000	0.005948891
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0001705911			
<IRON>						
SIZE FRACTIONS (MG):	54.796929	31.037321	7.432500	0.000000	0.000000	93.266655
SIZE DISTRIBUTION:	58.8 PERCENT	33.3 PERCENT	8.0 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.015688574	0.008886122	0.002127958	0.000000000	0.000000000	0.026702654
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0007657285			
<MANGANESE>						
SIZE FRACTIONS (MG):	1.520139	0.944369	0.115906	0.574194	0.000000	3.134608
SIZE DISTRIBUTION:	48.2 PERCENT	29.9 PERCENT	3.7 PERCENT	18.2 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000435223	0.000270377	0.000033184	0.000164394	0.000000000	0.000903178
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000258996			
<NICKEL>						
SIZE FRACTIONS (MG):	0.770024	0.620334	0.110303	78.940605	0.000000	80.457268
SIZE DISTRIBUTION:	1.0 PERCENT	0.8 PERCENT	0.1 PERCENT	98.1 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000222752	0.000179095	0.000031580	0.022801042	0.000000000	0.023035269
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0006605621			
<LEAD>						
SIZE FRACTIONS (MG):	2.669221	1.270575	0.343004	29.893296	0.000000	34.106096
SIZE DISTRIBUTION:	7.8 PERCENT	3.7 PERCENT	1.0 PERCENT	87.4 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000764210	0.000366062	0.000098204	0.008559155	0.000000000	0.009787629
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0002806712			
<ZINC>						
SIZE FRACTIONS (MG):	12.272779	7.601822	1.167598	0.018101	0.000000	21.060301
SIZE DISTRIBUTION:	58.3 PERCENT	36.1 PERCENT	5.5 PERCENT	0.1 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.003519477	0.002176435	0.000334200	0.000005182	0.000000000	0.006035383
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0001730714			
<ARSENIC>						
SIZE FRACTIONS (MG):	0.059840	0.057060	0.012903	0.029101	0.000000	0.158911
SIZE DISTRIBUTION:	37.7 PERCENT	35.9 PERCENT	8.1 PERCENT	18.3 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000017135	0.000016336	0.000003694	0.000008332	0.000000000	0.000045497
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000013047			
<MERCURY>						
SIZE FRACTIONS (MG):	0.000000	0.000529	0.000698	0.003799	0.000000	0.005177
SIZE DISTRIBUTION:	0.0 PERCENT	13.1 PERCENT	13.5 PERCENT	73.4 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000000000	0.000000151	0.000000200	0.000001088	0.000000000	0.000001482

PLANT H-INLET DATE OF COMPUTER RUN: 4/30/79 PARTICULATE FLOW (KG/HR): 10.14000

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG):	709.10	278.10	119.90	429.00	0.00	1616.10
<SILVER>						
SIZE FRACTIONS (MG):	0.296070	0.120807	0.067990	0.573101	0.000000	1.059976
SIZE DISTRIBUTION:	27.9 PERCENT	11.4 PERCENT	6.4 PERCENT	54.1 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000514015	0.000210551	0.000121997	0.000990846	0.000000000	0.001847409
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0006550049			
<CADMIUM>						
SIZE FRACTIONS (MG):	0.266006	0.077506	0.073403	0.903600	0.000000	1.320603
SIZE DISTRIBUTION:	20.1 PERCENT	5.9 PERCENT	5.6 PERCENT	68.4 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000463616	0.000135004	0.000127932	0.001575020	0.000000000	0.002301652
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0008171545			
<CHROMIUM>						
SIZE FRACTIONS (MG):	0.692909	0.191006	0.460200	0.460188	0.000000	1.005103
SIZE DISTRIBUTION:	38.4 PERCENT	10.6 PERCENT	25.5 PERCENT	25.5 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.001207656	0.000334294	0.000802073	0.000802053	0.000000000	0.003146076
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0011169501			
<COPPER>						
SIZE FRACTIONS (MG):	1.919486	0.705790	0.420295	1.253581	0.000000	4.307151
SIZE DISTRIBUTION:	44.6 PERCENT	16.4 PERCENT	9.9 PERCENT	29.1 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.003345431	0.001230107	0.000746466	0.002184840	0.000000000	0.007506844
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0026651516			
<IRON>						
SIZE FRACTIONS (MG):	25.790234	9.159195	5.469394	2.119904	0.000000	42.538727
SIZE DISTRIBUTION:	60.6 PERCENT	21.5 PERCENT	12.9 PERCENT	5.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.044949256	0.015963368	0.009532492	0.003694735	0.000000000	0.074139848
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0263218414			
<MANGANESE>						
SIZE FRACTIONS (MG):	1.924615	0.471101	0.272701	0.064607	0.000000	2.733024
SIZE DISTRIBUTION:	70.4 PERCENT	17.2 PERCENT	10.0 PERCENT	2.4 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.003354371	0.000821073	0.000475284	0.000112603	0.000000000	0.004763330
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0016911231			
<NICKEL>						
SIZE FRACTIONS (MG):	0.463912	0.130707	0.126303	0.093908	0.000000	0.940830
SIZE DISTRIBUTION:	48.9 PERCENT	13.8 PERCENT	27.4 PERCENT	9.9 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000808542	0.000227806	0.000453677	0.000163670	0.000000000	0.001653696
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0005871109			
<LEAD>						
SIZE FRACTIONS (MG):	2.605766	0.940590	0.756797	8.978412	0.000000	13.281565
SIZE DISTRIBUTION:	19.6 PERCENT	7.1 PERCENT	5.7 PERCENT	67.6 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.004541514	0.001639334	0.001319005	0.015648285	0.000000000	0.023148160
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0002102819			
<ZINC>						
SIZE FRACTIONS (MG):	7.721185	2.905005	2.066597	29.767712	0.000000	42.460499
SIZE DISTRIBUTION:	18.2 PERCENT	6.8 PERCENT	4.9 PERCENT	70.1 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.013457092	0.005063072	0.003601828	0.051881518	0.000000000	0.074003510
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0262734350			
<ARSENIC>						
SIZE FRACTIONS (MG):	0.057999	0.016297	0.019100	0.150493	0.000000	0.243089
SIZE DISTRIBUTION:	23.9 PERCENT	6.7 PERCENT	7.9 PERCENT	61.7 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000101005	0.000028403	0.000033289	0.000262271	0.000000000	0.000425069
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0001509119			
<MERCURY>						
SIZE FRACTIONS (MG):	0.003709	0.000501	0.000096	0.013685	0.000000	0.017990
SIZE DISTRIBUTION:	20.6 PERCENT	2.8 PERCENT	0.5 PERCENT	76.1 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000006464	0.000000872	0.000000167	0.000023851	0.000000000	0.000031355
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000111320			

PLANT J-OUTLET DATE OF COMPUTER RUN: 4/30/79 PARTICULATE FLOW (KG/HR): 0.04900

>10 MICRONS 1.5-10 MICRONS

PLANT H-OUTLET DATE OF COMPUTER RUN: 4/30/79 PARTICULATE FLOW (KG/HR): 14.73900

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG):	5298.10	4091.90	937.10	404.50	0.00	10731.60
<SILVER>						
SIZE FRACTIONS (MG):	0.054570	0.003274	0.005050	0.850583	0.000000	0.913477
SIZE DISTRIBUTION:	6.0 PERCENT	0.4 PERCENT	0.6 PERCENT	93.1 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000020819	0.000001249	0.000001931	0.000324502	0.000000000	0.000348500
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000051212			
<CADMIUM>						
SIZE FRACTIONS (MG):	0.041325	0.002046	0.004311	1.432901	0.000000	1.480583
SIZE DISTRIBUTION:	2.8 PERCENT	0.1 PERCENT	0.3 PERCENT	96.8 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000015768	0.000000781	0.000001645	0.000546860	0.000000000	0.000564851
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0001379640			
<CHROMIUM>						
SIZE FRACTIONS (MG):	0.353913	0.138306	0.186014	0.162407	0.000000	0.840640
SIZE DISTRIBUTION:	42.1 PERCENT	16.5 PERCENT	22.1 PERCENT	19.3 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000135020	0.000052765	0.000070966	0.000061959	0.000000000	0.000320709
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000703332			
<COPPER>						
SIZE FRACTIONS (MG):	0.283448	0.200503	0.234462	2.266292	0.000000	2.984706
SIZE DISTRIBUTION:	9.5 PERCENT	6.7 PERCENT	7.9 PERCENT	75.9 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000108137	0.000076493	0.000089449	0.000864603	0.000000000	0.001138602
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0002701231			
<IRON>						
SIZE FRACTIONS (MG):	3.333035	0.445199	0.715369	1.046401	0.000000	5.540205
SIZE DISTRIBUTION:	60.2 PERCENT	8.0 PERCENT	12.9 PERCENT	18.9 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.001271572	0.000169848	0.000272991	0.000399208	0.000000000	0.002113620
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0005162515			
<MANGANESE>						
SIZE FRACTIONS (MG):	0.119737	0.004092	0.023896	0.024391	0.000000	0.172116
SIZE DISTRIBUTION:	69.6 PERCENT	2.4 PERCENT	13.9 PERCENT	14.2 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000045680	0.000001561	0.000009116	0.000009305	0.000000000	0.000065663
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000160303			
<NICKEL>						
SIZE FRACTIONS (MG):	0.109141	0.029871	0.052103	0.040410	0.000000	0.231524
SIZE DISTRIBUTION:	47.1 PERCENT	12.9 PERCENT	22.5 PERCENT	17.5 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000041630	0.000011396	0.000019877	0.000015416	0.000000000	0.000088328
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000215740			
<LEAD>						
SIZE FRACTIONS (MG):	0.862001	0.047057	0.077606	16.041803	0.000000	17.920627
SIZE DISTRIBUTION:	4.8 PERCENT	0.3 PERCENT	0.4 PERCENT	94.5 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000328058	0.000017952	0.000027630	0.006425275	0.000000000	0.006001724
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0016613206			
<ZINC>						
SIZE FRACTIONS (MG):	1.295915	0.000000	0.164367	68.905205	0.000000	70.365485
SIZE DISTRIBUTION:	1.8 PERCENT	0.0 PERCENT	0.2 PERCENT	97.9 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000494359	0.000000000	0.000062707	0.026287731	0.000000000	0.026844037
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0065580492			

PLANT 6 OUTLET DATE OF COMPUTER RUN: 4/30/79 PARTICULATE FLOW (KG/HR): 0.05000

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG):	29.74	2.25	12.44	46.40	0.00	93.83
SILVER						
SIZE FRACTIONS (MG):	0.001401	0.000000	0.001800	10.424601	0.000000	10.427801
SIZE DISTRIBUTION:	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000000232	0.000000000	0.000000298	0.001727140	0.000000000	0.001727670
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.12439223430			
CADMIUM						
SIZE FRACTIONS (MG):	0.002699	0.000200	0.001300	0.484699	0.000000	0.488898
SIZE DISTRIBUTION:	0.6 PERCENT	0.0 PERCENT	0.3 PERCENT	99.1 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000000447	0.000000033	0.000000215	0.000000305	0.000000000	0.000081000
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0050320207			
CHROMIUM						
SIZE FRACTIONS (MG):	0.033000	0.011600	0.023500	0.027900	0.000000	0.096001
SIZE DISTRIBUTION:	34.4 PERCENT	12.1 PERCENT	24.5 PERCENT	29.1 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000005467	0.000001922	0.000003894	0.000004623	0.000000000	0.000015905
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0011451000			
COBALT						
SIZE FRACTIONS (MG):	0.085700	0.006800	0.042000	0.000000	0.000000	0.134500
SIZE DISTRIBUTION:	63.7 PERCENT	5.1 PERCENT	31.2 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000014199	0.000001127	0.000006959	0.000000000	0.000000000	0.000022284
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0016044309	N.D. - never detected		
IRON						
SIZE FRACTIONS (MG):	0.342001	0.085700	0.564900	0.000000	0.000000	0.992601
SIZE DISTRIBUTION:	34.5 PERCENT	8.6 PERCENT	56.9 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000056662	0.000014199	0.000093592	0.000000000	0.000000000	0.000164453
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0118406415	N.D. - never detected		
MANGANESE						
SIZE FRACTIONS (MG):	0.010299	0.017800	0.007700	0.349401	0.000000	0.385201
SIZE DISTRIBUTION:	2.7 PERCENT	4.6 PERCENT	2.0 PERCENT	90.7 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000001706	0.000002949	0.000001276	0.000057809	0.000000000	0.000063820
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0045950208			
NICKEL						
SIZE FRACTIONS (MG):	0.011500	0.010300	0.008399	20.908402	0.000000	20.938601
SIZE DISTRIBUTION:	0.1 PERCENT	0.1 PERCENT	0.0 PERCENT	99.8 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000001905	0.000003032	0.000001392	0.003462762	0.000000000	0.003469091
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.2497745454			
LEAD						
SIZE FRACTIONS (MG):	0.009001	0.000000	0.024900	29.930201	0.000000	29.964901
SIZE DISTRIBUTION:	0.0 PERCENT	0.0 PERCENT	0.1 PERCENT	99.9 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000001624	0.000000000	0.000004125	0.004958812	0.000000000	0.004964561
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.3574483991			
ZINC						
SIZE FRACTIONS (MG):	0.100000	0.012100	0.078600	0.196198	0.000000	0.395697
SIZE DISTRIBUTION:	27.5 PERCENT	3.1 PERCENT	19.7 PERCENT	49.6 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000018026	0.000002005	0.000013022	0.000032506	0.000000000	0.000065559
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0047202315			
ARSENIC						
SIZE FRACTIONS (MG):	0.001001	0.000500	0.000500	0.017400	0.000000	0.019401
SIZE DISTRIBUTION:	5.2 PERCENT	2.6 PERCENT	2.6 PERCENT	89.7 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000000166	0.000000083	0.000000083	0.000002883	0.000000000	0.000003214
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0002314279			
MERCURY						
SIZE FRACTIONS (MG):	0.001401	0.000700	0.000700	0.001401	0.000000	0.004202
SIZE DISTRIBUTION:	33.3 PERCENT	16.7 PERCENT	16.7 PERCENT	33.3 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000000232	0.000000116	0.000000116	0.000000232	0.000000000	0.000000695

PLANT A-OUTLET DATE OF COMPUTER RUN: 4/30/79 PARTICULATE FLOW (KG/HR): 0.91000

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG):	263.50	63.10	73.70	476.30	157.10	1033.70
<SILVER>						
SIZE FRACTIONS (MG):	0.044295	0.000631	0.002940	0.971652	0.050272	1.070290
SIZE DISTRIBUTION:	4.2 PERCENT	0.1 PERCENT	0.3 PERCENT	90.8 PERCENT	4.7 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000011050	0.000000156	0.000000727	0.000239694	0.000012401	0.000264020
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0010354047			
<CADMIUM>						
SIZE FRACTIONS (MG):	1.702210	0.013251	0.058223	11.574009	0.680243	14.028016
SIZE DISTRIBUTION:	12.1 PERCENT	0.1 PERCENT	0.4 PERCENT	82.5 PERCENT	4.8 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000419912	0.000003267	0.000014363	0.002855173	0.000167807	0.003460524
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0135706831			
<CHROMIUM>						
SIZE FRACTIONS (MG):	2.318000	0.024609	0.055275	1.052623	1.893055	5.344362
SIZE DISTRIBUTION:	43.4 PERCENT	0.5 PERCENT	1.0 PERCENT	19.7 PERCENT	35.4 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000572017	0.000006071	0.000013636	0.000259668	0.000466991	0.001318383
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0051701200			
<COPPER>						
SIZE FRACTIONS (MG):	0.201945	0.006941	0.033902	18.004139	0.364472	18.691399
SIZE DISTRIBUTION:	1.5 PERCENT	0.0 PERCENT	0.2 PERCENT	96.3 PERCENT	1.9 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000069552	0.000001712	0.000008363	0.004441381	0.000089910	0.004610918
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0190820320			
<IRON>						
SIZE FRACTIONS (MG):	17.100199	0.261234	0.666985	5.010860	13.950481	37.089759
SIZE DISTRIBUTION:	45.4 PERCENT	0.7 PERCENT	1.8 PERCENT	13.5 PERCENT	38.8 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.004238125	0.000064443	0.000164536	0.001433461	0.003441397	0.009341964
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0366351530			
<MANGANESE>						
SIZE FRACTIONS (MG):	0.492745	0.004117	0.000107	0.257202	0.388182	1.142653
SIZE DISTRIBUTION:	43.1 PERCENT	0.4 PERCENT	0.0 PERCENT	22.5 PERCENT	33.9 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000121554	0.000001090	0.000002000	0.000063440	0.000093788	0.000281877
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0011054010			
<NICKEL>						
SIZE FRACTIONS (MG):	0.072185	0.006941	0.018425	2.210032	1.371403	4.479066
SIZE DISTRIBUTION:	19.5 PERCENT	0.2 PERCENT	0.4 PERCENT	49.3 PERCENT	30.6 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000215156	0.000001712	0.000004545	0.000545185	0.000338327	0.001104926
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0043330425			
<LEAD>						
SIZE FRACTIONS (MG):	4.466325	0.047956	0.190083	97.403343	2.136560	104.245064
SIZE DISTRIBUTION:	4.3 PERCENT	0.0 PERCENT	0.2 PERCENT	93.4 PERCENT	2.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.001101703	0.000011830	0.000047008	0.024028104	0.000527061	0.025715865
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.1008465290			
<ZINC>						
SIZE FRACTIONS (MG):	1.180305	0.025071	0.103717	20.409452	1.688825	23.416451
SIZE DISTRIBUTION:	5.1 PERCENT	0.1 PERCENT	0.4 PERCENT	87.2 PERCENT	7.2 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000293159	0.000006382	0.000025635	0.005034739	0.000416611	0.005776525
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0226530414			
<ARSENIC>						
SIZE FRACTIONS (MG):	0.021000	0.006941	0.001474	0.000971	0.051843	0.162309
SIZE DISTRIBUTION:	13.0 PERCENT	4.3 PERCENT	0.9 PERCENT	49.9 PERCENT	31.9 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000005200	0.000001712	0.000000364	0.000017974	0.000012789	0.000040039
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0001570175			
<MERCURY>						
SIZE FRACTIONS (MG):	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
SIZE DISTRIBUTION:	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT
FLOW RATE (G/SEC):	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000000000			

PLANT C-OUTLET DATE OF COMPUTER RUN: 4/30/79 PARTICULATE FLOW (KG/HR): 1.63200

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG)	41.10	6.60	14.70	1016.50	47.00	1125.90
<SILVER>						
SIZE FRACTIONS (MG)	0.023016	0.000520	0.003520	0.965675	0.031020	1.023767
SIZE DISTRIBUTION	2.2 PERCENT	0.1 PERCENT	0.3 PERCENT	94.3 PERCENT	3.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000009267	0.000000213	0.000001421	0.000388020	0.000012490	0.000412210
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0009092077			
<CADMIUM>						
SIZE FRACTIONS (MG)	0.037401	0.045538	0.193011	06.009105	0.355320	07.460301
SIZE DISTRIBUTION	0.0 PERCENT	0.1 PERCENT	0.2 PERCENT	99.3 PERCENT	0.4 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000015059	0.000026300	0.000077714	0.034952094	0.000143066	0.035215124
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0776004164			
<CHROMIUM>						
SIZE FRACTIONS (MG)	0.159879	0.011616	0.000050	6.200650	0.137710	6.590705
SIZE DISTRIBUTION	2.4 PERCENT	0.2 PERCENT	1.2 PERCENT	94.1 PERCENT	2.1 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000064374	0.000004677	0.000032554	0.002496635	0.000055448	0.002693607
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0050537214			
<COPPER>						
SIZE FRACTIONS (MG)	0.077679	0.012936	0.068061	10.774900	0.086480	11.020057
SIZE DISTRIBUTION	0.7 PERCENT	0.1 PERCENT	0.6 PERCENT	97.8 PERCENT	0.8 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000031277	0.000005209	0.000027404	0.004338415	0.000034820	0.004437125
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0097077756			
<IRON>						
SIZE FRACTIONS (MG)	3.705165	0.102490	0.906549	27.445499	0.750120	32.909822
SIZE DISTRIBUTION	11.2 PERCENT	0.6 PERCENT	2.7 PERCENT	83.2 PERCENT	2.3 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.001491851	0.000073478	0.000365014	0.011050600	0.000302029	0.013283031
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0293008462			
<MANGANESE>						
SIZE FRACTIONS (MG)	0.185361	0.019734	0.018228	0.304950	0.096820	0.625093
SIZE DISTRIBUTION	29.7 PERCENT	3.2 PERCENT	2.9 PERCENT	48.8 PERCENT	15.5 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000074634	0.000007946	0.000007339	0.000122705	0.000038984	0.000251608
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0005551940			
<NICKEL>						
SIZE FRACTIONS (MG)	0.132342	0.010414	0.067473	2.947050	0.107160	3.273239
SIZE DISTRIBUTION	4.0 PERCENT	0.6 PERCENT	2.1 PERCENT	90.1 PERCENT	3.3 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000053286	0.000007414	0.000027167	0.001186925	0.000043147	0.001317940
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0029072200			
<LEAD>						
SIZE FRACTIONS (MG)	0.091653	0.042968	0.213444	44.624352	0.118440	45.090855
SIZE DISTRIBUTION	0.2 PERCENT	0.1 PERCENT	0.5 PERCENT	99.0 PERCENT	0.3 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000036903	0.000017300	0.000085941	0.017967505	0.000047609	0.018155420
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0400487185			
<ZINC>						
SIZE FRACTIONS (MG)	0.200522	0.006988	0.340011	108.663849	0.584210	109.963583
SIZE DISTRIBUTION	0.3 PERCENT	0.1 PERCENT	0.3 PERCENT	98.8 PERCENT	0.5 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000116171	0.000035025	0.000136902	0.043752506	0.000235227	0.044275831
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0976672694			
<ARSENIC>						
SIZE FRACTIONS (MG)	0.002077	0.001914	0.005586	17.505447	0.090870	17.605898
SIZE DISTRIBUTION	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	99.9 PERCENT	0.1 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000001150	0.000000771	0.000002249	0.007000821	0.000003974	0.007008773
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0156369992			
<MERCURY>						
SIZE FRACTIONS (MG)	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
SIZE DISTRIBUTION	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT
FLOW RATE (G/SEC)	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)						

PLANT B-BOILER | DATE OF COMPUTER RUN: 4/30/79 | PARTICULATE FLOW (KG/HR): 2.02600

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG)	110.30	55.00	67.70	2733.70	313.50	3209.00
<SILVER>						
SIZE FRACTIONS (MG)	0.040222	0.016102	0.144070	3.007070	0.010810	3.227162
SIZE DISTRIBUTION	1.2 PERCENT	0.5 PERCENT	4.5 PERCENT	93.2 PERCENT	0.6 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000006002	0.000002769	0.000024790	0.000514537	0.000003219	0.000552197
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0009811906			
<CADMIUM>						
SIZE FRACTIONS (MG)	0.003993	0.074772	0.004625	4.975334	0.351120	5.569844
SIZE DISTRIBUTION	1.5 PERCENT	1.3 PERCENT	1.5 PERCENT	89.3 PERCENT	6.3 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000014372	0.000012794	0.000014400	0.000851325	0.000060000	0.000953051
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0016934765			
<CHROMIUM>						
SIZE FRACTIONS (MG)	1.431430	0.241614	0.266730	2.761037	2.489190	7.190009
SIZE DISTRIBUTION	19.9 PERCENT	3.4 PERCENT	3.7 PERCENT	38.4 PERCENT	34.6 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000244931	0.000041342	0.000045641	0.000472438	0.000425923	0.001230276
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0021860776			
<COPPER>						
SIZE FRACTIONS (MG)	1.963780	0.292392	0.402701	1.26.762922	2.065965	31.567760
SIZE DISTRIBUTION	6.2 PERCENT	0.9 PERCENT	1.5 PERCENT	84.8 PERCENT	6.5 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000336021	0.000050031	0.000068695	0.004579379	0.000353505	0.005401530
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0095979013			
<IRON>						
SIZE FRACTIONS (MG)	9.913541	3.956220	4.143240	13.750512	12.414599	44.178112
SIZE DISTRIBUTION	22.4 PERCENT	9.0 PERCENT	9.4 PERCENT	31.1 PERCENT	28.1 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.001696297	0.000676945	0.000708946	0.002352837	0.002124251	0.007559276
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0134320799			
<MANGANESE>						
SIZE FRACTIONS (MG)	0.089908	0.095418	0.054837	8.310448	0.463980	9.014590
SIZE DISTRIBUTION	1.0 PERCENT	1.1 PERCENT	0.6 PERCENT	92.2 PERCENT	5.1 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000015384	0.000016327	0.000009383	0.001421993	0.000079391	0.001542478
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0027408302			
<NICKEL>						
SIZE FRACTIONS (MG)	0.432978	0.192510	0.172635	2.432993	1.956240	5.187356
SIZE DISTRIBUTION	8.3 PERCENT	3.7 PERCENT	3.3 PERCENT	46.9 PERCENT	37.7 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000074006	0.000032940	0.000029539	0.000416307	0.000334730	0.000887604
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0015771834			
<LEAD>						
SIZE FRACTIONS (MG)	4.081350	0.848160	1.902370	135.318146	7.586700	149.736725
SIZE DISTRIBUTION	2.7 PERCENT	0.6 PERCENT	1.3 PERCENT	90.4 PERCENT	5.1 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000698356	0.000145128	0.000325513	0.023154164	0.001298153	0.025621312
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0455265194			
<ZINC>						
SIZE FRACTIONS (MG)	2.090350	0.736560	1.008030	105.794109	9.091500	120.409431
SIZE DISTRIBUTION	2.4 PERCENT	0.6 PERCENT	1.6 PERCENT	87.9 PERCENT	7.6 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000495934	0.000126032	0.000323196	0.018102346	0.001555638	0.020603146
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0366077391			
<ARSENIC>						
SIZE FRACTIONS (MG)	0.009464	0.008370	0.008001	0.355381	0.018810	0.400026
SIZE DISTRIBUTION	2.4 PERCENT	2.1 PERCENT	2.2 PERCENT	88.7 PERCENT	4.7 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000001419	0.000001432	0.000001506	0.000060009	0.000003219	0.000060585
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0001210486			
<MERCURY>						
SIZE FRACTIONS (MG)	0.000000	0.000000	0.000000	0.000000	0.001081	0.001081
SIZE DISTRIBUTION	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	0.0 PERCENT	100.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)	0.000000000	0.000000000	0.000000000	0.000000000	0.000000322	0.000000322
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)			0.0000000717			

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PLANT 1-OUTLET DATE OF COMPUTER RUN: 4/30/79 PARTICULATE FLOW (KG/HR): 0.20500

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	PROBE WASH	TOTAL
SAMPLE WEIGHTS (MG):	230.50	13.70	16.30	251.91	0.00	520.41
<SILVER>						
SIZE FRACTIONS (MG):	0.126333	0.000090	0.017461	0.198505	0.000000	0.342299
SIZE DISTRIBUTION:	36.9 PERCENT	0.0 PERCENT	5.1 PERCENT	58.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000013024	0.000000000	0.000001911	0.000021721	0.000000000	0.000037455
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0006577400			
<CADMIUM>						
SIZE FRACTIONS (MG):	0.376435	0.008499	0.076760	1.964697	0.000000	2.446391
SIZE DISTRIBUTION:	16.2 PERCENT	0.3 PERCENT	3.1 PERCENT	80.3 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000043379	0.000000930	0.000008399	0.000214902	0.000000000	0.000267690
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0047000907			
<CHROMIUM>						
SIZE FRACTIONS (MG):	0.290612	0.063099	0.045091	0.250802	0.000000	0.647604
SIZE DISTRIBUTION:	44.7 PERCENT	9.7 PERCENT	6.9 PERCENT	38.6 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000031799	0.000006904	0.000004934	0.000027443	0.000000000	0.000071081
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0012402542			
<COPPER>						
SIZE FRACTIONS (MG):	0.462762	0.022400	0.005220	2.208293	0.000000	2.778874
SIZE DISTRIBUTION:	16.7 PERCENT	0.8 PERCENT	3.1 PERCENT	79.5 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000050636	0.000002451	0.000009325	0.000241636	0.000000000	0.000304049
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0053393939			
<IRON>						
SIZE FRACTIONS (MG):	2.914852	0.515399	0.097060	2.926590	0.000000	6.454701
SIZE DISTRIBUTION:	45.2 PERCENT	8.0 PERCENT	1.5 PERCENT	45.3 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000318950	0.000056396	0.000010708	0.000320234	0.000000000	0.000706288
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0124031072			
<MANGANESE>						
SIZE FRACTIONS (MG):	0.061199	0.009000	0.045100	0.067991	0.000000	0.183290
SIZE DISTRIBUTION:	33.4 PERCENT	4.9 PERCENT	24.6 PERCENT	37.1 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000006697	0.000000985	0.000004935	0.000007440	0.000000000	0.000020056
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0003522023			
<NICKEL>						
SIZE FRACTIONS (MG):	0.141303	0.003600	0.026310	0.263901	0.000000	0.435194
SIZE DISTRIBUTION:	32.5 PERCENT	0.8 PERCENT	6.0 PERCENT	60.6 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000015470	0.000000394	0.000002879	0.000028877	0.000000000	0.000047620
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0008362521			
<LEAD>						
SIZE FRACTIONS (MG):	9.530531	0.362301	0.780170	104.264992	0.000000	114.937996
SIZE DISTRIBUTION:	8.3 PERCENT	0.3 PERCENT	0.7 PERCENT	90.7 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.001042052	0.000039644	0.000085368	0.011400911	0.000000000	0.012576776
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.2208604515			
<ZINC>						
SIZE FRACTIONS (MG):	0.493700	0.240200	0.956549	42.746712	0.000000	52.445160
SIZE DISTRIBUTION:	16.2 PERCENT	0.5 PERCENT	1.8 PERCENT	81.5 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000929400	0.000027157	0.000104668	0.004672442	0.000000000	0.005733668
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.1007766128			
<ARSENIC>						
SIZE FRACTIONS (MG):	0.014095	0.001400	0.001301	0.065597	0.000000	0.082394
SIZE DISTRIBUTION:	17.1 PERCENT	1.7 PERCENT	1.6 PERCENT	79.6 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000001542	0.000000153	0.000000142	0.000007178	0.000000000	0.000009016
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0001583244			
<MERCURY>						
SIZE FRACTIONS (MG):	0.000191	0.000200	0.000200	0.000504	0.000000	0.001055
SIZE DISTRIBUTION:	17.4 PERCENT	18.3 PERCENT	18.3 PERCENT	46.0 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC):	0.000000021	0.000000022	0.000000022	0.000000055	0.000000000	0.000000120
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG):			0.0000210111			

PLANT F OUTLET DATE OF COMPUTER RUN 4/30/79 PARTICULATE FLOW (KG/HR)= 0.55600

	>10 MICRONS	3.5-10 MICRONS	1.0-3.5 MICRONS	0.1-1.0 MICRONS	FRONT WASH	TOTAL
SAMPLE WEIGHTS (MG)=	230.90	148.00	62.40	499.20	0.00	941.30
<SILVER>						
SIZE FRACTIONS (MG)=	0.030710	0.021516	0.026919	0.829920	0.000000	0.909066
SIZE DISTRIBUTION=	3.4 PERCENT	2.4 PERCENT	3.0 PERCENT	91.3 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)=	0.000005030	0.000003524	0.000004409	0.000135925	0.000000000	0.000148887
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)=			0.0009657554			
<CADMIUM>						
SIZE FRACTIONS (MG)=	0.097009	0.041575	0.058600	0.505590	0.000000	0.703574
SIZE DISTRIBUTION=	13.9 PERCENT	5.9 PERCENT	8.3 PERCENT	71.9 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)=	0.000016019	0.000006809	0.000009598	0.000082806	0.000000000	0.000115232
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)=			0.0007474487			
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SIZE FRACTIONS (MG)=	0.280497	0.112106	0.084901	0.107777	0.000000	1.365282
SIZE DISTRIBUTION=	20.5 PERCENT	8.2 PERCENT	63.3 PERCENT	7.9 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)=	0.000045940	0.000018361	0.000141654	0.000017652	0.000000000	0.000223607
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)=			0.0014504216			
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SIZE FRACTIONS (MG)=	0.206609	0.117299	0.095497	2.819282	0.000000	3.238687
SIZE DISTRIBUTION=	6.4 PERCENT	3.6 PERCENT	2.9 PERCENT	87.1 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)=	0.000033839	0.000019211	0.000015641	0.000461744	0.000000000	0.000530434
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)=			0.0034406534			
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SIZE FRACTIONS (MG)=	15.907301	9.449090	4.095099	3.766015	0.000000	33.218315
SIZE DISTRIBUTION=	47.9 PERCENT	28.4 PERCENT	12.3 PERCENT	11.3 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)=	0.002605307	0.001547579	0.000670029	0.000616000	0.000000000	0.005440915
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)=			0.0352890277			
<MANGANESE>						
SIZE FRACTIONS (MG)=	0.136600	0.069504	0.029503	0.082418	0.000000	0.318026
SIZE DISTRIBUTION=	43.0 PERCENT	21.9 PERCENT	9.3 PERCENT	25.9 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)=	0.000022372	0.000011303	0.000004832	0.000013498	0.000000000	0.000052086
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)=			0.0003370570			
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SIZE FRACTIONS (MG)=	0.141611	0.064996	0.056098	0.016524	0.000000	0.279228
SIZE DISTRIBUTION=	50.7 PERCENT	23.3 PERCENT	20.1 PERCENT	5.9 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)=	0.000023193	0.000010645	0.000009188	0.000002706	0.000000000	0.000045732
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)=			0.0002966407			
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SIZE FRACTIONS (MG)=	0.544601	0.336407	0.433299	18.068295	0.000000	19.382603
SIZE DISTRIBUTION=	2.8 PERCENT	1.7 PERCENT	2.2 PERCENT	93.2 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)=	0.000089195	0.000055097	0.000070966	0.002959236	0.000000000	0.003174494
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)=			0.0205913112			
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SIZE FRACTIONS (MG)=	0.022409	0.507096	0.417300	7.124004	0.000000	8.070968
SIZE DISTRIBUTION=	9.3 PERCENT	5.7 PERCENT	4.7 PERCENT	80.3 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)=	0.000134708	0.000003052	0.000060346	0.001166787	0.000000000	0.001452892
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)=			0.0074241650			
<ARSENIC>						
SIZE FRACTIONS (MG)=	0.022998	0.010600	0.065002	0.069508	0.000000	0.176108
SIZE DISTRIBUTION=	13.1 PERCENT	10.6 PERCENT	36.9 PERCENT	39.5 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)=	0.000003767	0.000003046	0.000010643	0.000011397	0.000000000	0.000028856
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)=			0.0001071754			
<MERCURY>						
SIZE FRACTIONS (MG)=	0.000092	0.000402	0.000100	0.001498	0.000000	0.002092
SIZE DISTRIBUTION=	4.4 PERCENT	19.2 PERCENT	4.8 PERCENT	71.6 PERCENT	0.0 PERCENT	100.0 PERCENT
FLOW RATE (G/SEC)=	0.000000015	0.000000066	0.000000016	0.000000245	0.000000000	0.000000343
RATIO OF METAL TO TOTAL SAMPLE WEIGHT (MG/MG)=			0.0000002220			

STAPPA/ALAPCO

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#100 10/28/86

SLUDGE INCINERATOR EMISSION TESTING
UNIT I
FOR
CITY OF OMAHA
PAPILLION CREEK
WATER POLLUTION CONTROL PLANT
JULY, 1978

Submitted

September 8, 1978

Prepared By

Particle Data Laboratories, Ltd.
115 Hahn Street
Elmhurst, Illinois 60126

312 832-5658

PREFACE

I certify that the work reported herein was conducted in a conscientious scientific manner, and the reported test results represent valid estimates of the actual events which occurred at the time of testing.

Sander E. Sundberg, Ph. D.
Technical Staff

I have reviewed the contents of this report and certify the calculations and testing followed good engineering practice and were done in an accurate and complete manner.

Richard Karuhn
General Manager

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I. INTRODUCTION AND SUMMARY

Particle Data Laboratories, Ltd. was retained to perform a compliance testing program on the particulate emissions from the Sludge Incineration System, Unit 1 at the City of Omaha's Papillion Creek Water Pollution Control Plant.

Emission testing was performed on July 27, 1978 by Dr. Sander E. Sundberg and Mr. Erik Berg of Particle Data Laboratories, Ltd., 115 Hahn Street, Elmhurst, Illinois 60126. A total of three test runs were made following U.S. EPA Methods 1 through 5. Messrs. Art Miller and Bill Swan of the City of Omaha coordinated the testing with system operation. Messrs. Don Chmura, Dan Marlowe and Frank Sage of Envirotech also coordinated the program and supervized the operation of the Sludge Incineration System, as did Mr. Jim Love of Martin K. Eby Company. Sludge samples were obtained by personnel from the Omaha Testing Laboratories. Observing the testing for the Nebraska Department of Environmental Control, Division of Air Pollution Control were Messrs. Joe Francis and Dale Murdoch. Mr. Phil York of the U.S. EPA Region VII was present during an aborted preliminary test period on July 19 and 20, 1978.

The following table summarizes the results of the testing on Unit #1 performed on July 27, 1978:

Test Run	1	2	3
Stack Gas Data			
Temperature, ^{o}F	115.4	126.7	118.3
Velocity, ft/sec	43.907	44.704	44.836
Gas Volume, actual cfm (wet)	25,346	25,806	25,882
Gas Volume, scfh (dry)	1.192×10^6	1.165×10^6	1.196×10^6
Moisture, %	12.1	14.0	13.1
Sampling Data			
Volume, scf (dry)	36.512	35.197	36.316
Isokinetic Ratio, %	98.4	97.0	97.6
Particulates			
Concentration, grams/scf (dry)	0.019	0.014	0.015
Emission Rate, lb/hr.	3.268	2.321	2.629
Opacity, %	≤ 5	≤ 5	≤ 5
Operating Conditions			
Dry Sludge Feed Rate(tons/hr)	2.730	3.276	3.538
Allowable Emissions @1.3 lb/ton/hr			
Particulates (lb/hr)	3.55	4.26	4.60

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II. PROCESS DESCRIPTION AND OPERATING CONDITIONS

The fluidized bed incineration facility is designed to incinerate dewatered sludge cake, grease, grit and screenings to a sterile ash and operate free from objectionable odor, smoke, fly ash or dust. The primary object is to dispose of the sewage solids in an economical and environmentally acceptable manner. Clean combustion, which is inherent to fluidized bed incineration, reduces the sewage solids to an inert ash and gaseous products of combustion. The hot combustion gases are used to preheat the fluidizing and combustion air in a gas-to-air heat exchanger thereby minimizing the amount of supplemental fuel oil required to sustain combustion. An important by-product is steam which is generated by the hot combustion gases in the waste heat boiler. The cooled combustion gases then pass through the primary and secondary scrubbers, where the particulate emissions are reduced to levels below regulatory requirements and the spent combustion gases are reduced in temperature to approximately 130°F.

Two identical combustion units form the total system. Each incineration unit is composed of a fluidizing air blower, fluidized bed reactor, sewage solids feed systems, hot cyclone, gas-to-air heat exchanger, waste heat boiler, primary wetted wall venturi scrubber, and a secondary scrubber. The unit is complete with a preheat system, an ash handling system, and a sand handling system for bed introduction and removal.

The dewatered sludge cake is pumped to the reactor at approximately 30 percent total solids and at a normal rate of 6500 pounds of dry solids per hour. The sludge solids contain approximately 70 percent volatile matter and 30 percent inert non-combustible matter. The combined sewage sludges have a gross heating value of approximately 9000 BTU's per pound of dry volatile solids. The sludge is injected into a feed gun mounted on top of the reactor. The sludge feed gun combines the sludge with atomizing air and injects the mixture into the fluidized bed reactor. The atomized sludge is directed, in the form of a cone shaped spray, towards the center of the fluidized bed where the sludge is evenly dispersed across the area of the fluidized bed. The counter current flow of hot combustion gases and

wet sludge causes some evaporation of the water in the sludge by the time it reaches the combustion or fluid bed zone. Combustion of the sludge feed occurs in the fluid bed section or immediately above the bed, and the temperatures in the freeboard section always exceed that temperature necessary for complete combustion.

Grease discharged from the grease tanks is pumped directly into the fluidized bed through four grease feed guns. Alternatively, grease can be introduced through the sludge feed gun. Grease is delivered to the reactor at approximately 30 percent total solids and at a normal rate of 1400 pounds of dry solids per hour. Grit and screenings delivered from ejectors can also be fed into the reactor through an above-bed injection port.

At design conditions, approximately 15,000 SCFM of fluidizing and combustion air is delivered to the combustion system. The air is preheated to a maximum of 1000°F in a gas-to-air heat exchanger and sent to the windbox of the fluidized bed reactor. An orifice plate separates the windbox from the fluidized bed zone of the reactor vessel and is used to provide uniform gas distribution throughout the fluidized bed. During normal operations, the reactor vessel will contain 50 to 60 inches of inert silica sand and ash in a fluidized state. Sewage solids serve as fuel, and the fluidizing air serves as combustion air for the burning process which takes place within the fluidized bed. Combustion gases rise from the bed at approximately 1400°F. carrying ash and fine bed material into the freeboard section of the reactor. The freeboard section acts as a disengaging chamber allowing fine bed material and coarse ash to separate from the rising combustion gases and fall back into the bed. Very fine ash is entrained by the rising combustion gases and carried to the hot cyclone. The fine particles which return to the bed are required to help maintain the particle size distribution necessary for good fluidization and overall system performance. Water sprays located in the dome of the reactor inject cooling water into the exhaust gases if the outlet temperature rises above 1450°F. The cooling water is atomized to provide small droplets of water for rapid vaporization and therefore efficient control of the gases.

Combustion gases from the reactor are passed through a cyclonic type dust collector. The hot dust-laden gas stream channels tangentially into the cyclone barrel, which imparts a spinning, vortexed flow-pattern to the gas-duct mixture. Centrifugal force separates the dust from the gas stream, and the dust travels first to the walls of the barrel, then down along the conical section to the dust outlet. The spinning gas also travels down along the wall

toward the apex of the cone, but reverses direction in the center of the cone, and leaves the cyclone through the gas outlet-tube at the top. The cyclone removes approximately 90 percent of the entrained ash. The cleaned gas stream passes through a gas-to-air heat exchanger. The fluidizing air is preheated to eliminate the supplemental fuel oil required to sustain the operating temperature while the combustion gases are cooled.

The gas stream then passes to a waste heat boiler where heat from the hot gases is transferred to water circulating through a tube bundle to produce steam. The boiler is a water tube, natural circulation type designed to produce 16,000 pounds per hour saturated steam at 250^{o}PSIG-Ch 1.

The exhaust gases then pass through a two-stage wet gas scrubber to remove the remaining ash particles entrained in the gases. The primary scrubber will remove approximately 99 percent of all particles. The scrubber is a high energy wetted-wall venturi type designed to operate with a gas pressure drop of up to 40 inches water column. Its efficiency is a function of pressure drop across the venturi throat. Since this pressure drop is a function of gas flow, scrubbing water flow rate and throat size, a variable throat is provided to permit adjustment to give good scrubbing efficiency at various reactor feed rates. In the venturi the gases are cooled to 180^{o}F by direct evaporation. Following the venturi scrubber the gases and the scrubbing water pass to the secondary scrubber. The lower portion of this scrubber is equipped with a sump for separation of the venturi scrubbing water and the gases. The scrubbing water collected in the scrubber sump is recycled back to the venturi by a recirculation pump. The gases enter the upper section of the secondary scrubber where an impingement tray section impedes the gas flow with two perforated plates. Target plates are situated above the perforations to deflect rising particles back into the water passing across the trays. This increases contact time and likelihood of absorption. Water enters on the top tray and overflows to the bottom tray and then overflows to the scrubber sump. Demister pads are located above the packed section to further trap any entrained droplets. The cleaned gases are emitted to the atmosphere at approximately 130^{o}F.

The ash handling system consists of an ash quencher, an ash tank, and three ash pumps. Hot ash is removed from the cyclone down-leg and cooled in the ash quencher with an ash water slurry from the secondary scrubber sump. The combined ash slurry then drops down into the ash tank, from where it is transferred by ash pumps to the ash lagoon.

The preheat system for each reactor consists of two overbed burners. The burners are designed to fire A.P.I. No. 2 fuel oil with combustion air from the fluidizing air blower. The overbed burners are required to preheat the bed material up to 1200°F at which point fuel oil can be injected directly into the bed.

The sand handling system consists of a sand storage silo, three blow tanks and a sand conveying blower. This system provides both a method to put bed material into the reactor and a method to remove bed material from the reactor. When charging the reactor, sand flows through a rotary feeder from the silo to the blow tank from where it is pneumatically conveyed to the reactor. When discharging the reactor, sand flows from the reactor to a blow tank from where it is pneumatically conveyed to the storage silo.

The reactor vessel, cyclone, and connecting gas ducts are lined with insulating refractory materials to protect against erosion by dust-laden gases and conserve heat for preheating the fluidizing air in the heat exchanger and for steam generation in the waste heat boilers. Pumps and tanks are either rubber lined or fabricated of special alloys to resist erosion by the abrasive ash-water slurry and corrosion by the liquids. The venturi and secondary scrubbers are fabricated of stainless steel to resist erosion and corrosion.

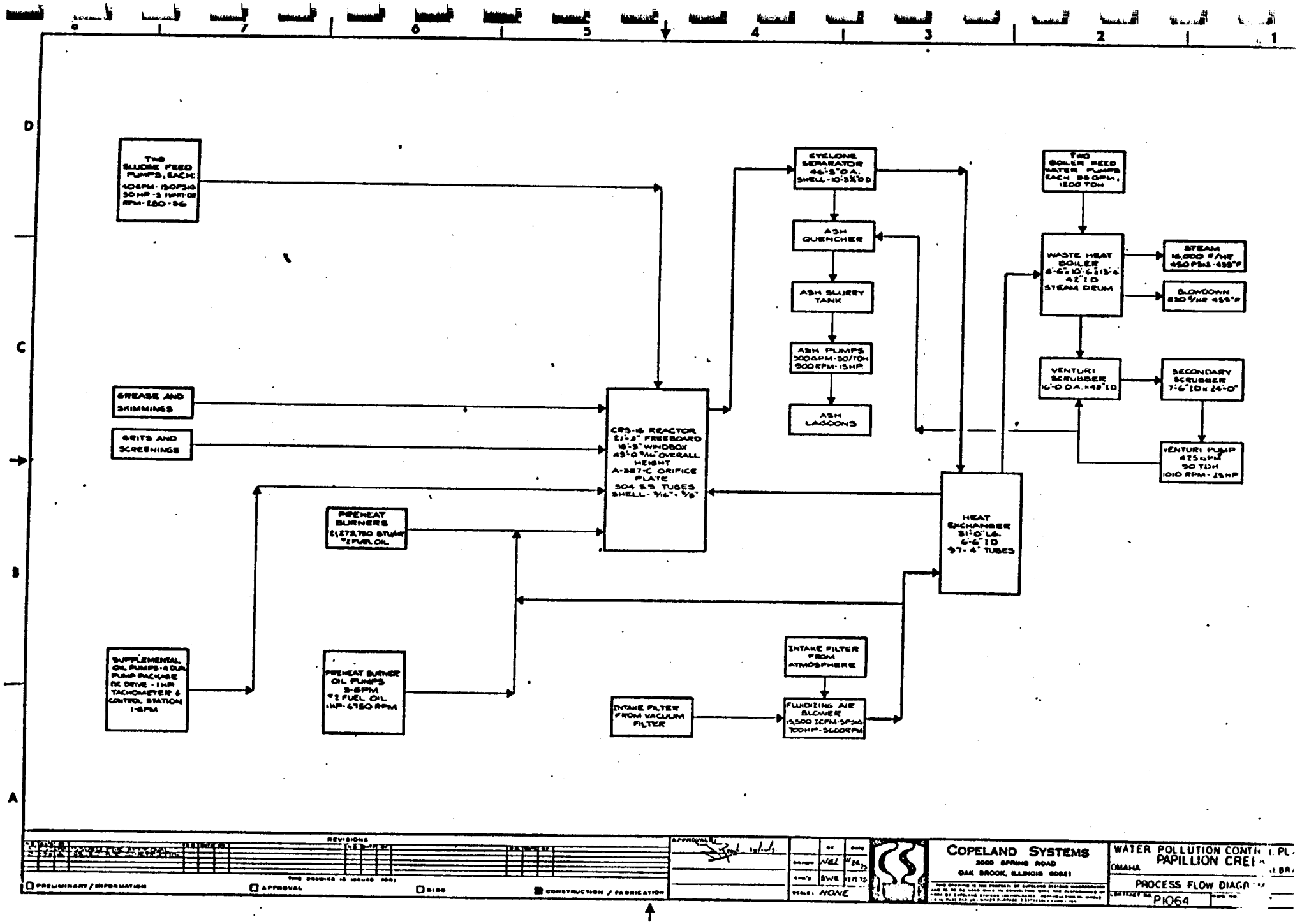
Design Criteria Versus Performance Data

The design criteria for incineration of sludge at the Papillion Creek WWTP is compared to the average performance data in the following table:

	Specifications Basis of Design	July 27, 1978 Performance (Based on Primary Sludge)
Feed rate lbs/hr (wet basis)	21,700	22,385
Sludge cake feed % TS	30	30.5
Sludge volatiles solids % V.S.	70	50.6
Sludge heat value BTU/lb.V.S.	9,000	12,931
Fuel oil rate, GPH	0	33.50
Grease feed rate lbs/hr	4,600	0
Grease feed % TS	30	76.3
Grease feed % V.S.	94.9	92.2
Grease heat value, BTU/lb.V.S.	14,000	17,636
Grit feed rate lbs/hr	1,500	1,460
Grit feed % TS	50	40
Grit feed % V.S.	25.3	29.9
Heat value BTU/lb V.S.	9,000	7,711
Screenings Feed rate lbs/hr	200	614
Screenings feed % TS	30	40
Screenings feed % V.S.	83.3	29.9
Heat value BTU/lb V.S.	9,000	7,711
Ash volatile solids % V.S. max.	4	2.4
Furnace exhaust temperature ^{o}F	1,400	1,410
Scrubber exhaust Temperature ^{o}F	130	117
Power KW/hr	503	501
Emissions rate lbs/ton dry sludge solids	1.3	0.88

The sludge cake feed rate is based on average readings taken over a continuous 8 hour period on July 27. During this period the incinerator handled 22,315 lbs/hr of wet cake. This is in excess of the design rate of 21,700 lbs/hr. The deviation in solids content, volatile content and heat value from specified conditions explains why fuel oil was used during the performance test. Grease feed to the incinerator was sporadic and could not be used to operate under the autogenous mode. The grit supply was limited which explains why most of what was available was added during the emission testing period. To make up the deficiency in the grit it was decided to make up the difference with screenings. The screenings injected during the performance run at 614 lbs/hr was well in excess of the design rate of 200 lbs/hr. Grit and screenings injection rates will be discussed later on in this report.

The volatile content of the ash was 2.4% which is below the 4% maximum limitation.



Guide

Plant Operations Preface

Operational Procedures

Fluidization Control System

Operational Graphs

Determination of Sludge Feed Rates

Sludge feed rates to the incinerator were determined by Omart weigh scales mounted on the feed belt conveyors. Panels mounted in the vicinity of the two filters provided continuous digital readouts of the capacity that each belt filter was handling. These were recorded on an hourly basis.

The Omart scales were calibrated prior to the performance run and recalibrated after the test. The recalibration showed that the north scale drifted 1.8% on the high side which is insignificant while the south scale drifted 20%. The drift on the south scale is easily detected from the strip chart, a copy of which will be found in the Appendix. The chart clearly shows that the drift began around 3:00 PM on July 27. The feed rates from 3:00 PM - 5:00 PM have been adjusted for this 20% drift.

Total feed rate on a wet basis was determined from one of two totalizing systems for each of the test runs. These observations were made by either Joe Francis or Dale Murdoch of the Nebraska DEC.

Readings for the first test run were made on the feed totalizers located in the System Control Room. These readings are then multiplied by a factor of 16.7 to obtain pounds. Since the sampling period exceeded one hour by 5 minutes due to off-time during the change from one sampling port to the other, the feed rate in pounds per hour was adjusted accordingly. The feed rate for dry sludge was obtained by multiplying the total feed rate of wet sludge by the average percent dry solids present in the sludge as determined by tests performed by Omaha Testing Laboratories, Inc. For test run #1, the sample taken at 11:00 hrs. was used to determine this average, since data for 09:00 and 10:00 hrs. were not available. While a sample taken and analyzed in the plant lab at 8:40 hrs. yielded a somewhat higher Dry Solids content (Average = 34.3%), it was felt that the conservatism introduced by using the lower number (28.9%) was preferable.

Readings for the second and third test runs were made on the individual Ohmart scale totalizers. These totalizers read directly in pounds. Data for each test run was adjusted to reflect the fact that the period between initial and final readings was 63 minutes. The average dry solids content was based on three observations: the first made approximately one-half hour before the start of the stack test; the second approximately half way through; and the third one-half hour after the completion of the test run.

The sludge feed rate data for all three test runs are summarized for the North and South Vacuum Filters as follows:

Test Run	Filter	Wet Sludge (Pounds)	Time Between Readings (Min)	Wet Sludge Feed Rate (Lb/hr)	Average Dry Solids (%)	Dry Sludge Feed Rate (Lb/hr)
1	N	8,400	65	7,754	29.2	2,264
	S	12,108	65	11,176	28.6	3,196
	Both			18,930		5,460
2	N	8,475	63	8,071	29.03	2,343
	S	15,121	63	14,401	29.23	4,210
	Both			[illegible]		6,553
3	N	8,385	63	7,986	30.73	2,454
	S	15,740	63	14,990	30.83	4,622
	Both			[illegible]		7,076

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III. STACK TESTING AND ANALYTICAL PROCEDURES

The procedures of sampling, testing, instrumentation and analysis as prescribed by the U.S. EPA were followed. The EPA Reference Methods used in this testing program are summarized below.

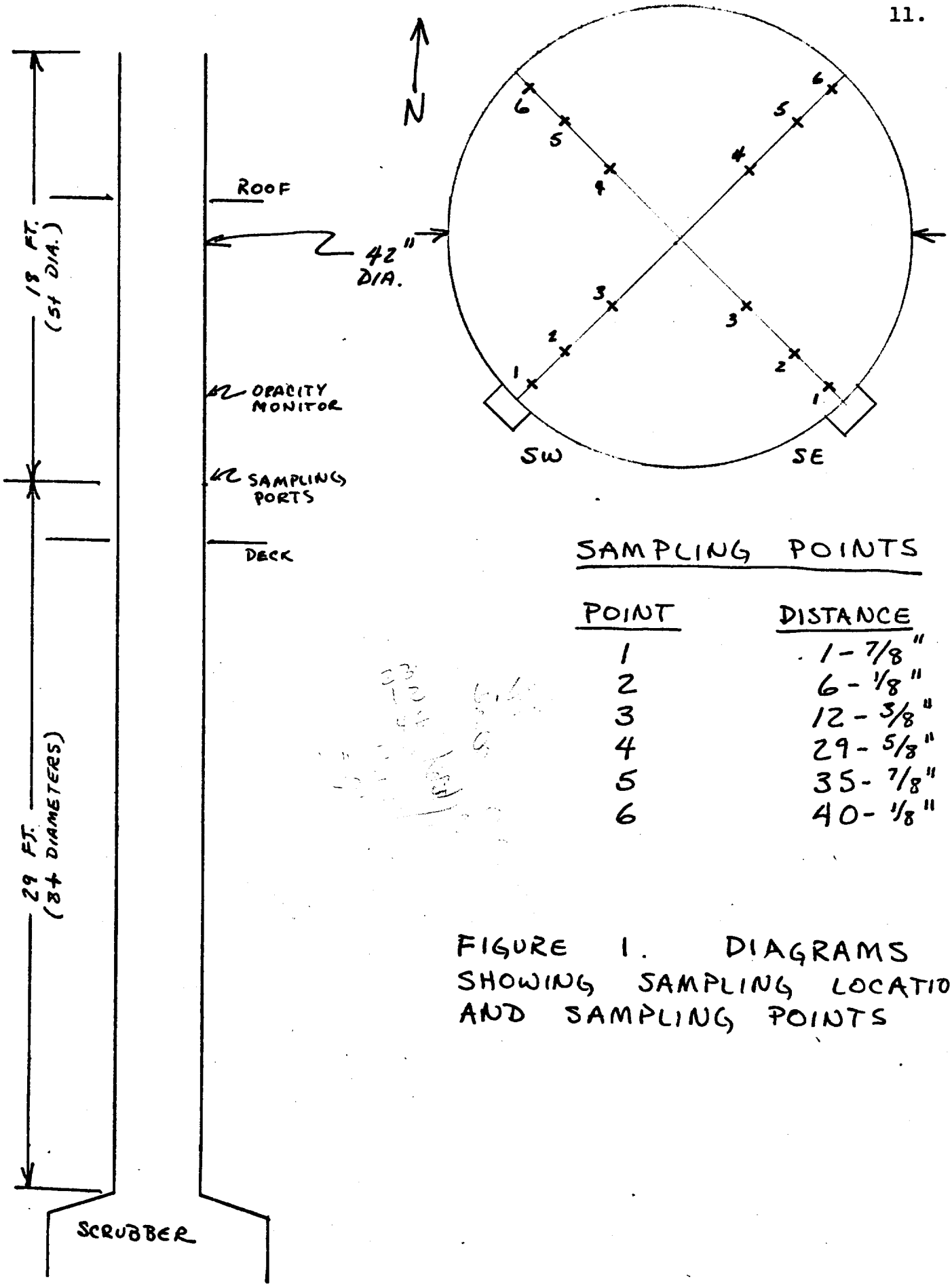
Method 1. Sample and Velocity Traverse Locations

The sampling site selected lies in a straight section of each of the Scrubber Exhaust Stack. The sampling site was 8 diameters downstream from the nearest disturbance, slightly more than the scrubber, and approximately 6 diameters upstream from the top of the stack. The continuous opacity monitor was approximately one diameter downstream from the sampling location. The sample ports for the opacity monitor were flush along the inside stack wall and therefore would present only minimal flow disturbance. Six points, lying in the centroid of equal sized areas were sampled on each of the two perpendicular traverse lines. Those sampling points accessed through the southeast port were designated SE1 through SE6, and those accessed through the southwest port SW1 through SW6. The stack had an inside diameter of 42.0 inches and a cross-sectional area of 9.621 square feet. (see Figure 1)

Method 2. Stack Gas Velocity and Volumetric Flow Rate

Velocity traverses were made with a calibrated Type S pitot tube having a coefficient (C_p) of 0.83. (See Appendix) The velocity head was read on a manometer to the nearest 0.05 inches of water. The pitot tube used was attached to the particulate sampling probe which also had a chromel-alumel thermocouple. A preliminary velocity traverse was performed on an earlier date. Subsequent traverses were performed in conjunction with each particulate test run. Prior to each test run the system was leak checked.

Sampling site barometric pressure was obtained by correcting national weather service data for the Omaha Airport for sampling site altitude.



SAMPLING POINTS

POINT	DISTANCE
1	1 - 7/8"
2	6 - 1/8"
3	12 - 3/8"
4	29 - 5/8"
5	35 - 7/8"
6	40 - 1/8"

FIGURE 1. DIAGRAMS SHOWING SAMPLING LOCATION AND SAMPLING POINTS

Method 3. Component Gas Analysis

Analysis for CO_2, O_2, and $CO+N_2$ were performed in the field using an Orsat analyzer. Grab samples were obtained through a stainless steel probe whose opening was positioned in the center of the stack. Prior to sampling, the entire system was leak checked and the activity of the absorbing solutions was determined to be adequate. Between three and four analyses were performed during each particulate test run. Results were read and recorded to the nearest 0.2% volume, dry basis.

Dry molecular weight calculations were made from the average values for each particulate test run.

Method 4. Moisture Content

The moisture content of the stack gas was determined by the EPA Reference method which involves the condensation and adsorption by silica gel of the moisture present in the particulate sample gas stream. To determine an approximate moisture content, the stack gases were assumed to be saturated at stack temperature.

Method 5. Particulate Emissions

Particulate material is withdrawn isokinetically from the stack and collected on a glass fiber filter maintained at a temperature in the range of 223-273° F. Moisture is collected in a series of impingers maintained in an ice-water bath. The sample gas is then passed through a metering system which measures both the cumulative volume of gas sampled and the instantaneous sampling rate.

Sampling Train

A schematic of the sampling train used in this method is shown in Figure 2. The sampling train consists of the following components:

1. Probe Nozzle. Stainless steel (316) with sharp, tapered leading edge. A 15/64-inch diameter nozzle was used for testing. Nozzle diameter calibration was verified using a caliper (See Appendix).

2. Probe Liner. Stainless steel (316) with a heating system capable of maintaining a gas temperature at the exit end during sampling of 223-273° F.

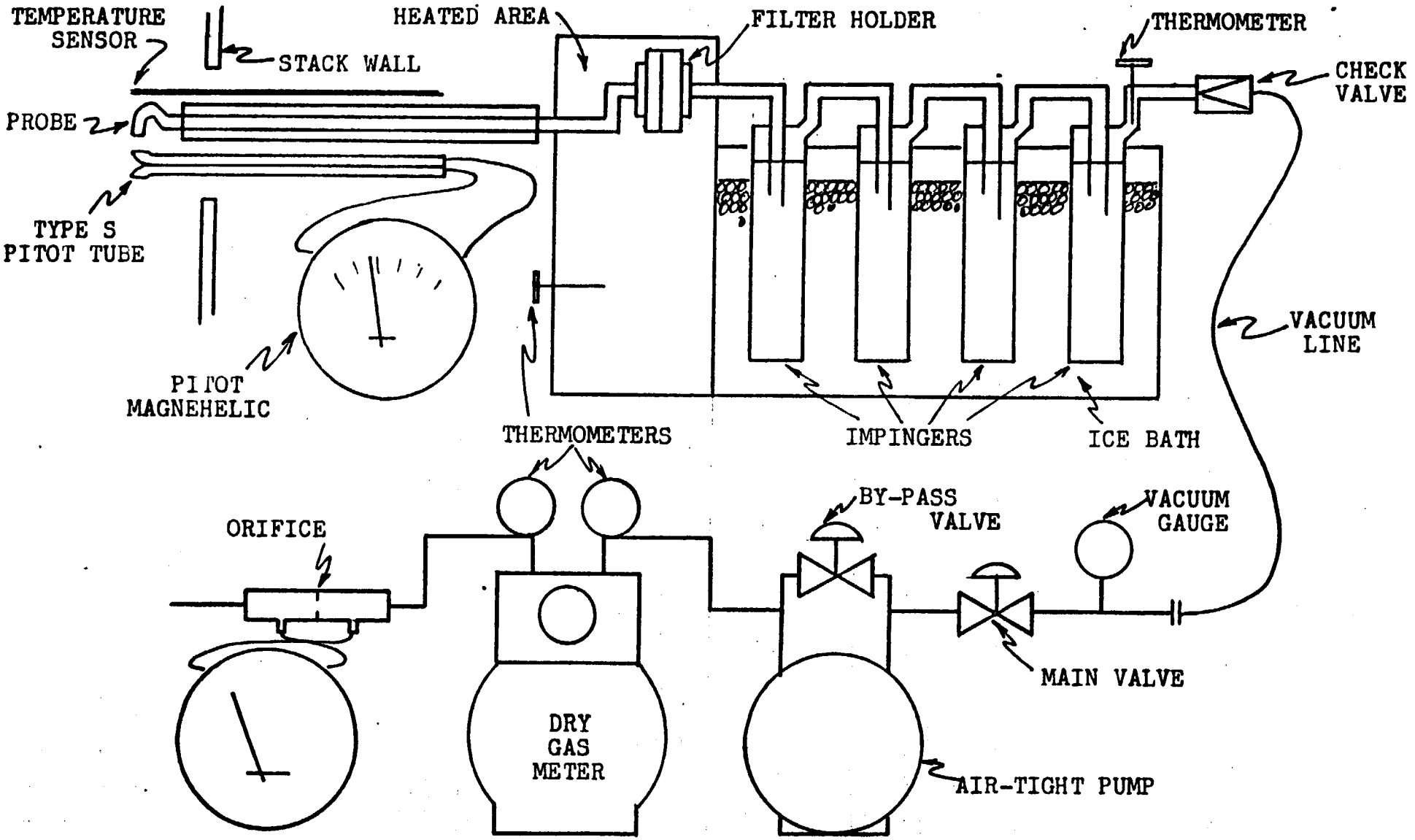


FIGURE 2. PARTICULATE SAMPLING TRAIN

3. Pitot Tube. A Type S pitot tube attached to the probe to allow constant monitoring of the stack gas velocity. The pitot tube coefficient was determined by comparison with a Standard pitot tube under laboratory conditions (See Appendix for Calibration data).

4. Differential Pressure Gauge. Inclined manometer having a range of 0 to 2 in. H_2O.

5. Filter Holder. Borosilicate glass, with a glass frit filter support and a silicone rubber gasket.

6. Filter Heating System. Rheostat controlled electrical resistance-type heater capable of maintaining a temperature of 223-273° F around the filter holder.

7. Impingers. Four Pyrex glass impingers connected in series with leak-free ground glass fittings. The first, third, and fourth impingers were Greenburg-Smith design with modified (straight) tip. The second was a Greenburg-Smith with a standard tip. A thermometer was present to measure the temperature at the outlet of the fourth impinger.

8. Metering system. Vacuum gauge, leak-free pump, thermometers temperature compensated dry gas meter, and related equipment as shown in Figure 2.

SAMPLING PROCEDURES

Prior to testing, the sampling train was cleaned and set-up as follows: A 5-inch diameter glass fiber filter was dried in an oven at 105° C overnight. The filter was then removed to a desicator for two hours and weighed on an analytical balance to the nearest 0.1 milligram. One hundred milliliters of water was placed in each of the first two impingers. Two hundred grams of silica gel was placed in the fourth impinger. The sampling train was then assembled as shown in Figure 2. Based on the preliminary velocity and temperature traverse an appropriate nozzle size was selected to provide an adequate sampling rate.

After assembly, the sampling train was leak checked as follows: the inlet of the filter holder was plugged and the pump was started. The main and by-pass valves were adjusted to give a system vacuum of 15 in. Hg, and the dry gas meter was checked. If the reading change was less than 0.02 cubic feet the system was declared to be leak free and the sampling probe was connected. If leakage exceeded 0.02 cubic feet, the pump was turned off and the system was checked and any leaks were corrected. The leak-check procedure was then repeated until all leaks were eliminated.

Approximately one-half hour before the start of a test run, the sample probe and filter box heaters were turned on and allowed to warm up to sampling temperatures. Crushed ice was placed around the impingers.

At the start of the test run, the dry gas meter reading was recorded on the data sheet, the probe was placed in the stack at the first sampling point, and the velocity pressure was read. Using an isokinetic flow rate calculator, the desired orifice meter pressure was determined. The sample pump was then turned on and the time of the start of testing was recorded. The main and by-pass valves were immediately adjusted to give the desired sampling rate. For each point the following data were recorded: traverse point number, sampling time, stack temperature, velocity head, orifice meter reading, dry gas meter volume, box temperature and pump vacuum. In addition the temperature at the outlet of the last impinger was checked. Near the end of the sampling time, with approximately 15 seconds to go, the nozzle was moved to the next point and exactly at the start of the next period the dry gas meter was read. The point-by-point sampling procedures were then repeated until the test run was completed. While moving between ports, the sample pump was turned off. Sampling time was 5 minutes per point for a total of 60 minutes.

At the completion of the test run, the pump was turned off, the dry gas meter reading recorded, and the probe was removed from the stack. The probe was disconnected and the inlet to the filter was plugged. The leak check precedure outlined above was repeated at 15 in. Hg. vacuum to verify the leak-free integrity of the system.

Sample Recovery

Sample recovery was accomplished in a draft-free lab near the sampling site. While the probe and filter holder were cooling, the contents of the first three impingers measured volumetrically and discarded. The silica gel in impinger 4 was transferred to its original container.

The filter was transferred with a forceps to a plastic bag. Any filter material which stuck to the gasket or filter holder was scraped loose with a knife and transferred to the Acetone Wash Jar. The upstream portion of the filter holder was washed with acetone which was collected in a clean glass jar and labeled to identify the test run.

The probe nozzle was then removed and the inner surfaces were rinsed with acetone and a nylon bristle brush until no visible particulate matter was present in the rinse. Similarly the probe liner was washed with acetone and a nylon bristle brush. Both the probe liner and nozzle washes were collected in the Acetone Wash jar.

The samples were maintained in the custody of Dr. Sundberg and were carried aboard the plane during the return trip to the Laboratory.

Sample Analysis

Upon returning to the laboratory, the filter and loose particulates present were placed in an oven to dry for four hours at 105°C. The material was then transferred to a desicator for 2 hours and weighed on the same analytical balance to the nearest 0.1 mg. by Dr. Sundberg.

The volume of the Acetone Wash was measured and transferred to a tared beaker. The acetone was then evaporated on a low temperature warming plate without boiling. After desication for 2 hours, the beaker was reweighed. Simultaneously a 100 ml acetone blank was evaporated and the residue weight was determined. The net residue weight reported has been adjusted for the acetone blank. These weighings were performed by Particle Data Laboratories personnel.

The total particulates collected was taken as the net residue weight of the Acetone Wash plus the weight gained by the filter.

The used silica gel weighed on a gramatic balance to the nearest 0.5 gm. The weight gain of the silica gel was then added to the volume of liquid water collected in the first three impingers to obtain the total water collected by condensation and adsorption.

Data Handling and Calculations

All mathematical calculations were made according to accepted techniques using EPA equations. Standard conditions of 29.92 in. Hg and 70° F were used. Field calculations were rechecked, and final results for each test run are presented in detail in the Appendix. Complete sample calculations are presented for Test Run #1. All calculations were made using a programmable portable calculator.

Stack Opacity

Stack opacity was monitored continuously by an in-stack optical Transmissometer. Readings were recorded on a strip chart in the control room. In addition, stack opacity observations were made by Messrs. Joe Francis and Dale Murdoch of the Nebraska Department of Environmental Control.

SLUDGE INCINERATOR EMISSION TESTING
UNIT I
FOR
CITY OF OMAHA
PAPILLION CREEK
WATER POLLUTION CONTROL PLANT
JULY, 1978

IV. RESULTS

The results of the testing are summarized in the following tables. Field data sheets and detailed calculations for each test run are presented in the Apprendix.

TABLE I
SUMMARY OF EMISSION TESTING DATA
FOR SLUDGE INCINERATOR UNIT I

Date	7-27-78	7-27-78	7-27-78
Time	09:09-10:14	11:27-12:30	13:33-14:36
Test Run	1	2	3
Stack Gas Data			
Temperature, ^{o}F	115.4	126.7	118.3
Velocity, ft/sec	43.907	44.704	44.836
Gas volume, actual cfm (wet)	25,346	25,806	25,882
Gas Volume, scfh (dry)	1.192×10^6	1.165×10^6	1.196×10^6
Moisture, %	12.1	14.0	13.1
Carbon Dioxide, % (dry)	7.73	8.80	8.47
Oxygen, % (dry)	10.93	9.73	10.60
Carbon Monoxide + Nitrogen, % (dry)	81.34	81.47	80.93
Molecular Weight, (wet)	28.256	28.150	28.230
Sampling Data			
Total Time, min	60	60	60
Volume, scf (dry)	36.512	35.197	36.316
Isokinetic Ratio, %	98.4	97.0	97.6
Solid Particulates			
Amount Collected, mg	45.4	31.8	36.2
Concentration, grains/scf (dry)	0.019	0.014	0.015
Emission Rate, lb/hr	3.268	2.321	2.629
Stack Opacity, %	$\leq$ 5%	$\leq$ 5%	$\leq$ 5%

APPENDIX

CALCULATIONS FOR UNIT #1 DATE 7-27-78 TEST RUN # 1

Dry gas meter volume	V_m = 36.891 ft^3	Particulates collected	M_n = 45.4 mg
Total water collected	V_{lc} = 106.5 ml	Stack area	A = 9.621 ft^2
Absolute stack pressure	P_s = 28.96 in.Hg	Total sampling time	θ = 60 min
Absolute meter pressure	P_m = 29.06 in.Hg	Pitot tube coefficient	C_p = .83
Absolute stack temperature	T_s = 575.4 °R	Average velocity head $(\sqrt{\Delta P})_{avg}$	= .738
Absolute meter temperature	T_m = 520 °R	Nozzle area	A_n = .0002996 ft^2

Volume of sample at standard conditions, dry basis.

$$[17.71]\, V_m \frac{P_m}{T_m} = [17.71]\,(36.891)\,\frac{(29.06)}{520} = V_{mstd} = 36.512\ ft^3$$

Volume of water vapor in sample at standard conditions.

$$[0.0474]\, V_{lc} = [0.0474]\,(106.5) = V_{wstd} = 5.048\ ft^3$$

Proportion of water vapor in gas stream

$$\frac{V_{wstd}}{V_{mstd} + V_{wstd}} = \frac{(5.048)}{(5.048) + (36.512)} = B_{wo} = .121$$

Concentration of particulate matter, dry basis

$$[0.0154]\, \frac{M_n}{V_{mstd}} = [0.0154]\, \frac{(45.4)}{(36.512)} = c_s' = .019\ gr/scf$$

$$[2.205 \times 10^{-6}]\, \frac{M_n}{V_{mstd}} = [2.205 \times 10^{-6}]\, \frac{(45.4)}{(36.512)} = c_s = 2.742 \times 10^{-6}\ lb/scf$$

Dry molecular weight of stack gas

$0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2 + \%CO)$ = 0.44×7.73 = _____

0.32×10.93 = _____

0.28×81.34 = _____ M_d = 29.671

Molecular weight of stack gas, wet basis.

$$M_d\,(1 - B_{wo}) + 18\,B_{wo} = (29.671)(.879) + 18(.121) = M_s = 28.256$$

Stack gas velocity.

$$[85.48]\, C_p\, (\sqrt{\Delta P})_{avg} \sqrt{\frac{T_s}{P_s M_s}} = [85.48](.83)(.738)\sqrt{\frac{(575.4)}{(28.96)(28.256)}} = V_s = 43.907\ ft/sec$$

Volumetric flow rate, dry basis, standard conditions.

$$[63770](1-B_{wo})V_s A \frac{P_s}{T_s} = [63770](.879)(43.907)(9.621)\frac{(28.96)}{(575.4)} \qquad Q_s = 1.192 \times 10^6\ scfh$$

Emission Rate

$$Q_s \times c_s = (2.742 \times 10^{-6})(1.192 \times 10^6) = E.R. = 3.268\ lb/hr$$

Percent of Isokinetic sampling

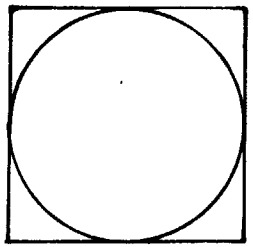
$$\frac{K_1 \left[K_2 V_{lc} + \frac{V_m}{T_m} P_m\right] T_s}{\theta V_s P_s A_n} = \frac{[1.667]\left[(.00267)(106.5) + \frac{(36.891)}{(520)}(29.06)\right](575.4)}{(60)(43.907)(28.96)(.0002996} = I = 98.4\ \%$$

PMM (DEC)

COMPANY OMAHA-PAPILLION
LOCATION #1
DATE 7-27-78
TEST RUN # 1
STACK AREA 9.1-2.1
OPERATOR JRS

AMBIENT TEMPERATURE 80
BAROMETRIC PRESSURE 29.01
ASSUMED MOISTURE, % 10
HEATER BOX SETTING 250°
PROBE HEATER SETTING 250°
FILTER NUMBER

SAMPLE BOX # RED
METER BOX # GREEN
METER ΔH@ 1.07
C FACTOR
PROBE LENGTH 48" SS
NOZZLE DIAMETER 13/64


STACK CROSS SECTION

	TRAVERSE POINT NUMBER	SAMPLING TIME (θ, min)	STATIC PRESSURE (in.H_2O)	STACK TEMP (T_s, °F)	VELOCITY HEAD (Δp)	($\sqrt{\Delta p}$)	ORIFICE METER (ΔH)	DRY GAS METER VOLUME (V_m, ft^3)	DRY GAS METER INLET (T_{mi}, °F)	DRY GAS METER OUTLET (T_{mo}, °F)	BOX TEMP (°F)	PUMP VACUUM (in.Hg)	O2
0907	SW-1	5		120	.50	.707	.62	2165.065	68		230	2.5	12.0
	2	5		115	.55		.69	71.07			230	3.0	12.6
	3	5		120	.20		.25	74.25			230	1.5	11.2
	4	5	-.80	115	.75		.93	76.28			230	4.5	11.4
	5	5		115	1.05		1.32	77.86			230	5.5	11.6
	6	5		120	.85		1.06	84.20			230	4.0	12.0
0944	SE 1	5		120	.50		.62	37.76			255	3.0	11.6
	2	5		115	.50		.62	90.79			255	3.0	12.3
	3	5		110	.10		.12	93.75			265	1.0	13.0
	4	5	-.65	110	.65		.81	95.05			270	4.0	12.1
	5	5		115	.75		.90	98.39			265	4.0	10.7
10/4	6	5		110	.55		.69	201.83			250	3.0	12.5
TOTAL		60				8.853	8.63	2204.96					
AVERAGE			-.05	115.4		.738	+.05	36.541	60				

WATER COLLECTED	IMPINGERS 1	2	3	4
FINAL		272		234.5
INITIAL	←	200	→	200.0
NET H_2O		72		34.5
TOTAL H_2O COLLECTED, ml				206.5

PARTICULATE COLLECTED	FILTER	PROBE WASH
FINAL		
TARE	533.6	
NET GAIN		
TOTAL WEIGHT, mg		

ORSATS TIME	CO_2	O_2	CO	N_2
0905	7.6	11.0		
0955	7.2	11.6		
1005	8.4	10.2		
AVERAGE	7.73	10.93	81	1.34

COMMENTS:

.01 @ 15 in Hg
.015 @ 15

22.

LABORATORY DATA

COMPANY OMAHA - PAPILLION

LOCATION UNIT #1

DATE 7/27/78

TEST RUN # 1

FILTER NUMBER —

AMOUNT OF LIQUID LOST DURING TRANSPORT	0
ACETONE BLANK VOLUME, ml	100
ACETONE WASH VOLUME, ml	270
ACETONE BLANK CONCENTRATION, mg/ml	.026
TOTAL ACETONE WASH BLANK, mg	7.0

WEIGHT OF PARTICULATE COLLECTED

FILTER	FINAL WEIGHT	859.0	
	TARE WEIGHT	- 833.6	
	WEIGHT GAIN		25.4
ACETONE WASH			
	FINAL WEIGHT	49,667.8	
	TARE WEIGHT	- 49,640.8	
	WEIGHT GAIN	27.0	
	ACETONE BLANK	- 7.0	
	NET GAIN		20.0
	TOTAL WEIGHT OF PARTICULATES		45.4 mg

CALCULATIONS FOR UNIT #1 DATE 7-27-78 TEST RUN # 2

Dry gas meter volume	V_m = 35.550 ft^3	Particulates collected	M_n = 31.8 mg
Total water collected	V_{lc} = 120.5 ml	Stack area	A = 9.621 ft^2
Absolute stack pressure	P_s = 28.98 in.Hg	Total sampling time	O = 60 min
Absolute meter pressure	P_m = 29.07 in.Hg	Pitot tube coefficient	C_p = .83
Absolute stack temperature	T_s = 586.7 °R	Average velocity head $(\sqrt{\Delta P})_{avg}$	= .743
Absolute meter temperature	T_m = 520 °R	Nozzle area	A_n = .0002996 ft^2

Volume of sample at standard conditions, dry basis.

$[17.71]\ V_m \frac{P_m}{T_m} = [17.71]\ (\quad)\ \{\quad\} =$ V_{mstd} = 35.197 ft^3

Volume of water vapor in sample at standard conditions.

$[0.0474]\ V_{lc} = [0.0474]\ (\quad) =$ V_{wstd} = 5.712 ft^3

Proportion of water vapor in gas stream

$\frac{V_{wstd}}{V_{mstd} + V_{wstd}} = \frac{(\quad)}{(\quad)+(\quad)} =$ B_{wo} = .140

Concentration of particulate matter, dry basis

$[0.0154]\ \frac{M_n}{V_{mstd}} = [0.0154]\ \{\quad\} =$ c_s' = .014 gr/scf

$[2.205 \times 10^{-6}]\ \frac{M_n}{V_{mstd}} = [2.205 \times 10^{-6}]\ \{\quad\} =$ c_s = 1.992 $\times 10^{-6}$ lb/scf

Dry molecular weight of stack gas

$0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2+\%CO)$ = 0.44 x 8.80 = _____

0.32 x 9.73 = _____

0.28 x 81.47 = _____ M_d = 29.197

Molecular weight of stack gas, wet basis.

$M_d(1 - B_{wo}) + 18\ B_{wo} = (\quad)(\quad) + 18(\quad) =$ M_s = 28.150

Stack gas velocity.

$[85.48]\ C_p\ (\sqrt{\Delta P})_{avg} \sqrt{\frac{T_s}{P_s M_s}} = [85.48](\quad)(\quad)\sqrt{\frac{(\quad)}{(\quad)(\quad)}} =$ V_s = 44.704 ft/sec

Volumetric flow rate, dry basis, standard conditions.

$[63770](1-B_{wo})V_s A \frac{P_s}{T_s} = [63770](\quad)(\quad)(\quad)\{\quad\} =$ Q_s = 1.165 scfh

Emission Rate

$Q_s \times c_s = (\quad)(\quad) =$ E.R. = 2.321 lb/hr ✓

Percent of Isokinetic sampling

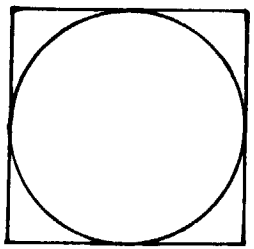
$\frac{K_1 [K_2 V_{lc} + \frac{V_m}{T_m} P_m}{O V_s P_s A_n} = \frac{[1.667]\left[(.00267)(\quad) + \{\quad\}(\quad)\right](\quad)}{(\quad)(\quad)(\quad)(\quad)} =$ I = 97.0 %

OK (DEC)

COMPANY OMAHA – PAPILLION
LOCATION UNIT #1
DATE 7-27-78
TEST RUN # 2
STACK AREA 9.621
OPERATOR SAS EB

AMBIENT TEMPERATURE 100
BAROMETRIC PRESSURE 29.01
ASSUMED MOISTURE, % 14
HEATER BOX SETTING 250°F
PROBE HEATER SETTING 250°F
FILTER NUMBER

SAMPLE BOX # RED
METER BOX # GREEN
METER ΔH@ 1.07
C FACTOR
PROBE LENGTH 48" SS
NOZZLE DIAMETER 15/64


STACK CROSS SECTION

	TRAVERSE POINT NUMBER	SAMPLING TIME (θ, min)	STATIC PRESSURE ($in.H_2O$)	STACK TEMP (T_s, °F)	VELOCITY HEAD (Δp)	VELOCITY HEAD ($\sqrt{\Delta p}$)	ORIFICE METER (ΔH)	DRY GAS METER VOLUME (V_m, ft^3)	DRY GAS METER INLET (T_{mi}, °F)	DRY GAS METER OUTLET (T_{mo}, °F)	BOX TEMP (°F)	PUMP VACUUM (in.Hg)	O_2
1127	SE 1	5		130	.45		.54	2205.662	60		255	2.5	7.6
	2	5		145	.35		.44	08.52			250	2.0	9.3
	3	5		125	.10		.12	10.97			250	1.0	10.2
	4	5	-.50	125	.90	~~.55~~	1.12	12.18			245	5.0	10.1
	5	5		125	.85		1.06	15.84			240	5.0	10.0
	6	5		130	.90		1.12	19.54			235	5.5	10.0
1200	SW 1	5		130	.50		.62	23.48			235	3.0	~~7.2~~
	2	5		125	.50		.62	26.37			255	3.0	~~4.6~~ ?
	3	5		120	.10		.12	29.20			265	1.0	~~4.3~~
	4	5		120	.75		.94	30.19			270	5.0	~~4.9~~
	5	5	-.40	125	1.00		1.25	33.65			265	6.0	~~4.7~~ 10.
~~1230~~	6	5		125	.85		1.06	37.55			260	5.5	10.1
TOTAL		60				5.916	9.01	2041.212					
AVERAGE			-.03	126.7		.743	.75	35.552	60				

WATER COLLECTED	IMPINGERS 1	2	3	4
FINAL	360			220.5
INITIAL	200	—		200
NET H_2O	160			20.5
TOTAL H_2O COLLECTED, ml				120.5

PARTICULATE COLLECTED	FILTER	PROBE WASH
FINAL		
TARE		
NET GAIN		
TOTAL WEIGHT, mg		

~~ORSATS~~ TIME	CO_2	O_2	CO	N_2
1130	8.3	9.3		
1150	9.6	9.6		
1220	8.1	10.8		
AVERAGE	8.80	9.73	81.47	

COMMENTS:
Lk Ck .015 @ 15 in Hg
.01 @ 15 in Hg

25.

LABORATORY DATA

COMPANY OMAHA - PAPILLION

LOCATION UNIT #1

DATE 7/27/78

TEST RUN # 2

FILTER NUMBER —

AMOUNT OF LIQUID LOST DURING TRANSPORT	0
ACETONE BLANK VOLUME, ml	100
ACETONE WASH VOLUME, ml	150
ACETONE BLANK CONCENTRATION, mg/ml	.026
TOTAL ACETONE WASH BLANK, mg	3.9

WEIGHT OF PARTICULATE COLLECTED

FILTER	FINAL WEIGHT	843.9	
	TARE WEIGHT	- 829.0	
	WEIGHT GAIN		14.9
ACETONE WASH			
	FINAL WEIGHT	51,084.2	
	TARE WEIGHT	-51,063.4	
	WEIGHT GAIN	20.8	
	ACETONE BLANK	- 3.9	
	NET GAIN		16.9
	TOTAL WEIGHT OF PARTICULATES		31.8 mg

CALCULATIONS FOR UNIT #1 DATE 7-27-78 TEST RUN # 3

Dry gas meter volume	V_m = 36.706 ft^3	Particulates collected	M_n = 36.2 mg
Total water collected	V_{lc} = 116 ml	Stack area	A = 9.621 ft^2
Absolute stack pressure	P_s = 28.93 in.Hg	Total sampling time	O = 60 min
Absolute meter pressure	P_m = 29.05 in.Hg	Pitot tube coefficient	C_p = .83
Absolute stack temperature	T_s = 578.3 °R	Average velocity head	$(\sqrt{\Delta P})_{avg}$ = .751
Absolute meter temperature	T_m = 520 °R	Nozzle area	A_n = .002996 ft^2

Volume of sample at standard conditions, dry basis.

$$[17.71]\, V_m \frac{P_m}{T_m} = [17.71]\,(\quad)\left(\frac{\quad}{\quad}\right) = \quad V_{mstd} = 36.316\ ft^3$$

Volume of water vapor in sample at standard conditions.

$$[0.0474]\, V_{lc} = [0.0474]\,(\quad) = \quad V_{wstd} = 5.498\ ft^3$$

Proportion of water vapor in gas stream

$$\frac{V_{wstd}}{V_{mstd} + V_{wstd}} = \frac{(\quad)}{(\quad)+(\quad)} = \quad B_{wo} = .131$$

Concentration of particulate matter, dry basis

$$[0.0154]\frac{M_n}{V_{mstd}} = [0.0154]\left(\frac{\quad}{\quad}\right) = \quad c_s' = .015\ gr/scf$$

$$[2.205 \times 10^{-6}]\frac{M_n}{V_{mstd}} = [2.205 \times 10^{-6}]\left(\frac{\quad}{\quad}\right) = \quad c_s = 2.198 \times 10^{-6}\ lb/scf$$

Dry molecular weight of stack gas

$0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2+\%CO)$ = $0.44 \times 8.47 =$ ____

$0.32 \times 10.60 =$ ____

$0.28 \times 80.93 =$ ____ $M_d = 29.779$

Molecular weight of stack gas, wet basis.

$M_d(1 - B_{wo}) + 18\,B_{wo} = (\quad)(\quad) + 18(\quad) = \quad M_s = 28.230$

Stack gas velocity.

$$[85.48]\, C_p\, (\sqrt{\Delta p})_{avg} \sqrt{\frac{T_s}{P_s M_s}} = [85.48](\quad)(\quad)\sqrt{\frac{(\quad)}{(\quad)(\quad)}} = V_s = 44.836\ ft/sec$$

Volumetric flow rate, dry basis, standard conditions.

$$[63770](1-B_{wo})V_s A \frac{P_s}{T_s} = [63770](\quad)(\quad)(\quad)\left(\frac{\quad}{\quad}\right) \quad Q_s = 1.196 \times 10^6\ scfh$$

Emission Rate

$$Q_s \times c_s = (\quad)(\quad) = \quad E.R. = 2.629\ lb/hr$$

Percent of Isokinetic sampling

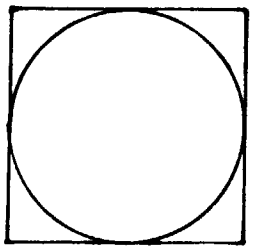
$$\frac{K_1\left[K_2 V_{lc} + \frac{V_m}{T_m} P_m\right]}{O\, V_s\, P_s\, A_n} = \frac{[1.667]\left[(.00267)(\quad) + \left(\frac{\quad}{\quad}\right)(\quad)\right](\quad)}{(\quad)(\quad)(\quad)(\quad)} = I = 97.6\ \%$$

JF (DEC)

COMPANY OMAHA - PAPILLION
LOCATION UNIT #1
DATE 7/27/73
TEST RUN # 3
STACK AREA 9.621
OPERATOR SS EB

AMBIENT TEMPERATURE 100
BAROMETRIC PRESSURE 28.99
ASSUMED MOISTURE, % 15
HEATER BOX SETTING 250
PROBE HEATER SETTING 250
FILTER NUMBER

SAMPLE BOX # RED
METER BOX # GREEN
METER ΔH@ 1.07
C FACTOR
PROBE LENGTH 48" SS
NOZZLE DIAMETER 15/64


STACK CROSS SECTION

	TRAVERSE POINT NUMBER	SAMPLING TIME (θ, min)	STATIC PRESSURE (in.H_2O)	STACK TEMP (T_s, °F)	VELOCITY HEAD (Δp)	($\sqrt{\Delta p}$)	ORIFICE METER (ΔH)	DRY GAS METER VOLUME (V_m, ft^3)	DRY GAS METER INLET (T_{mi}, °F)	DRY GAS METER OUTLET (T_{mo}, °F)	BOX TEMP (°F)	PUMP VACUUM (in.Hg)	O_2
1333	SW 1	5		115	.50		.62	2241.547	60	—	245	3.0	10.9
	2	5		120	.50		.62	44.50			240	3.0	11.1
	3	5		120	.25		.31	47.41			235	1.5	12.0
	4	5		115	.75		.94	49.56			250	4.0	12.1
	5	5		115	.95		1.19	52.82			230	5.0	11.6
	6	5	-.45	115	.80		1.00	57.00			250	4.5	12.2
1406	SE 1	5		110	.45		.56	60.61			270	3.0	12.8
	2	5		115	.45		.56	63.55			270	3.0	11.6
	3	5		120	.10		.12	66.06			270	1.0	10.3
	4	5	-1.05	125	.90		1.12	67.40			270	6.0	10.0
	5	5		125	.85		1.06	71.20			270	5.5	10.7
1436	6	5		125	.70		.89	74.84			265	5.0	10.5
TOTAL		60					5.99	2278.253					
AVERAGE			-.06	118.5		.751	+.06	36.706	60				

WATER COLLECTED	IMPINGERS 1	2	3	4
FINAL		505		208
INITIAL	—	200		200
NET H_2O		168		8
TOTAL H_2O COLLECTED, ml		116		

PARTICULATE COLLECTED	FILTER	PROBE WASH
FINAL		
TARE		
NET GAIN		
TOTAL WEIGHT, mg		

ORSATS TIME	CO_2	O_2	CO	N_2
1355	9.0	10.0		
1355	9.2	9.6		
1410	7.2	12.2		
AVERAGE	8.47	10.60	8	80.93

COMMENTS:
Leak Ck .015 @ 15 in Hg
Leak Ck .01 @ 15

28.

LABORATORY DATA

COMPANY OMAHA - PAPILLION

LOCATION UNIT #1

DATE 7-27-78

TEST RUN # 3

FILTER NUMBER —

AMOUNT OF LIQUID LOST DURING TRANSPORT	0
ACETONE BLANK VOLUME, ml	100
ACETONE WASH VOLUME, ml	215
ACETONE BLANK CONCENTRATION, mg/ml	.026
TOTAL ACETONE WASH BLANK, mg	5.6

WEIGHT OF PARTICULATE COLLECTED

FILTER	FINAL WEIGHT	867.2	
	TARE WEIGHT	- 848.8	
	WEIGHT GAIN		18.4
ACETONE WASH			
	FINAL WEIGHT	48,532.5	
	TARE WEIGHT	- 48,509.1	
	WEIGHT GAIN	23.4	
	ACETONE BLANK	- 5.6	
	NET GAIN		17.8
	TOTAL WEIGHT OF PARTICULATES		36.2 mg

PITOT TUBE CALIBRATION

Pitot tube identification number 4' SS w/PROBE w/1/4 Nozz
Date 4-25-78 Calibrated by S.E. SUNDBERG

1. Face opening alignment OK? OK
2. External tubing diameter D_t = .250 in.
3. Base-to-opening plane distances P_A = .4375 in.
   P_B = .4375 in.
4. Pitot-nozzle distance X = .875 in.
5. Pitot-probe sheath distance Y = 2.25 in.
6. Pitot-thermocouple distance Z = 1.31 in.

"A" SIDE CALIBRATION

RUN NO.	Δp_{std} in.H_2O	$\Delta p_{(s)}$ in.H_2O	$\Delta p_{std}/\Delta p_{(s)}$	$C_{p(s)}$	DEVIATION $\lvert C_{p(s)} - \bar{C}_p(A) \rvert$
1	.66	.93	.7097	.834	.006
2	.645	.94	.6861	.820	.008
3	.67	.95	.7046	.831	.003
			$\bar{C}_p(A)$ =	.828	σ = .006

"B" SIDE CALIBRATION

RUN NO.	Δp_{std} in.H_2O	$\Delta p_{(s)}$ in.H_2O	$\Delta p_{std}/\Delta p_{(s)}$	$C_{p(s)}$	DEVIATION $\lvert C_{p(s)} - \bar{C}_p(B) \rvert$
1	.63	.90	.6995	.828	.007
2	.66	.93	.7097	.834	.001
3	.68	.94	.7234	.842	.007
			$\bar{C}_p(B)$ =	.835	σ = .005

$$C_{p(s)} = 0.99 \sqrt{\frac{\Delta p_{std}}{\Delta p_{(s)}}} \qquad \sigma\,(\text{A or B}) = \frac{\sum^{3} \lvert C_{p(s)} - \bar{C}_p(\text{A or B}) \rvert}{3}$$

TEMP. – ICE WATER = 30°F
BOILING WATER = 210°F
AIR TEMP = 70°F

DRY GAS METER CALIBRATION

METER BOX IDENTIFICATION GREEN METER # —

DATE 4-25-78 CALIBRATED BY S. E. SUNDBERG

BAROMETRIC PRESSURE, P_b = 28.95 in. Hg

	DRY GAS METER					WET TEST METER		
	ORIFICE SETTING ΔH in. H_2O	TIME θ min.	GAS VOLUME V_d ft^3	METER TEMP. T_d ^oR	METER PRES. P_d in.Hg	GAS VOLUME V_w ft^3	METER TEMP. T_w ^oR	METER PRES. P_w in.Hg
.51	0.5	5.00	2.631	520	28.99	2.666	528	28.87
1.02	1.0	5.00	3.560	520	29.02	3.673	528	28.81
1.50	1.5	5.00	4.403	520	29.06	4.436	528	28.76
1.98	2.0	5.00	4.989	520	29.10	5.087	528	28.74
2.96	3.0	5.00	6.537	520	29.17	6.748	528	28.67

MANOMETER MAGNEHELIC

CALCULATIONS

ΔH	γ $\frac{V_w P_w T_d}{V_d P_d T_w}$ =	$\Delta H_@$ $\frac{0.0317\ \Delta H}{P_w T_d}\left[\frac{T_w\ \theta}{V_w}\right]^2$ =
0.5	.994	1.035
1.0	1.009	1.093
1.5	.982	1.126
2.0	.992	1.146
3.0	.999	0.976
AVERAGE	.995	1.075

NOTE MANOMETER VS. MAGNEHELIC CALIBRATION

NOZZLE CALIBRATION - 7-18-78

BY S.E. SUNDBERG

#1	15/64
#2	15/64
#3	15/64

AVG $\overline{15/64}$ = .2344 in

area = .0002996 sq. ft.

SOURCE TESTING

Source testing is the set of procedures by which an investigator can estimate the emissions from a particular emission source. It involves representative sampling of the parameters of interest. For any given contaminant it is necessary only to know the rate of gas flow and the concentration of the contaminant to determine the emission rate.

Gas Flow

Stack gas velocity is usually determined with a device called a pitot tube which when connected to a manometer measures the velocity pressure of the moving gas. The equation for the stack gas velocity is:

$$V_s = 85.48 \; C_p \; (\sqrt{\Delta P})_{avg} \sqrt{\frac{T_s}{P_s \; M_s}}$$

where: V_s = Stack gas velocity, feet per second (ft/sec).

C_p = Pitot tube coefficient for actual stack conds.

$(\sqrt{\Delta P})_{avg}$ = Average of square roots of velocity pressures (also called average velocity head).

T_s = Absolute stack gas temperature, ^oR ($^oR = {}^oF + 460$).

P_s = Absolute stack gas pressure, inches of Hg.

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

The molecular weight of the stack gas is determined from knowledge of its gaseous composition using the equation:

$$M_s = (1-B_{wo})(.44(\%CO_2) + .32(\%O_2) + .28(\%CO + \%N_2)) + 18\,B_{wo}$$

where: B_{wo} = Proportion by volume of water vapor in the gas stream, dimensionless.

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

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

$\%CO$ = Percent carbon monoxide by volume, dry basis.

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

.44 = Molecular weight of CO_2 divided by 100.

.32 = Molecular weight of O_2 divided by 100.

.28 = Molecular weight of CO and N_2 divided by 100.

18 = Molecular weight of water.

For stacks serving combustion processes the CO_2, O_2 and CO are measured with an Orsat type gas analyzer. The N_2 is taken to be the remaining fraction. For non-combustion processes, CO_2 and CO are taken to be 0, O_2 = 21% and N_2 = 79%.

The proportion of water vapor by volume may be measured using a psychrometer, or by condensation and/or adsorption by silica gel (see below) or it may be estimated from the vapor pressure for gas streams that are saturated with water.

The volumetric flow rate is determined by multiplying the velocity by the cross-sectional area of the stack. In most cases, the volumetric flow rate is adjusted to standard conditions of temperature (70°F) and pressure (29.92 in.Hg.) using the equation:

$$Q_s = 3600(1-B_{wo})\ V_s\ A \left[\frac{T_{std}}{T_s}\right]\left[\frac{P_s}{P_{std}}\right]$$

where: Q_s = Volumetric flow rate, dry basis, standard conditions, ft^3/hr.

A = Cross-sectional area of the stack, ft^2.

T_{std} = Absolute temperature at standard conditions, 530°R.

P_{std} = Absolute pressure at standard conditions, 29.92 inches Hg.

and other terms are as defined previously.

Contaminant Concentration

The concentration of a contaminant in a gas stream is usually determined by isolating the contaminant present in a representative gas sample of known volume.

In order to obtain a representative sample of the stack gas, a hollow probe is introduced into the stack, the nozzle opening is directed into the gas stream, and a composite sample is removed from each of several points. For particulates it is necessary that the velocity be equal to the velocity in the nozzle, or in other words the sampling rate be as nearly isokinetic as possible. This is because large particles tend to travel in a straight line and are less likely to be affected by flow disturbances, while small particles tend to follow the flow lines. Thus, varying too much from isokinetic will tend to cause bias with respect to certain particle sizes and will therefore give erroneous results. Generally, variations within the range of 90-100% of isokinetic is acceptable.

Sampling for gaseous contaminants need not be isokinetic but should be in proportion to the velocity at the sampling points.

Isolation of the contaminant is accomplished in one of many ways. A filter of some sort (ceramic or glass fiber depending on stack conditions and particulate characteristics) it usually used to collect particulate matter. Various chemical solutions are used to absorb other contaminants (e.g. 3% hydrogen peroxide will absorb sulfur dioxide, etc.) The total amount of the contaminant is then determined.

The total volume of the gas sample is determined using a displacement type dry gas meter. Since metering conditions tend to vary, it is necessary to measure the meter temperature and pressure in order to adjust the volume to standard conditions. To protect the metering system from moisture, the gas sample is passed through a series of condensers or impingers to remove all or most of the water vapor present. Furthermore by measuring the amount of water collected, the moisture content of the stack gas can be estimated by the following equation:

$$B_{wo} = \frac{V_{w_{std}}}{V_{w_{std}} + V_{m_{std}}}$$

where: B_{wo} = Proportion by volume of water vapor in the gas stream, dimensionless.

$V_{w_{std}}$ = Volume of water in the gas sample (standard conditions), ft^3.

$V_{m_{std}}$ = Volume of gas sample through the dry gas meter (standard conditions), ft^3.

For the above equation:

$$V_{m_{std}} = V_m \left[\frac{T_{std}}{T_m}\right] \left[\frac{P_m}{P_{std}}\right]$$

where: V_m = Volume of gas sample through the dry gas meter (meter conditions), ft^3.

T_m = Average absolute gas meter temperature, ^oR.

P_m = Average absolute meter pressure, inches Hg.

and: $V_{w_{std}} = 0.0474\ V_{l_c}$

where: V_{l_c} = Total volume of water collected in condensers, ml.

The concentration of material is calculated from the equation:

$$c'_s = 0.0154\ \frac{M_n}{V_{m_{std}}}$$

where: c'_s = Concentration of the contaminant in the stack gas, grains/scf, dry basis.

M_n = Total amount of contaminant collected, milligrams.

The concentrations of certain gaseous components of a gas stream are most often reported in parts per million by volume, ppm (vol). This then reports the number of cubic feet of the contaminant present in 1,000,000 cubic feet of gas. Conversion from ppm (vol) to pounds made use of the fact that at standard conditions a pound-mole of a gas occupies 385.1 ft^3.

Emission Rates

The emission rate of the contaminant is calculated from the equation:

$$c'_s Q_s = (2.205 \times 10^{-6}) \frac{M_n}{V_{m_{std}}} Q_s$$

where: $c'_s Q_s$ = Emission rate, lb/hr.

NOMENCLATURE

The following is a partial list of abbreviations and nomenclature used in preparing this report. Other terms used are defined in the text of in the preceding Source Testing section.

ACFM = Actual cubic feet per minute at stack conditions, wet basis (cfm(wet)).
CU-FT = Actual cubic feet at specified conditions (ft^3).
DSCF = Cubic feet at standard conditions, dry (scf(dry)).
DSCFH = Cubic feet at standard conditions, dry, per hour (scfh (dry)). May be written in exponential form, e.g., 534,774 = .534774 x 10^6.
F = Degrees Fahrenheit (^oF).
FT/SEC = Feet per second (ft/sec).
GR = Grains (gr.)(1 pound = 7000 grains).
IN,HG = Inches of mercury (in.Hg or inches Hg).
IN,H2O = Inches of water (in.H_2O og inches H_2O).
LB/HR = Pounds per hour (lb/hr).
MG = Milligrams (mg).
MIN = Minutes (min).
ML = Milliliters (ml).
R = Degrees Rankine (^oR).
SQ-FT = Square feet (ft^2).
WSCFM = Cubic feet at standard conditions, wet basis, per minute (scfm (wet)).

Omaha Testing
Laboratories, Inc.
2917 DOUGLAS STREET/OMAHA, NE 68131
(402)341-5181

22 August 1978

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PROCESS ENGINEERING

Report Number
C 8694 (9)

37

Report made for Travelers Indemnity Company
c/o Surety Services Corp.
175 West Jackson Blvd., Suite A-1704
Chicago, Illinois 60604

Report on Sludge, Grease, Grit and Screenings, Scrubber Effluent and Nonpotable Water sampled by us on 26 and 27 July 1978 at the Papillion Creek Water Pollution Control Plant.

Test Results on Sludge Cake:

Sludge Identification	Total Solids to 103°C % by Weight	Volatile Solids to 600°C, 1 hr., % of Total Solids	Moisture, % by Weight	BTU's per lb. of Volatile Solids	Calcium, % of Ash
North 9:00 hrs. 7-26-78	39.2	42.1	60.8	12737	6.6
South 9:00 hrs. 7-26-78	35.5	45.4	64.5	12818	5.7
North 10:00 hrs. 7-26-78	35.4	43.5	64.6	13390	6.2
South 10:00 hrs. 7-26-78	31.9	45.1	68.1	13133	7.6
North 11:00 hrs. 7-26-78	36.4	44.1	63.6	12589	5.6
South 11:00 hrs. 7-26-78	33.4	46.6	66.6	14060	5.6
North 12:00 hrs. 7-26-78	37.6	46.3	62.4	12860	5.5

Travelers Indemnity Company
c/o Surety Services Corp.
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Test Results on Sludge Cake: (continued)

Sludge Identification	Total Solids to 103°C, % by Weight	Volatile Solids to 600°C, 1 hr., % of Total Solids	Moisture, % by Weight	BTU's per lb. of Volatile Solids	Calcium, % of Ash
South 12:00 hrs. 7-26-78	31.6	48.0	68.4	12785	6.6
North 13:10 hrs. 7-26-78	33.5	48.1	66.5	12855	5.6
South 13:10 hrs. 7-26-78	32.7	47.5	67.3	12751	5.6
North 14:00 hrs. 7-26-78	34.6	47.3	65.4	11978	5.3
South 14:00 hrs. 7-26-78	32.5	45.9	67.5	12246	5.1
North 15:00 hrs. 7-26-78	33.3	47.3	66.7	12440	5.7
South 15:00 hrs. 7-26-78	31.5	47.6	68.5	13610	5.4
North 16:00 hrs. 7-26-78	36.3	46.1	63.7	13609	6.2
South 16:00 hrs. 7-26-78	29.5	48.0	70.5	13297	7.3

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Test Results on Sludge Cake: (continued)

Sludge Identification	Total Solids to 103°C, % by Weight	Volatile Solids to 600°C, 1 hr., % of Total Solids	Moisture, % by Weight	BTU's per lb. of Volatile Solids	Calcium, % of Ash
North 17:00 hrs. 7-26-78	33.2	46.5	66.8	13294	5.9
South 17:00 hrs. 7-26-78	32.6	47.9	67.4	13146	5.5
North 18:00 hrs. 7-26-78	31.1	50.0	68.9	12443	5.6
South 18:00 hrs. 7-26-78	36.9	49.7	63.1	11937	5.1
North 19:00 hrs. 7-26-78	33.3	48.1	66.7	12170	6.1
South 19:00 hrs. 7-26-78	31.3	50.2	68.7	12264	5.8
North 20:00 hrs. 7-26-78	32.7	45.6	67.3	13861	5.1
South 20:00 hrs. 7-26-78	32.3	44.7	67.7	14043	5.8
North 21:00 hrs. 7-26-78	36.9	46.8	63.1	12541	5.5

Travelers Indemnity Company
c/o Surety Services Corp.
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Test Results on Sludge Cake: (continued)

Sludge Identification	Total Solids to 103°C, % by Weight	Volatile Solids to 600°C, 1 hr., % of Total Solids	Moisture, % by Weight	BTU's per lb. of Volatile Solids	Calcium, % of Ash
South 21:00 hrs. 7-26-78	30.5	49.0	69.5	11636	7.0
North 22:00 hrs. 7-26-78	36.1	48.8	63.9	12830	7.6
South 22:00 hrs. 7-26-78	30.5	50.8	69.5	12329	6.1
North 11:00 hrs. 7-27-78	29.2	46.5	70.8	13770	5.5
South 11:00 hrs. 7-27-78	28.6	49.7	71.4	13523	6.5
North 12:00 hrs. 7-27-78	28.6	49.0	71.4	13058	6.0
South 12:00 hrs. 7-27-78	28.3	48.8	71.7	13033	5.9
North 13:00 hrs. 7-27-78	29.3	51.5	70.7	12798	6.9

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2917 DOUGLAS STREET / OMAHA, NEBRASKA 68131

Travelers Indemnity Company
c/o Surety Services Corp.
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Test Results on Sludge Cake: (continued)

Sludge Identification	Total Solids to 103°C, % by Weight	Volatile Solids to 600°C, 1 hr., % of Total Solids	Moisture, % by Weight	BTU's per lb. of Volatile Solids	Calcium, % of Ash
South 13:00 hrs. 7-27-78	30.8	52.4	69.2	12430	6.6
North 14:00 hrs. 7-27-78	31.6	50.6	68.4	13592	6.3
South 14:00 hrs. 7-27-78	29.5	51.4	70.5	13156	4.6
North 15:00 hrs. 7-27-78	31.3	49.9	68.7	13275	5.7
South 15:00 hrs. 7-27-78	32.2	51.9	67.8	12148	6.1
North 16:00 hrs. 7-27-78	32.0	52.1	68.0	12645	6.2
South 16:00 hrs. 7-27-78	30.8	52.6	69.2	12061	5.9
North 17:00 hrs. 7-27-78	32.7	49.5	67.3	13113	6.4
South 17:00 hrs. 7-27-78	32.2	52.5	67.8	13325	6.7.

Travelers Indemnity Company
c/o Surety Services Corp.
22 August 1978
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Test Results on Grease:

Grease Identification	Total Solids to 103°C, % by Weight	Volatile Solids to 600°C, 1 hr., % of Total Solids	Moisture, % by Weight	BTU's per lb. of Volatile Solids
Pump 1 15:00 hrs. 7-26-78	70.8	91.4	29.2	17327
Pump 1 16:05 hrs. 7-26-78	80.3	92.7	19.7	18107
Pump 1 17:05 hrs. 7-26-78	81.7	92.4	18.3	17814
Pump 1 18:05 hrs. 7-26-78	78.9	91.8	21.1	17590
Pump 1 19:05 hrs. 7-26-78	77.4	93.1	22.6	16985
Pump 1 20:05 hrs. 7-26-78	68.7	91.7	31.3	18041
Pump 1 21:05 hrs. 7-26-78	74.2	91.8	25.8	17874.

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Test Results on Grit and Screenings:

Sample Identification	Total Solids to 103°C, % by Weight	Volatile Solids to 600°C, 1 hr., % of Total Solids	Moisture, % by Weight	BTU's per lb. of Volatile Solids	Ash, % by Weight of Total Sample
Grit 7-26-78					
9:20 hrs.					
14:30 hrs.					
15:25 hrs.					
19:30 hrs.	50.1	19.1	49.9	11720	40.5
21:30 hrs.					
Screenings 7-26-78					
14:40 hrs.					
15:20 hrs.					
19:30 hrs.					
Grit 7-27-78					
11:30 hrs.					
Screenings 7-27-78					
10:00 hrs,					
11:30 hrs.	29.9	67.7	70.1	7711	9.7.
12:00 hrs.					
13:45 hrs.					
15:00 hrs.					
16:00 hrs.					

Tests made on composite of grit and screenings.

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Test Results on Scrubber Effluent:

Sample Identification	Total Solids, grams/liter	Volatile Solids, % by Weight of Total Solids
9:40 hrs. 7-26-78	16.0	1.2
11:40 hrs. 7-26-78	18.6	1.1
13:40 hrs. 7-26-78	12.5	1.1
15:40 hrs. 7-26-78	4.8	1.5
17:40 hrs. 7-26-78	9.2	1.2
19:40 hrs. 7-26-78	11.2	1.0
21:40 hrs. 7-26-78	8.0	1.3
14:30 hrs. 7-27-78	2.7	2.0
15:30 hrs. 7-27-78	0.9	3.9
16:30 hrs. 7-27-78	5.5	1.6
17:00 hrs. 7-27-78	7.4	2.0.

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Test Results on Nonpotable Water:

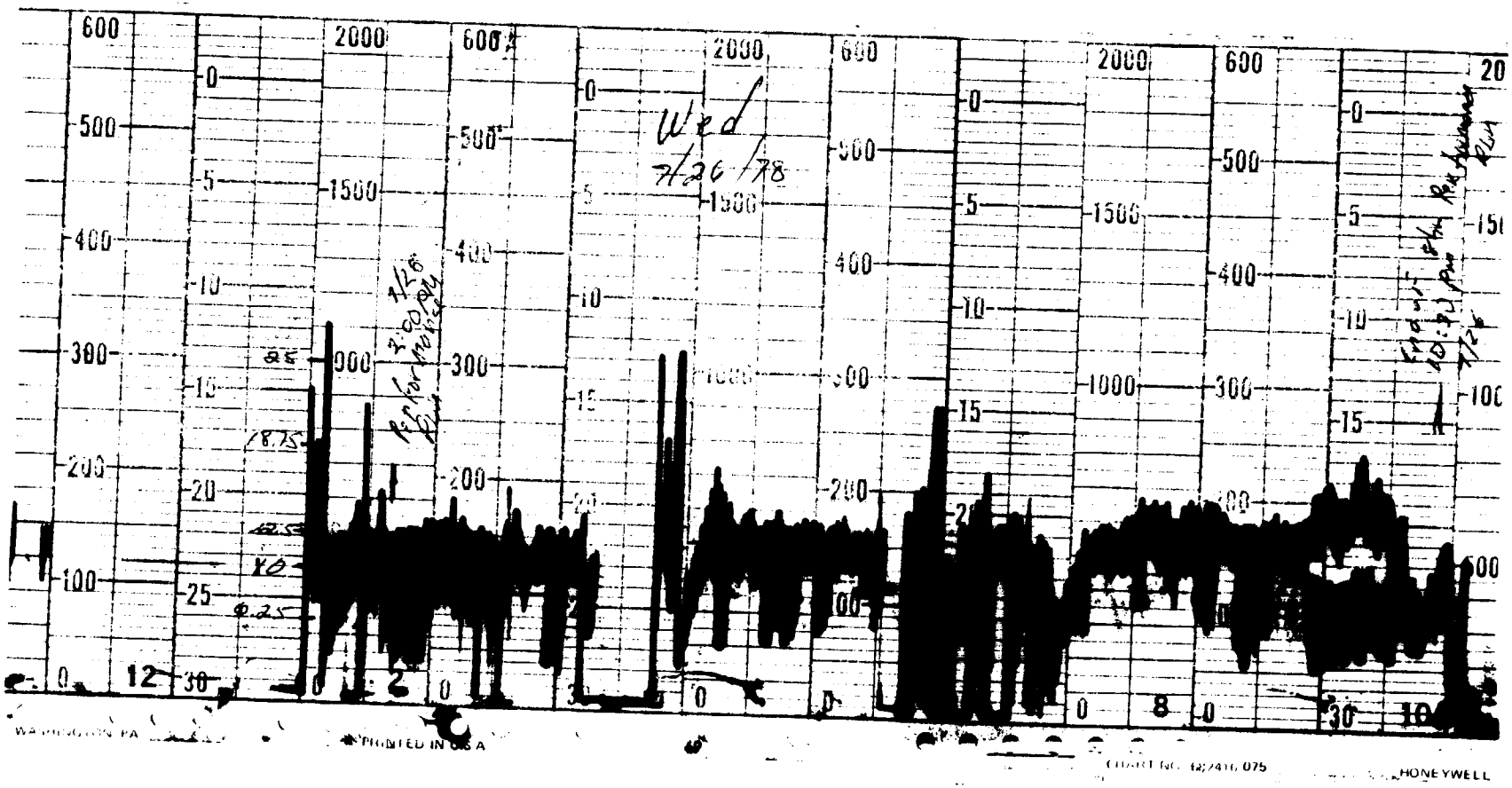
Sample Identification	Total Solids to 103°C, grams/liter	Volatile Solids to 600°C, 1 hr., % of Total Solids
Nonpotable Water 9:05 hrs. 7-26-78	5.1	5.7
Hot Water Tub 11:00 hrs. 7-27-78	7.4	4.6
Hot Water Tub 15:00 hrs. 7-27-78	3.8	7.6.

OMAHA TESTING LABORATORIES, INC.

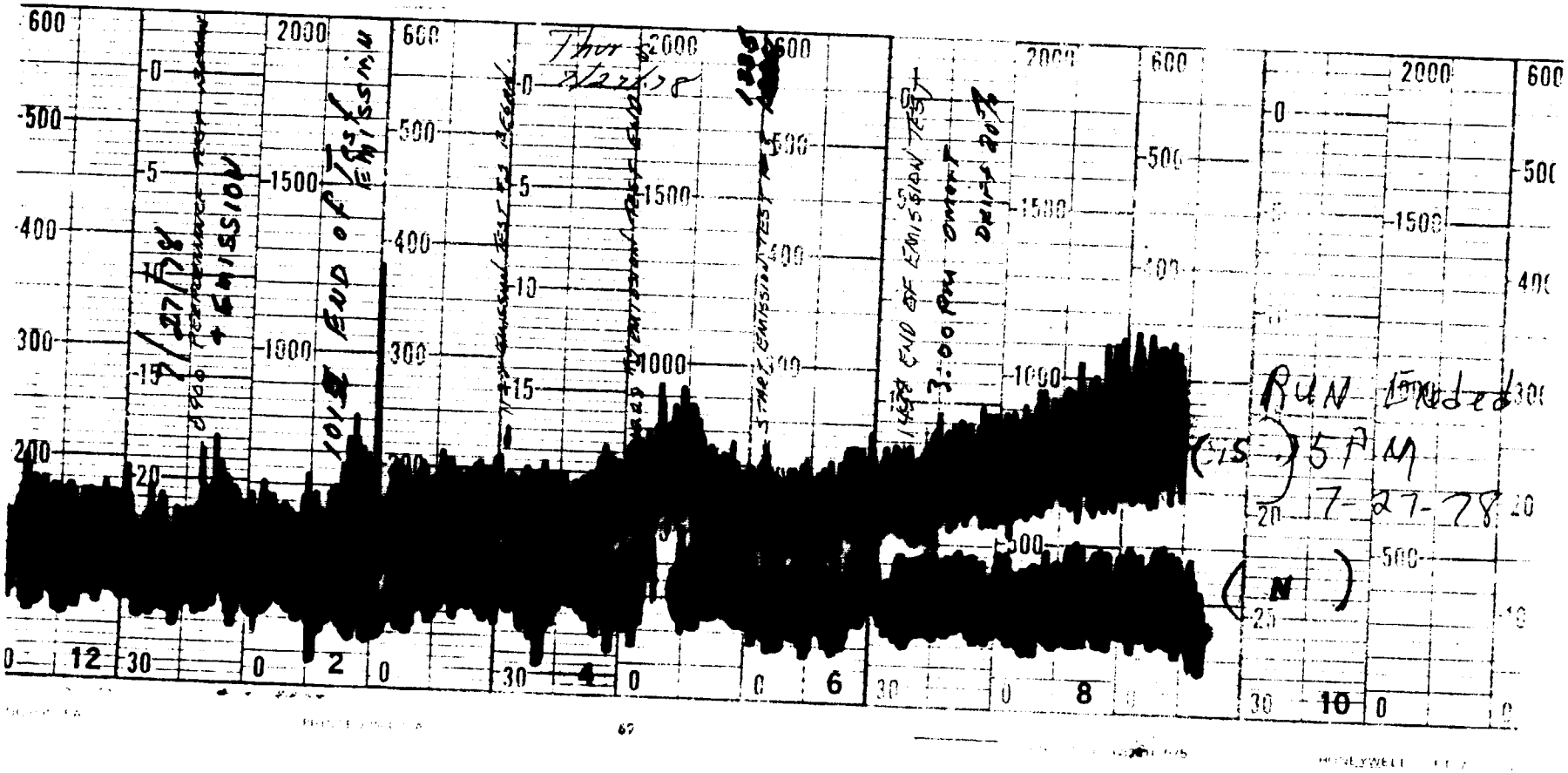
L. R. Mertz
Executive Vice President

LRM/ee

O: File
2xc: Travelers Indemnity Co.
c/o Surety Services Corp.
1xc: Envirotech
Attn: Mr. Dan Marlowe



Omaha, NEBRASKA
SLUDGE FEED RATES, lbs/hr
July 26, 1978



OMAHA, NEBRASKA
SLUDGE FEED RATES
July 27, 1978

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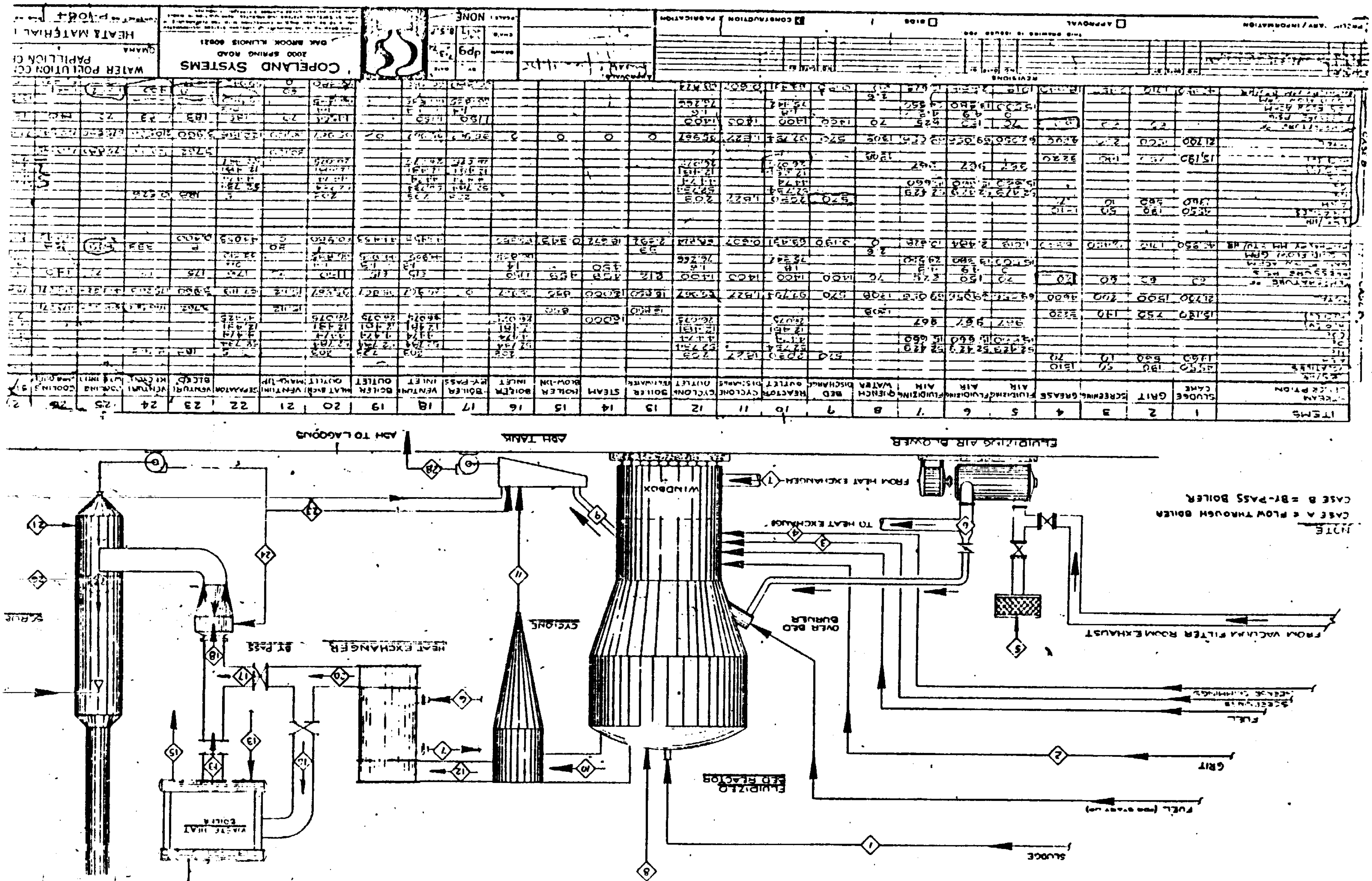
FLUIDIZED BED REACTOR
WINDBOX
OVER BED BURNER
CYCLONE
HEAT EXCHANGER
BY PASS
WASTE HEAT BOILER
SCRUB
ASH TANK
ASH TO LAGOONS
FLUIDIZING AIR BLOWER
TO HEAT EXCHANGER
FROM HEAT EXCHANGER
SLUDGE
FUEL (FOR START UP)
GRIT
FUEL
SCREENINGS
GREASE SKIMMINGS
FROM VACUUM FILTER ROOM EXHAUST
NOTE
CASE A = FLOW THROUGH BOILER
CASE B = BY-PASS BOILER
ITEMS
STREAM DESCRIPTION
SLUDGE CAKE
GRIT
SCREENING
GREASE
FLUIDIZING AIR
QUENCH WATER
BED DISCHARGE
REACTOR OUTLET
CYCLONE DISCHARGE
CYCLONE OUTLET
BOILER FEEDWATER
STEAM
BOILER BLOW-DN
BOILER INLET
BOILER BY-PASS
VENTURI INLET
BOILER OUTLET
HEAT EXCH. OUTLET
VENTURI MAKE-UP
SEPARATOR
VENTURI BLEED
COPELAND SYSTEMS
2000 SPRING ROAD
OAK BROOK, ILLINOIS 60521
WATER POLLUTION CONTROL
PAPILLION
OMAHA
HEAT & MATERIAL BALANCE
APPROVAL
BIDS
CONSTRUCTION
FABRICATION
REVISIONS
NONE

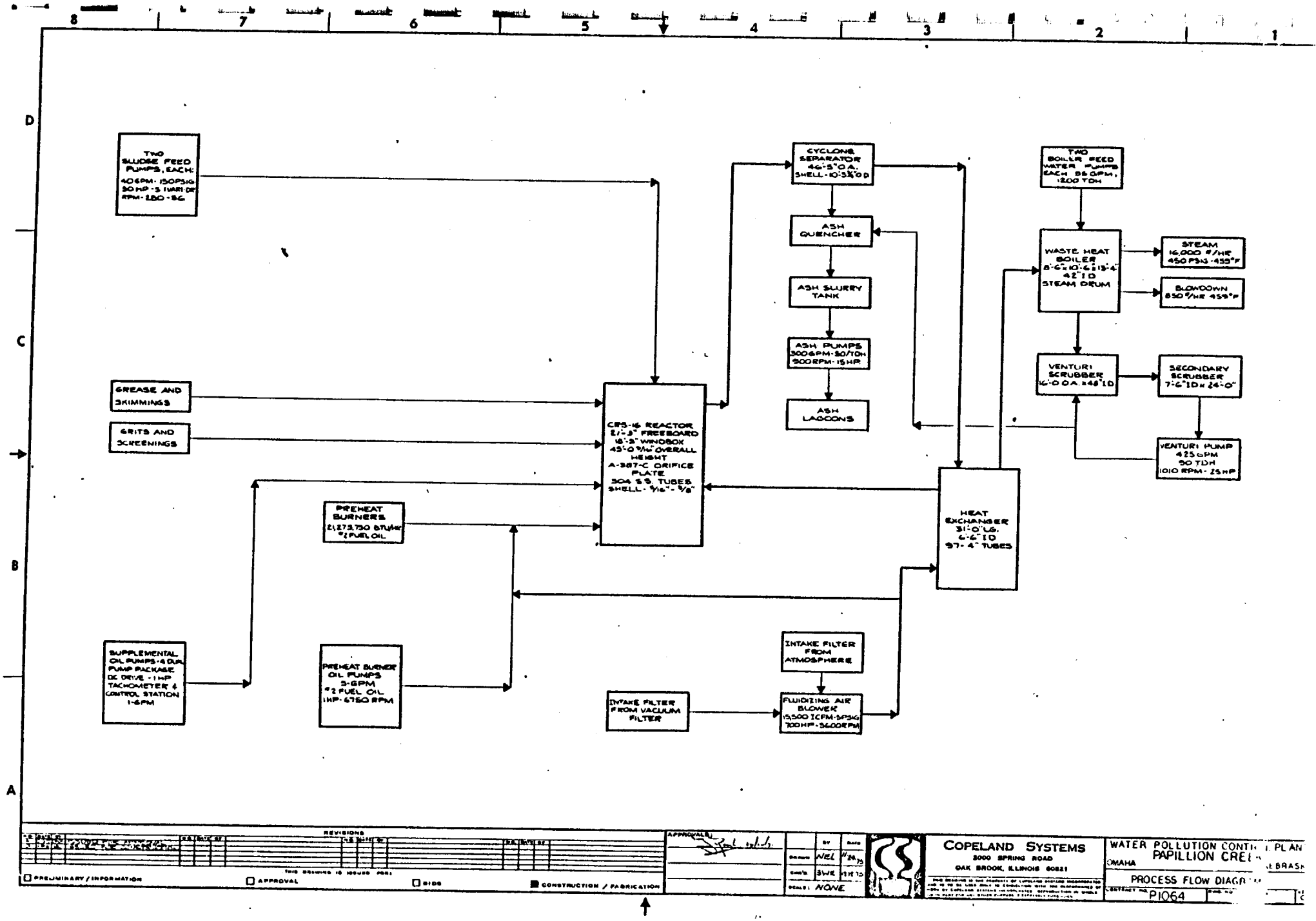

TABLE NO. I

DATE	TIME	SLUDGE FEED LBS/HR NORTH FILTER #2	SLUDGE FEED LBS/HR SOUTH FILTER #1	TOTAL FILTER CAKE LBS/HR WET BASIS	TOTAL FILTER CAKE LBS/HR DRY BASIS	GRIT LBS/HR WET BASIS	GRIT LBS/HR DRY BASIS	SCREENINGS LBS/HR WET BASIS	SCREENINGS LBS/HR DRY BASIS	GREASE WET BASIS	GREASE DRY BASIS	FUEL OIL GPH	POWER KW/HR	EMISSION RUN
7-26	2:00PM	--	--	--										
	3:00PM	8240	9350	17590	5699	1200	480			2752	2100	35.	450	
	4:00PM	4350	4550	8900[1]	2928	800	320					38.	400	
	5:00PM	9610	13150	22760	7488					4103	3131	40.	600	
	6:00PM	6908	7690	14598	4963					2532	1932	19.	500	
	7:00PM	4742	10390	15132	4888							193[3]	550	
	8:00PM	9155	11850	21005	6827					2532	1932	60.	475	
	9:00PM	9155	11850	21005	7079					2532	1932	38.	475	
	10:PM	8030	12950	20980	6986								550	
7-27	9:00AM	--	--	--									500 AVE.	
	10:AM	8130	11690	19820	5728	900	360	150	60			40.	550	1st
	11:AM	5860	10750	16610	4800	2200	880	350	140			28.	500	
	12:AM	9150	15600	24750	7054	2400	960	500	200			35.	500	2nd
	1:00PM	7820	14400	22220	6682	400	160	500	200			37.	550	2nd
	2:00PM	8290	15700	23990	7341	1400	560	1150	460			22.	550	3rd
	3:00PM	7680	14400	22080	7021	--		1350	540			41.	500	3rd
	4:00PM	8110	18200(15167[2])	26310 (23277[2])	7309	--		300	120			40.	550	
	5:00PM	8530	21350(17792[2])	29880 (26322[2])	8554	--						25.	450	
				22385 AVE. (8 hrs)								35 AVE.	518.8 AVE.	

NOTES:

1. System shut down for 25 min. due to air compressors K.O.
2. Feed rate adjusted due to 20% Ohmart drift.
3. Upset conditions occurring.

509.4 KW ave. for 16 hrs - 8.4 KW panel power = 501K

50

SAMPLE ANALYSIS RESULTS - PERFORMANCE TEST - TABLE NO. II

TIME	% TOTAL SOLIDS		% VOLATILE SOLIDS		H.V. BTU/LB V.S.		SCRUBBER ASH
	NORTH	SOUTH	NORTH	SOUTH	NORTH	SOUTH	% VOLATILE SOLID
7/26 11:00 AM	36.4	33.4	44.1	46.6	--	--	
12:00 AM	37.6	31.6	46.3	48.0	--	12,785	1.1
1:00 PM	33.5	32.7	48.1	47.5	12,855	12,751	1.1
2:00 PM	34.6	32.5	47.3	45.9	--	--	
3:00 PM	33.3	31.5	47.3	47.6	--	--	
4:00 PM	36.3	29.5	46.1	48.5	13,609	13,297	
5:00 PM	33.2	32.6	46.5	47.9	13,294	13,146	1.2
6:00 PM	31.1	36.9	50.0	49.7	12,443	--	
7:00 PM	33.3	31.3	48.1	50.2	--	--	1.0
8:00 PM	32.7	32.3	45.6	44.7	13,861	14,043	
9:00 PM	36.9	30.5	46.8	49.0	--	--	
10:00 PM	36.1	30.5	48.8	50.8	12,830	12,329	
7/27 11:00 AM	29.2	28.6	46.5	49.7	13,770	13,523	
12:00 AM	28.6	28.3	49.0	48.8	13,058	13,033	
1:00 PM	29.3	30.8	51.5	52.4	12,798	12,430	
2:00 PM	31.6	29.5	50.6	51.4	13,592	13,156	2.0
3:00 PM	31.3	32.2	49.9	51.9	13,275	12,148	3.9
4:00 PM	32.0	30.8	52.1	52.6	12,645	12,061	1.6
5:00 PM	32.7	32.2	49.5	52.5	13,113	13,325	2.0

ENVIROTECH BSP

SLUDGE FEED RATES - TABLE III

TIME	TOTAL FILTER CAKE LBS/HR	TOTAL SOLIDS LBS/HR	VOLATILE SOLIDS LBS/HR	ASH LBS/HR
7/26				
3:00 PM	17590	5699	2707	2992
4:00 PM	8900	2928	1385	1543
5:00 PM	22760	7488	3534	3954
6:00 PM	14598	4963	2476	2487
7:00 PM	15132	4888	2405	2483
8:00 PM	21005	6827	3079	3748
9:00 PM	21005	7079	3391	3688
10:00 PM	20980	6986	3479	3507
7/27				
9:00 AM	--	--		
10:00 AM	19820	5728	2755	2973
11:00 AM	16610	4800	2309	2491
12:00 PM	24750	7054	3449	3605
1:00 PM	22220	6682	3475	3207
2:00 PM	23990	7341	3744	3597
3:00 PM	22080	7021	3574	3447
4:00 PM	23277	7309	3823	3486
5:00 PM	26322	8554	4363	4191
Performance Test lbs/hr. ave., (8 hours)	22384	6811	3436	3375
Design specs., lbs/hr	21700	6510	4550	1960

DATE: 7-26-78

INCINERATOR PERFORMANCE DATA

OMAHA PAPILLON CREEK PLANT

SIGNATURE: J E Sage

REACTOR NUMBER: #1

S N

				SLUDGE CAKE			FUEL OIL		WORK KW HRS		
NO	TIME	FLUIDIZING AIR FLOW SCFM	STACK GAS O_2 X %125	FILTER I INTEGRATOR READING lbs.	FILTER II INTEGRATOR READING lbs.	SAMPLE NO.	PUMP SUCT. GAL.	RETURN GAL.	X-100 480 V	X-50 2300 V	REMARKS
1	0815	13000	7.5	32690	69890		38582	3225	2772	550	
2	0900	13000	6.5	40950	76960		38589	3225	2772	556	
3	1000	13000	9	52880	84730		38591	3225	2773	564	
4	1100	13000	8	65840	93530		38599	3225	2774	573	
5	1200	13500	6.75	79880	102650		38599	3225	2775	582	
6	1300	13500	10.25	82329	115900		38624	3225	2786	593	
7	1400	13500	8.75	90350	122200		38677	3225	2787	601	Test Start.
8	1500	13000	9.25	99700	130440		38712	3225	2788	608	
9	1600	14000	7	104250	134790		38750	3225	2789	614	Lost Air Comp's.
10	1700	13500	8.5	117400	144400		38790	3225	2790	624	
11	1800	13000	6	125090	151308		38809	3225	2791	632	
12	1900	13500	9	135480	156050		39002	3225	2792	641	
13	2400	14000	4	159180	174360		39062	3225	2793	658	
14	2200	14000	8.75	172130	182390		39100	3225	2794	667	
15	2300										
16	2400										

Power

480 V

10:00 PM 2794

2:00 PM − 2787

7 × 100 = 700 KW / 8 hrs = 87.5 kwhr

2300 V

10:00 PM 667

2:00 PM − 601

66 × 50 = 3300 / 8 hrs = 412.50

412.5 + 87.5 = 500 kwhr

Panel power

$kw = \frac{(I)(E)}{1000}$

$\frac{(700 \text{ amps})(120}{1000}$

= 8.4 kw

53

DATE: 7-27-78

SIGNATURE: T. E. Sage

INCINERATOR PERFORMANCE DATA

OMAHA PAPILLON CREEK PLANT

REACTOR NUMBER: #1

				SLUDGE CAKE (S N)			FUEL OIL		WORK KW HRS		
	TIME	FLUIDIZING AIR FLOW SCFM	STACK GAS O_2 X %1.25	FILTER I INTEGRATOR READING lbs.	FILTER II INTEGRATOR READING lbs.	SAMPLE NO.	PUMP SUCT. GAL.	RETURN GAL.	X-100 480V	X-50 2300V	REMARKS
1	0900	13500	9.0	18160	202160		39352	3225	2889	694	
2	1000	13000	8	29850	210290		39392	3225	2890	703	
3	1100	13500	8	40600	216150		39428	3225	2891	711	
4	1200	13000	6.5	56200	225300		39455	3225	2892	719	
5	1300	13000	8	70600	233120		39492	3225	2893	728	
6	1400	13500	9	86300	241410		39514	3225	2894	737	
7	1500	13000	8.5	100700	249090		39555	3225	2895	745	
8	1600	13000	8	118900	257200		39595	3225	2896	754	
9	1700	13000	8.5	140250	265730		39629	3225	2896	763	
10											
11			10.2% O_2								
12											
13											
14											
15											
16											

Power

480V

10:00 PM 2896

2:00 PM 2889

7 x 100 = 700 KW / 8 hrs = 87.5 kwhr

2300V

10:00 AM 763

2:00 PM 694

69 x 50 = 3450 KW / 8 hrs = 431.25 kwhr

87.5 + 431.25 = 518.75 kwhr

Check H_2O content in sample results

Panel Power

518.75 - 8.4 = 510.35 kwhr

510.35 + 491.6 = 501

45

TE3 - 1170

PAPIO PLANT REACTOR LOG

REACTOR 301 DATE 7-27-78

TIME	S.S.V.	FLUID. AIR FLOW	ORIFICE Δ DIFF.	BED DIFF.	WINDBOX PRESSURE	FACEBOARD PRESS.	W.H.B. DIFF.	VENTURI DIFF.	ASH CYCLONE DIFF.	HEAT EXCHANGER DIFF.	SEC. REHEATER DIFF.	TE-1	TE-2	TE-3	TE-4	TE-5	TE-6	TE-7	TE-8	TE-9	TE-10	TE-11	TE-12	TE-13	TE-14	TE-15	TE-16	TE-17	TE-18	OIL	SLUDGE #1 / #2	BOILER PRESSURE	F.A.B. AMPS	BED OUT	PUMP SPEED %	GREASE PUMP SPEED %	VENTURI REFRETO WATER FLOW	GREASE FLOW	GREASE TRUCK LEVEL 1	2	3	4	#2	
2400																																														
0100																																														
0200																																														
0300																																														
0400																																														
0500																																														
0600																																														
0700	3.4	140	29	60	43	24	.7	16	1.1	1.5	0	521	1359	1365	1351	1333	1340	101	1137	251	901	94	990	108	196	73	168	108	133	121	58		113	1000		OK		44	44	38	74	104	91
0800	3.3	135	30	60	47	35	1.2	27	1.5	2.1	0	610	1370	1370	1340	1350	1368	109	1157	247	1179	115	1181	106	192	73	177	107	129	243	58		110	180		OK		45	43	38	73	106	91
0900	3.3	135	29	60	45	29	.9	27	1.5	2.1	0	608	1370	1371	1340	1357	1396	112	1169	274	1190	116	1098	97	190	73	174	107	128	243	58		109	180		OK		45	44	38	74	105	91
1000	3.2	13	29	60	43	24	.9	20	1	1.6	0	607	1369	1370	1355	1359	1400	111	1173	282	1190	116	1088	100	190	73	174	107	125	243	58		109	190		OK		45	44	38	73	105	91
1100	3.2	12	29	60	47	32	1.1	26	1.9	2.3	0	628	1378	1371	1360	1368	1406	112	1190	288	1207	121	1135	102	192	74	178	106	123	243	58		107	140		OK		45	43	38	72	105	91
1200	3.3	13.5	29	60	46	31	1.	27	1.5	2.	0	635	1367	1369	1367	1362	1409	113	1205	282	1237	125	1134	106	200	75	177	106	121	418	58		106	180		O.K		45	44	39	72	105	91
1300	3.2	12.	29	60	46	33	1.	26	1.5	2.	0	631	1370	1370	1361	1362	1423	118	1233	288	1288	124	1143	108	207	75	179	106	120	418	58		107	160		OK		44	43	39	72	105	91
1400	3.3	13.5	29	60	45	30	1.	22	1.5	2.	0	632	1378	1376	1349	1347	1422	117	1237	285	1244	126	1136	111	213	75	178	105	118	418	58		107	180		OK		44	42	37	71	106	92
1500	3.2	12.	29	60	45	30	1.	23	1.8	2.1	0	624	1371	1373	1341	1363	1422	116	1235	306	1241	128	1136	112	214	75	179	105	118	418	58		107	160		ok		44	42	35	70	106	92
1600	3.3	13	29	60	46	30	1	23	1.5	2	0	624	1371	1372	1363	1344	1443	116	1233	310	1246	122	1152	114	215	75	178	105	117	585	58		107	160		ok		44	42	34	70	107	92
1700	3.3	13.	29	60	45	30	1	25	1.5	1.8	0	619	1370	1371	1361	1359	1435	116	1230	313	1243	120	1122	116	215	75	121	105	116	585	58		109	320		OK		45	42	34	70	108	92
1800																																													
1900																																													
2000																																													
2100																																													
2200																																													
2300																																													
2400																																													

PERFORMANCE RUN @ HRS

OIL

SHIFT	START	END	AMT.
11:30-7:30			
7:30-3:30	0	418	418
3:30-11:30	418		
TOTAL			X.XX

SLUDGE

SHIFT	#1 FILTER START	#1 FILTER END	#2 FILTER START	#2 FILTER END	AMT.
11:30-7:30					
7:30-3:30	0	6298	0	43242	10,540
3:30-11:30	6298		43242		
TOTAL					X16.7

STEAM FLOW

SHIFT	START	END	AMT.	GAS AMT.
11:30-7:30				
7:30-3:30				
3:30-11:30				
TOTAL			X	X

OPERATORS 11:30-7:30 [illegible] 7:30-3:30 Richard Zuck 3:30-11:30 Pauline F Zuck

55

#1 INLET REACTOR WIND BOX
2 REACTOR BED LOW POINT
3 REACTOR BED MID POINT
4 REACTOR BED HIGH POINT
5 REACTOR BED HIGH POINT
6 REACTOR EXHAUST DUCT FREEBOARD TEMP.
7 SCRUBBER
8 OUTLET WASTE HEAT BOILER
9 VENTURI INLET
10 INLET TO ASH QUENCHER
11 ASH TANK
12 OUTLET HEAT EXCHANGER
13 FEED H_2O INLET WASTE HEAT BOILER
14 STEAM DRUM WASTE HEAT BOILER
15 H_2O INLET SCRUBBER
16 VENTURI DISCHARGE
17 GREASE TANK #1
18 GREASE TANK #2

TE-2 1072

PAPIO PLANT REACTOR LOG

REACTOR 301 DATE 7-26-78

TIME	S.S.V.	FLUID. AIR FLOW	ORIFICE Δ DIFF.	BED DIFF.	WINDBOX PRESSURE	FREEBOARD PRESS.	W.H.B. DIFF.	VENTURI DIFF.	ASH CYCLONE DIFF.	HEAT EXCHANGER DIFF.	SEC. SCRUBBER DIFF.	TE-1	TE-2	TE-3	TE-4	TE-5	TE-6	TE-7	TE-8	TE-9	TE-10	TE-11	TE-12	TE-13	TE-14	TE-15	TE-16	TE-17	TE-18	OIL	SLUDGE #1/TOP	BOILER PRESSURE	F.A.B. AMPS	BED GUN PUMP SPEED %	GREASE PUMP SPEED %	VENTURI RECIRC WATER FLOW	GREASE FLOW	GREASE TANKS LEVEL 1	2	3	4	#2 17	18
2400																																											
0100																																											
0200																																											
0300																																											
0400																																											
0500																																											
0600																	↓	↓																									
0700	3.6	14.5	30	60	4.1	16	.4	11	.9	1.4	0	463	1383	1385	1367	1349	1259	91	668	188	672	94	855	101	116	73	147	116	113	0	30		115	600		OK			48	40	48	60	110	93
0800	3.3	13.	30	59	4.6	32	1	20	1	1.7	0	559	1380	1382	1368	1342	1368	107	818	208	985	108	1007	100	115	73	175	113	112	0	175 / 497		109	0		O.K.			48	41	48	60	109	93
0900	3.3	13.	30	60	4.5	29	.9	21	1.2	1.9	0	605	1377	1378	1365	1351	1391	110	899	223	1105	118	1063	100	115	73	175	112	111	0	818 / 1084		109	0		OK			48	42	48	60	109	93
1000	3.4	13.5	29	62	4.6	31	1	24	1.5	2	0	606	1371	1372	1359	1342	1343	110	915	241	1145	117	1070	101	115	73	173	117	111	146	1550 / 1574		106	0		OK			46	41	48	60	128	94
1100	3.4	13.5	29	64	5	37	1.4	23	1.6	2.1	0	635	1371	1374	1360	1360	1410	109	961	250	1194	123	1104	103	115	74	178	121	111	146	[illegible]		109	0		OK			46	41	48	60	131	94
1200	3.4	13.5	29	62	4.9	38	1.2	26	1.9	2.3	0	646	1390	1391	1379	1369	1442	108	1001	258	1230	126	1135	104	115	74	180	122	113	146	[illegible]		110	0		OK			46	42	48	60	137	94
1300	3.4	13.5	29	64	5	35	1	22	1.7	2	0	607	1376	1377	1365	1350	1413	110	974	249	1197	117	1101	106	116	75	177	124	150	146	[illegible]		110	0		OK			45	44	48	59	136	94
1400	3.4	13.5	29	62	4.7	35	1.1	24	1.8	2.1	0	627	1378	1378	1366	1337	1399	114	993	267	1217	124	1110	108	117	75	179	123	154	146	[illegible]		110	0		OK			45	42	48	59	129	94
1500	3.4	13.5	29	64	4.9	30	1.1	22	1.7	2	0	641	1375	1376	1364	1336	1438	116	1015	276	1239	127	1128	111	119	75	178	121	156	30	[illegible]		111	0		OK			40	42	48	59	123	95
1600	3.4	13.5	29	60	4.5	37	1.2	20	1.2	1.8	0	[illegible]	[illegible]	1354	[illegible]	1353	1412	121	[illegible]	[illegible]	[illegible]	112	1104	112	111	120	180	113	150	30	[illegible]		105	0		OK			40	42	44	58	124	95
1700	3.4	14.0	29	60	4.5	30	1	24	1.8	2	0	642	[illegible]	[illegible]	[illegible]	[illegible]	1445	117	[illegible]	272	1302	124	1118	113	[illegible]	75	173	116	152	306	[illegible]		110	300		OK			42	42	46	58	126	95
1800	3.4	14.0	29	60	4.5	30	1	40	1.5	2	0	637	[illegible]	[illegible]	1352	1354	[illegible]	[illegible]	[illegible]	[illegible]	1227	[illegible]	1104	113	128	75	[illegible]	[illegible]	157	415	[illegible]		110	300		OK			40	42	46	58	122	95
1900	3.4	14.0	29	60	4.5	30	1	18	1.5	1.8	0	644	1371	1372	1362	1340	1396	114	1001	290	1225	120	1100	116	140	74	173	114	157	54	[illegible]		110	250		OK			40	42	46	58	121	96
2000	3.4	14.5	29	60	4.5	39	1.4	2.4	1.8	2	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1456	111	[illegible]	272	[illegible]	129	1157	117	[illegible]	75	181	113	[illegible]	545	[illegible]		110	300		OK			40	42	46	64	119	94
2100	3.4	13.5	29	60	4.7	30	1	20	1.9	2	0	647	[illegible]	1378	1366	1341	1422	[illegible]	[illegible]	297	[illegible]	123	1110	118	[illegible]	75	178	113	156	548	[illegible]		110	150		OK			40	43	47	66	115	95
2200	3.4	14.0	30	60	4.7	25	1.3	21	1.3	1.8	0	[illegible]	[illegible]	[illegible]	[illegible]	1352	[illegible]	115	[illegible]	[illegible]	124	118	1127	119	[illegible]	75	177	[illegible]	157	591	[illegible]		110	247		OK			40	42	30	64	[illegible]	95
2300																																											

← 8 hours → Performance Run

OIL

SHIFT	START	END	AMT.
11:30-7:30			
7:30-3:30	0	306	306
3:30-11:30	306	699	393
			699
			X.88
		TOTAL	[illegible]

SLUDGE

SHIFT	#1 FILTER START	#1 FILTER END	#2 FILTER START	#2 FILTER END	AMT.
11:30-7:30					
7:30-3:30	0	4598	0	154 *	11752
3:30-11:30	4595	5579	154	337	2432
					12185
					X16.7
				TOTAL	203539.6

STEAM FLOW / GAS

SHIFT	START	END	AMT.	GAS AMT.
11:30-7:30				
7:30-3:30				
3:30-11:30				
			X	X
	TOTAL			

OPERATORS	11:30-7:30	7:30-3:30 Beske - Leak	3:30-11:30 [illegible]

*1500 #2 SLUDGE TOTALIZER ZEROED.

W.H.B. - 5" DOWN FROM TOP 55 P.S.I.G.
CLEANED VENTURI PUMP DISCHARGE STRAINER. BLEW OUT FT-42 AND FLOW IND. TO SEC. SCRUBBER.
FILLED AND EMPTIED ASH TANK WITH EACH PUMP - SAT.
THROTTLED ASH DISCHARGE VALVE AS NEEDED.

① STEAM LEAK ON GREASE TRACING BETWEEN REACTORS.
② VENTURI FLANGE STILL LEAKS.
③ FLOW IND. TO ASH CYCLONE STUCK - (3" LINE)
④ SIGHT PORT ON OVERBED BURNER #2 LEAKS.
⑤ NO INDICATION OF DIFF. ON SEC. SCRUBBER.

ALL OTHER CHECKS SAT.
IZZ OUT TODAY.

@ 0650 F.W.B. ON.
@ 0653 B.G. ON.
@ 0703 SLUDGE ON #2 FILTER
@ 0710 OIL IN AUTO.
@ 0743 SLUDGE ON #1 FILTER
@ 0858 STARTED ADDING SAND TO 301 FROM S.T.
@ 0855 2000# sand to #301 reactor
@ 0930 2000# " " "
@ 1020 BED GUN OIL PUMP WILL NOT RUN.
@ 1040 #1 B.G.O.P. BACK IN SERVICE ?
@ 1120 #1 B.G.O.P. IN MAN. IT QUIT AGAIN.
@ 1133 #1 " " IN AUTO
@ 1205 #1 + 2 FILTERS OFF (TOO MUCH SLUDGE)
@ 1210 #2 FILTER ON (NORTH)
@ 1310 #1 ON
@ 1320 #1 + 2 OFF (SEAL POT BLEW)
@ 1335 #1 ON
@ 1336 #2 ON
@ 1400 STARTING PERFORMANCE TEST.
@ 1409 #1 GREASE PUMP ON
@ 1413 SHOT OF GRITS 4 CU. FT LOOKED GOOD
@ 1420 SHOT OF GRITS 4 CU FT
@ 1430 SHOT OF GRITS 4 CU FT (ROUGH)
@ 1500 TOTALIZER ON & ZEROED.
@ 1503 SHOT OF GRITS 4 CU FT LOOKED OK
@ 1517 EVERYTHING SHUT DOWN NO AIR.

1540 Reactor Lit back off
1545 Received Load Grits 4 Cu. FT.
1545 #2 Filter ON
1549 #1 Filter ON
1625 Bed Guns OFF
1640 " ON
1623 Grease Set At 89%
1645 Switched #1 Grease Pump to #3 40%
1700 #3 Pump 55%
1745 Sludge OFF getting water
1748 " ON
1750 Bed Guns Manual
1754 " " Aut.
0730-1530

1745 - Sludge OFF
1750 - " ON #2
1755 - " ON #1
1800 - Sludge OFF over Loaded
1813 - " ON #1
1818 - " " #2
1825 - " OFF #2
1035 - " ON #2
1915 - #3 Grease Pump ON
1927 - 4 Cu. Ft. Grits
1945 - " " " "
2035 - #3 Grease Pump OFF
2055 - " " " ON
2058 " " " OFF
2215 Sludge OFF both Filters
Washed out Sludge LINE
2240 Reactor Shut Down

TANK LEVEL 5 - FULL E -

T.P.	T.T.	Tank Level 2"
		TP TT
		39195 3225.5
38716.	3225.1	38422 3225.5
38422	3225.5	773
.294	0.	

Cont From Logsheet — Reactor 301 — 1-27-78

1452	2 CF	Screen	Good
1455	"	"	"
1458	"	"	"
1500	"	"	"
1503	"	"	"
1509	"	"	"
1510	"	"	"
1518	"	"	"
1520	"	"	"
1522	"	"	"
1523	"	"	"
1524	"	"	"
1526	"	"	"
1527	"	"	"
1530	"	"	"
1547	3 CF	Screen - slight	
1605	2 "	"	
1612	4 "	2 Shots Air + Water	
1614	Shot of Air		

7:30-3:30 SHIFT
TANK LEVEL 5-3½" END 3"

To Pump	To Tank
39560	3225.5
- 39195	3225.5 -
365	0

W.H.B. 4' DO. TOP 150 P.S.I.G.
BLEW OUT FT-4 ✓
① LEAK ON LEVEL TRANSMITTER #1 W.H.B. (STEAM)
② STEAM LEAK ON GREASE TRACING BETWEEN REALTORS.
③ FLOW IND. TO ASH CYCLONE STUCK (3" LINE)
④ VENTURI FLANGE LEAKING.
⑤ SIGHT PORT ON # O.B.B. LEAKS.
⑥ NO IND OF DIFF ON SEC. SCRUBBER.
⑦ WERE GOING TO RUN INTO PROBLEMS WITH W.H.B. SAFETIES LIFTING. SEEME

ADJUSTED ASH DISCHARGE VALVE AND SHIFTED PUMPS AS NEEDED.
ALL OTHER CHECK SAT.
II OUT TODAY.

@ 0641 #1 A.A.B. ON
@ 0643 #1 B.G.O.D. ON
@ 0652 SLUDGE ON #2
@ 0700 OIL IN AUTO
@ 0708 SLUDGE ON #1
@ 0720 #1 OFF
@ 0722 #1 ON
@ 0825 ADDED SOME FEEDWATER TO #1 W.H.B.
@ 0832 LOAD OF GRITS - CLEANING LINE, 2 CU.FT.
@ 0837 LOAD OF GRITS - " " 3 CU.FT.
@ 0840 D. CHUMRA BLOWING OUT GREASE GUNS WITH STEAM.
@ 0847 INCREASED POLYMER FROM 40 TO 45 GAL/HR.
@ 0900 PERFORMANCE TEST BEGAN. EMISSION TEST START
@ 0918 INCREASED POLYMER TO # 3 FROM 45 TO 50.
@ 0924 SHOWER ARM SPEED #1 BY 1/4.
@ 0927 ACKNOWLEDGED OPACITY HIGH ALARM # 1 UNIT.
@ 0937 INCREASED POLYMER #3 FROM 45 TO 50.
@ 0955 LOAD OF GRIT 1 ~~SCREEN~~ 3 GRIT - GOOD
@ 1002 LOWER AIR FLOW 500 SCFM. LOAD OF GRIT 1 SCREEN 1 3 GRIT GOOD.
@ 1010 LOAD OF GRIT 1 SCREEN - 3 GRIT.
@ 1012 EMISSION'S TEST SECURED.
@ 1015 LOAD OF GRIT. (SAME)
@ 1023 G+S GOOD (SAME)
@ 1027 G+S (SAME) L.I.R.A.F. ALARM ONLY
@ 1034 G+S L.I.R.A.F. ALL FEED CUT OUT (FUEL)
@ 1040 G+S - GOOD
1045 G+S
1100 #1+2 Bedguns Plugged. G+S. 200psig steam on W.H. Boiler.
1104 G+S Steam Header Press High Alarm Reactor 321.
1110 G+S
1117 G+S - slight indication
1122 G+S NEW - GOOD.
1127 G+S GOOD (SAME)
1128 RESET OPACITY ALARM #1 - START EMISSION TEST #3
1130 G+S
1138 G+S Ran out of Grits
1158 2 CU. FT OF SCREENING REAL GOOD 35" W.C. INDICATION.
NOW 0² READING.
1205 #1-2 AND 6 BED GUNS PLUGGED.
1222 O² BACK TO NORMAL.
1228 EMISSION TEST #2 END
1303 INCREASED DRUM SPEED #1 BY 1/4 AND RAISED LEVEL A LITTLE.
1328 START EMISSION TEST #3 AND 2 CU.FT. SCREENINGS
1335 2 CU.FT. SCREENINGS GOOD
1337 " " " "
1340 " " " " Slight ind.
1355 1 CF Screen + 3 CF Grit - Good
1400 2 CU.FT GRIT 2 CU.FT SCREENING GOOD
1405 " " " " " " " " Increased drum speed #2 a 1/4 turn.
1411 " " " " " " " "
1415 " " " " " " " "
1421 " " " " " " " "
1428 " " " " " " " "
1430 2 CF SCREEN + 1 CF Grit - Good.
1435 Emission Test #3 End.
1438 2 CF SCREEN.
1445 " " "

Interstate Industrial Instrumentation, Inc.

INSTRUMENT AND CONTROL SPECIALISTS

11069 "I" STREET, OMAHA, NEBRASKA 68137
Phone: (402) 331-3535
Telex: 48486

August 2, 1978

Eby Construction Co.
P.O. Box 11128 Ames Ave., Sta.,
Omaha, Nebraska 68111

Attn: Mr. Jim Love

Dear Jim:

Per your request I will put down what was found in checking calibration on south scale:

July 26th	Reset zero before test	Reset zero immediately fo llowing test.
	Zero had drifted up 2 per cent prior to test.	Zero had drifted up 4 per cent during test.
July 27th	Reset zero before test. Had drifted up 4 per cent overnight.	Zero had drifted up 19 to 21 per cent during test. Did not adjust per Eby's request.
July 28th	7:00 a.m. Zero had drifted up 80 per cent since beginning of test.	

Zero drift on July 27th increased during last part of performance run, and continued at high rate of drift during night.

No adjustment of Span was ever necessary on south Ohmart scale during this period.

No zero or Span adjustment was necessary on north Ohmart scale during this period.

Yours truly,

INTERSTATE INDUSTRIAL INSTRUMENTATION, INC.

Donald L. Grove

Donald Grove
Service Manager

DG:mj
cc: Don Chmura