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AIR POLLUTION CONTROL

SLUDGE INCINERATOR EMISSION TESTING
UNIT II
FOR
CITY OF OMAHA
PAPILLION CREEK
WATER POLLUTION CONTROL PLANT
APRIL, 1980

PDL Project I-5990

Submitted

May 20, 1980

Prepared By

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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

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

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 2 at the City of Omaha's Papillion Creek Water Pollution Control Plant.

Emission testing was performed on April 18, 1980 by Dr. Sander E. Sundberg and Mr. Rich Shimkus 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. Jim Swan and Mike Bolan of the City of Omaha coordinated the testing with system operation. Mr. Aki Jacobsen of Envirotech observed the operation of the Sludge Incineration System. 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.

The following table summarizes the results of the testing on Unit #2 performed on April 18, 1980:

Test Run	1	2	3	
Stack Gas Data				
Temperature, °F	91.2	90.0	93.3	
Velocity, ft/sec	29.64	28.63	28.56	
Gas Volume, actual cfm (wet)	17,110	16,525	16,483	
Gas Volume, scfh (dry)	$.905\times10^6$	$.890\times10^6$	$.878\times10^6$	
Moisture, %	6.3	4.9	5.3	
Sampling Data				
Volume, scf (dry)	34.330	36.407	35.706	
Isokinetic Ratio, %	94.8	102.3	101.7	
Particulates				
Concentration, grams/scf (dry)	0.0205	0.0179	0.0204	
Emission Rate, lb/hr.	2.6460	2.2745	2.5655	2.5
Opacity, %	<5	<5	<5	
Operating Conditions				
Dry Sludge and Grease Feed Rate (tons/hr)	2.335	2.132	2.346	
Allowable Emissions @1.3 lb/ton/hr				
Particulates (lb/hr)	3.04	2.77	3.05	2.75

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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 100^{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.

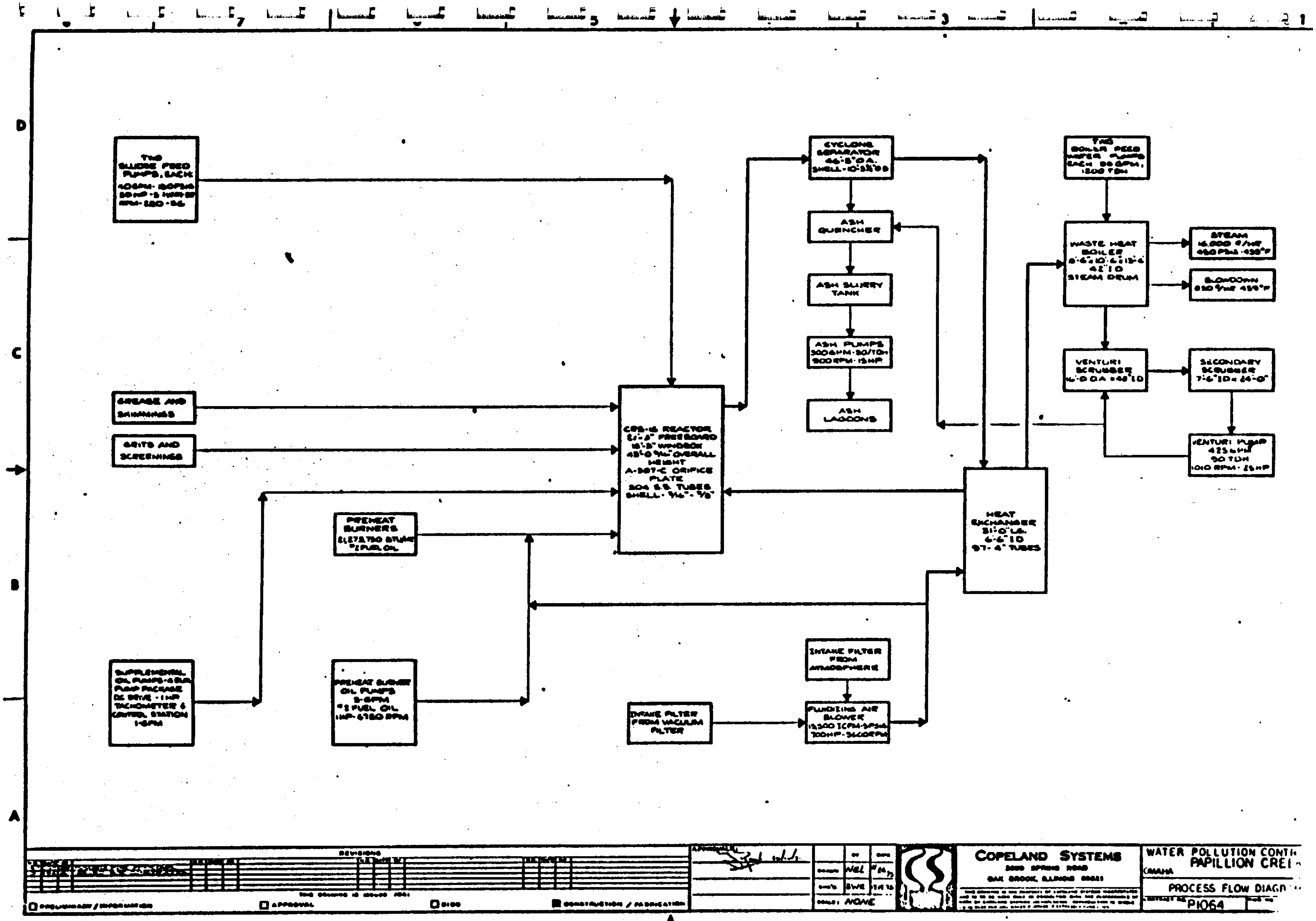
The reactor vessel, cyclone, and connecting gas ducts are lined with insulating refractory materials to protect against erosion by dust-laden gases and conserve heat for preheating the fluidizing air in the heat exchanger and for steam generation in the waste heat boilers. Pumps and tanks are either 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	April 18, 1980 Performance (Based on Primary Sludge)	
Feed rate lbs/hr (wet basis)	21,700	14,787	68%
Sludge cake feed % TS	30	29.8	
Sludge volatiles solids % V.S.	70	32.9	
Sludge heat value BTU/lb.V.S.	9,000	11,490	
Fuel oil rate, GPH	0	101.1	14%
Crease feed rate lbs/hr	4,600	627	
Grease feed % TS	30	63.8	
Grease feed % V.S.	94.9	96.19	
Grease heat value, BTU/lb.V.S.	14,000	16,301	
Grit feed rate lbs/hr	1,500	0	
Grit feed % TS	50	0	
Grit feed % V.S.	25.3	-	
Heat value BTU/lb V.S.	9,000	-	
Screenings Feed rate lbs/hr	200	-	
Screenings feed % TS	30	-	
Screenings feed % V.S.	83.3	-	
Heat value BTU/lb V.S.	9,000	-	
Ash volatile solids % V.S. max.	4	1.7	
Furnace exhaust temperature °F	1,400	1,467	
Scrubber exhaust Temperature °F	130	87	
Power KW/hr	503	-	
Emissions rate lbs/ton dry sludge solids	1.3	-	

The sludge cake feed rate is based on average readings taken over a continuous 8 hour period on April 18. During this period, the incinerator handled 14,787 lbs/hr of wet cake. This is less than 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.


TWO SLUDGE FEED PUMPS, EACH 40GPM · 150PSIG 50HP · 5 HWH SP RPM · 180 · 56
GREASE AND SKIMMINGS
GRITS AND SCREENINGS
SUPPLEMENTAL OIL PUMPS · 4 GUN PUMP PACKAGE DC DRIVE · 1HP TACHOMETER & CONTROL STATION 1·GPM
PREHEAT BURNERS 21,872,730 BTU/HR #2 FUEL OIL
PREHEAT BURNER OIL PUMPS 3·GPM #2 FUEL OIL 1HP · 1750 RPM
CPS-16 REACTOR 21'-3" FREEBOARD 18'-3" WINDBOX 43'-0 9/16" OVERALL HEIGHT A-387-C ORIFICE PLATE 304 S.S. TUBES SHELL · 9/16" · 7/8"
CYCLONE SEPARATOR 46'-5" O.A. SHELL · 10'-3 3/4" OD
ASH QUENCHER
ASH SLURRY TANK
ASH PUMPS 300GPM · 30/TDH 900RPM · 15HP
ASH LAGOONS
INTAKE FILTER FROM VACUUM FILTER
INTAKE FILTER FROM ATMOSPHERE
FLUIDIZING AIR BLOWER 13,300 ICFM · 5PSIG 700HP · 3600RPM
HEAT EXCHANGER 31'-0" LG. 6'-6" ID 97 · 4" TUBES
TWO BOILER FEED WATER PUMPS EACH 30 GPM, 1200 TDH
WASTE HEAT BOILER 8'-6" ID · 6'-13'-6 42" ID STEAM DRUM
STEAM 16,000 #/HR 450 PSIG · 459°F
BLOWDOWN 820 #/HR 459°F
VENTURI SCRUBBER 16'-0 OA × 48" ID
SECONDARY SCRUBBER 7'-6" ID × 24'-0"
VENTURI PUMP 425 GPM 90 TDH 1010 RPM · 25HP
A
B
C
D
1
2
3
5
7
COPELAND SYSTEMS
2000 SPRING ROAD
OAK BROOK, ILLINOIS 60521
WATER POLLUTION CONTR
PAPILLION CREE
OMAHA
PROCESS FLOW DIAGR
P1064
WEL
SWE
SCALE: NONE
REVISIONS
☐ PRELIMINARY / INFORMATION
☐ APPROVAL
☐ BIDS
■ CONSTRUCTION / FABRICATION

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.

The sludge and grease feed rate data for all three test runs are summarized as follows:

Test Run	Type	Wet Weight (Pounds)	Time Between Readings (Min)	Wet Feed Rate (Lb/hr)	Average Dry Solids (%)	Dry Feed Rate (Lb/hr)
1	Sludge	15,143	65	13,978	29.57	4,133
	Grease	695	60	695	77.3	537
						4,670
2	Sludge	14,160	67	12,681	30.10	3,817
	Grease	645	60	645	69.1	446
						4,263
3	Sludge	15,868	62	15,356	29.40	4,515
	Grease	695	60	695	25.6	178
						4,693

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III. STACK TESTING AND ANALYTICAL PROCEDURES

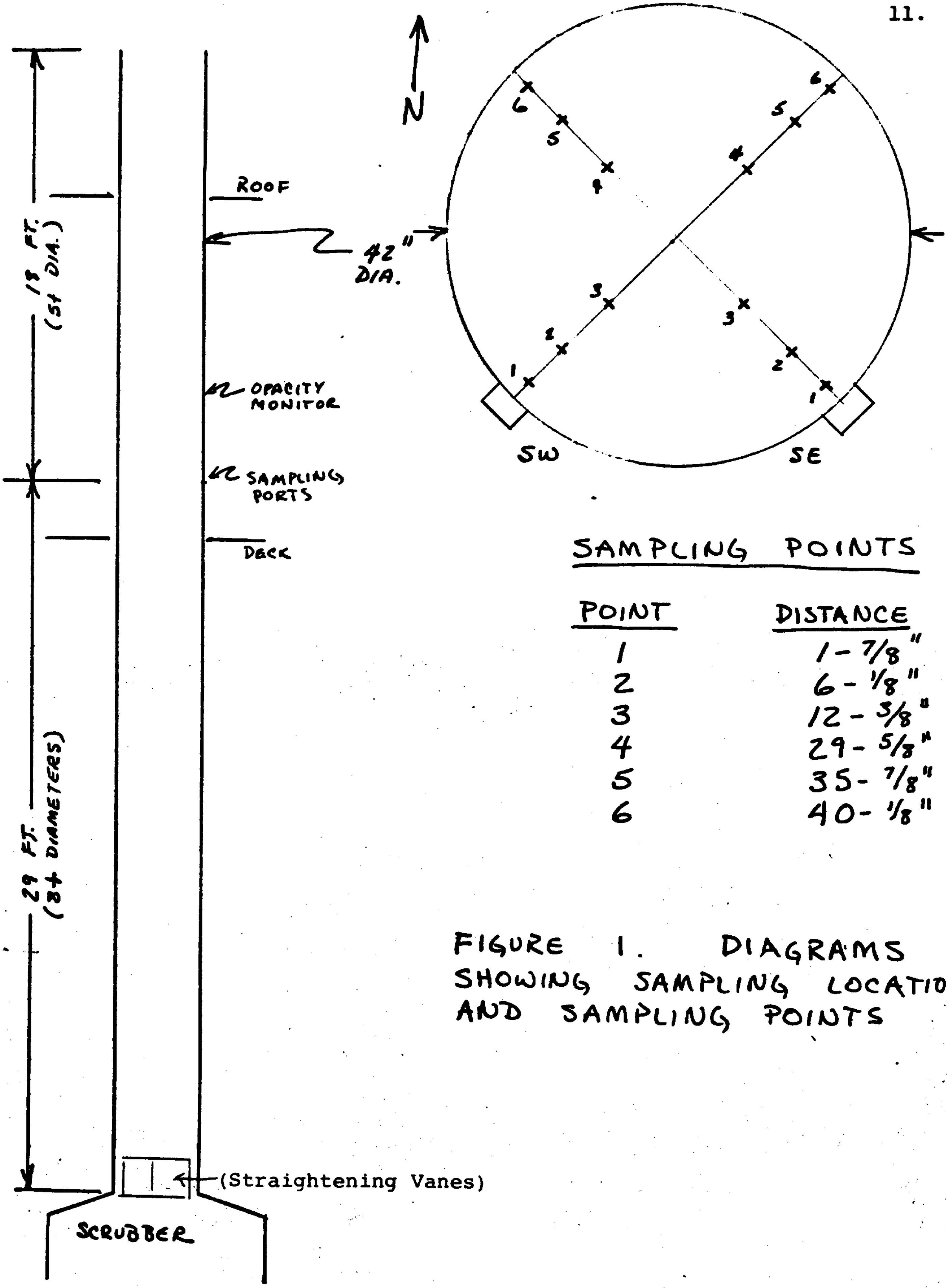
The procedures of sampling, testing, instrumentation and analysis as prescribed by the U.S. EPA were followed. The EPA Reference Methods used in this testing program are summarized below.

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 slightly more than 8 diameters downstream from the nearest disturbance, the scrubber, and approximately 6 diameters upstream from the top of the stack. A test, to determine if cyclonic flow was present, indicated that it was a problem. To correct this, a "+" shaped set of straightening vanes was installed at the top of the scrubber. It was subsequently determined that cyclonic flow was virtually eliminated. 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 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

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

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. Two 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.

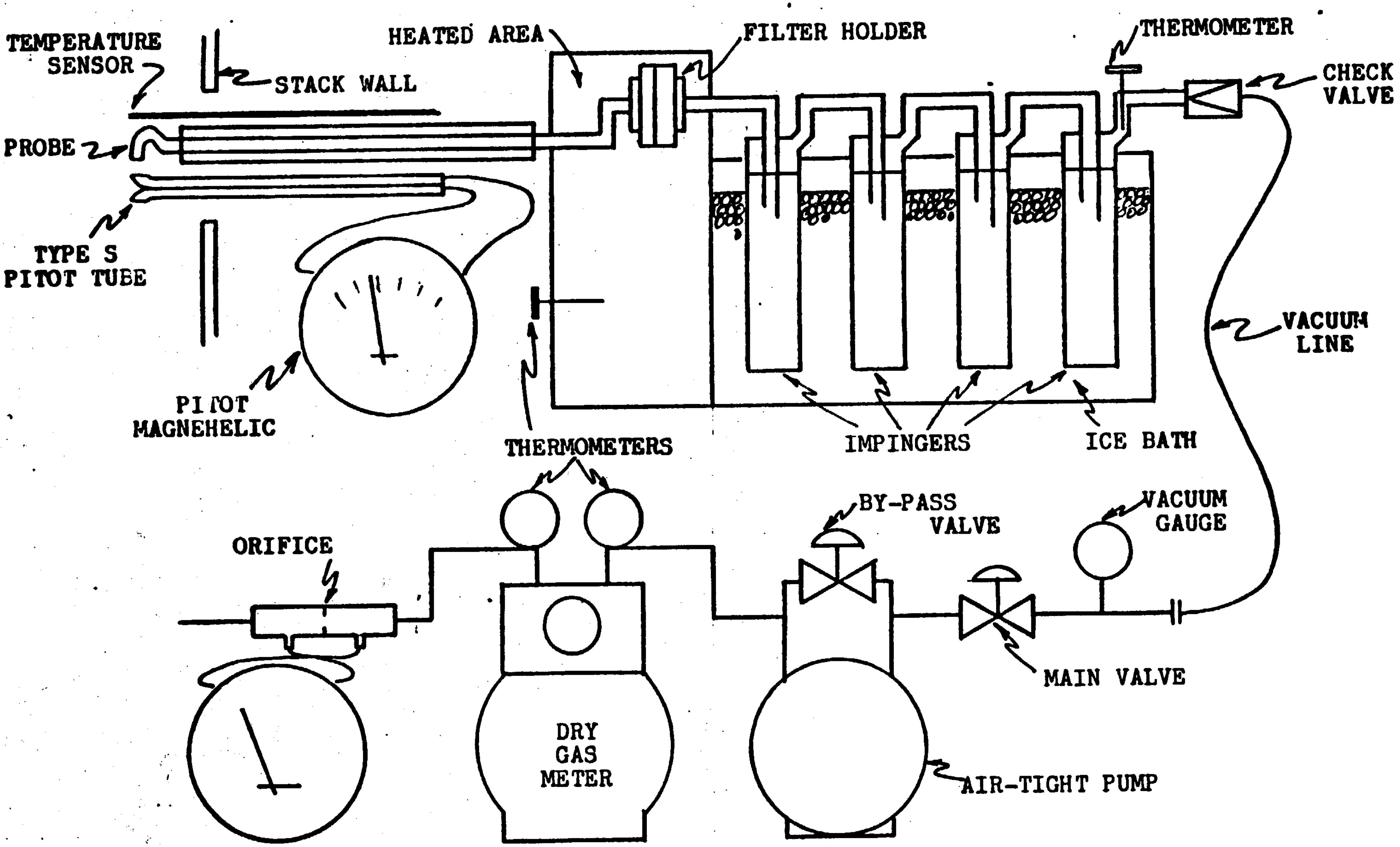


FIGURE 2. PARTICULATE SAMPLING TRAIN

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 procedure outlined above was repeated at 15 in. Hg. vacuum to verify the leak-free integrity of the system. For test run #3 only, a post test leakage rate of 0.04 CFM was discovered. The sample volume was corrected in accordance with the Federal Register.

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 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 and a TRS-80 minicomputer.

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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.

```
                    LOCATION...UNIT #2   ..UNIT #2   ..UNIT #2

                    DATE.......4-18-80   ..4-18-80   ..4-18-80

                    TIME.......1553-1658..1828-1935 ..2033-2135 HRS

                    TEST RUN #.1         #.2         #.3

STACK GAS DATA

   TEMPERATURE, F                91.2        90.0        93.3

   VELOCITY, ft/sec              29.64       28.63       28.56

   GAS VOLUME, ACFM            17110.3     16525.4     16483.8

   GAS VOLUME, SCFM(WET)       16111.3     15594.5     15462.5

   GAS VOLUME, SCFH(DRY)      905420.0    889903.0    878312.0

   MOISTURE, %                    6.3         4.9         5.3

   CARBON DIOXIDE, %(DRY)         7.3         7.0         7.3

   OXYGEN, %(DRY)                12.3        12.6        12.0

   CARBON MONOXIDE, %(DRY)        0.0         0.0         0.0

   NITROGEN, %(DRY)              80.4        80.4        80.7

   MOLECULAR WEIGHT, (WET)       28.92       29.06       29.03

SAMPLING DATA

   TOTAL TIME, min               60.0        60.0        60.0

   VOLUME, SCF(DRY)              34.330      36.407      35.706

   ISOKINETIC RATIO, %           94.8       102.3       101.7

SOLID PARTICULATES

   AMOUNT COLLECTED, mg          45.5        42.2        47.3

   CONCENTRATION, Grains/SCF      0.0205      0.0179      0.0204

   EMISSION RATE, lb/hr           2.6460      2.2745      2.5655
```

SOURCE TEST DATA SUMMARY

COMPANY....OMAHA-PAPILLION
LOCATION...UNIT #2
DATE.......4-18-80
TIME.......1553-1658 HRS
TEST RUN #.1

VOLUME THRU DG METER Vm = 34.334 cu-ft
VOLUME OF CONDENSATE Vlc = 49.0 ml
BAROMETRIC PRESSURE Pbar = 29.30 in,Hg
STATIC PRESSURE STATIC = 0.00 in,H2O
ABS. STACK GAS PRESSURE Ps = 29.30 in,Hg
ABS. GAS METER PRESSURE Pm = 29.36 in,Hg
ABS. STACK GAS TEMPERATURE Ts = 551.2 R
ABS. GAS METER TEMPERATURE Tm = 520.0 R
STACK AREA As = 9.621 sq-ft
PITOT TUBE COEFFICIENT Cp = 0.830
AVE. VELOCITY HEAD OF STACK GAS = 0.518
NOZZLE AREA An = 0.000385 sq-ft

STACK GAS DATA

TEMPERATURE, F	91.2
VELOCITY, ft/sec	29.64
GAS VOLUME, ACFM	17110.3
GAS VOLUME, SCFM(WET)	16111.3
GAS VOLUME, SCFH(DRY)	905420.0
MOISTURE, %	6.3
CARBON DIOXIDE, %(DRY)	7.3
OXYGEN, %(DRY)	12.3
CARBON MONOXIDE, %(DRY)	0.0
NITROGEN, %(DRY)	80.4
MOLECULAR WEIGHT, (WET)	28.92

SAMPLING DATA

TOTAL TIME, min	60.0
VOLUME, SCF(DRY)	34.330
ISOKINETIC RATIO, %	94.8

SOLID PARTICULATES

AMOUNT COLLECTED, mg	45.5
CONCENTRATION, Grains/SCF	0.0205
EMISSION RATE, lb/hr	2.6460

APPENDIX

77

COMPANY OMAHA

LOCATION UNIT #2

DATE 4-18-80

TEST RUN # 1

STACK AREA 42"ϕ (9.621)

OPERATOR SB

AMBIENT TEMPERATURE 90

BAROMETRIC PRESSURE 29.3

ASSUMED MOISTURE, % 5

HEATER BOX SETTING 250

PROBE HEATER SETTING 250

FILTER NUMBER .8360

SAMPLE BOX # BLUE

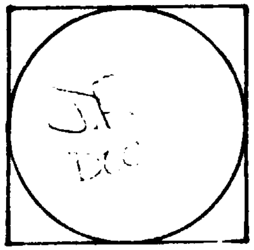
METER BOX # GREEN

METER H@ 1.05

C FACTOR —

PROBE LENGTH 4' SS

NOZZLE DIAMETER 17/64 .00038416



STACK CROSS SECTION

DN 2 MIN

	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)	
1553	SE 1	5		90	.20	.447	.40	839.276	60		260	2.0	
	2	5	0	90	.30	.548	.90	841.86				3.0	
.41	3	5		95	.35	.592	1.05	44.91				3.5	
16:10	4	5		90	.30	.548	.90	48.13				3.0	
16:15	5	5	0	95	.25	.500	.75	51.41				3.0	
16:20	6	5		95	.30	.548	.90	54.10				3.0	
1628	SW1	5		90	.15	.387	.45	57.29				2.0	
	2	5	0	90	.30	.548	.90	59.55				3.5	
	3	5		90	.35	.592	1.05	62.78				4.0	
	4	5		90	.25	.500	.75	65.48				3.0	
	5	5		90	.25	.500	.75	67.93				3.0	
	6	5		90	.25	.500	.76	70.61				3.0	
TOTAL		60	0.0	1095		6.210	9.55	73.61					
AVERAGE				91.2		.518	.80	34.334	60				

WATER COLLECTED	IMPINGERS 1	2	3	4
FINAL	65	150		234
INITIAL	100	100		200
NET H_2O	-35	50		34
TOTAL H_2O COLLECTED, ml				49

PARTICULATE COLLECTED	FILTER	PROBE WASH
FINAL		
TARE	.8360	
NET GAIN		
TOTAL WEIGHT, mg		

ORSATS TIME	CO_2	O_2	CO	N_2
1605	7.2	12.4		
16:35	7.4	12.2		
AVERAGE	7.3	12.3		80.4

COMMENTS:

10" Hg

9:25

Leak Ck

5:25

<.01

LABORATORY DATA

LOCATION OMAHA - PAPILLION DATE 04-18-80 RUN #1

UPSTREAM WASH	# 8		FINAL	70,182.4	
			TARE	-70,168.9	
		275 x .008 =	BLANK	- 2.2	
			NET		11.3 mg
THIMBLE	# —		FINAL		
			TARE	-	
			NET		
FILTER	# —		FINAL	870.2	
			TARE	- 836.0	
			NET		34.2 mg
DOWNSTREAM WASH	#		FINAL		
			TARE	-	
		x =	BLANK	-	
			NET		
CONDENSATE	#		FINAL		
			TARE	-	
		x =	BLANK	-	
			NET		

TOTAL WEIGHT OF PARTICULATES 45.5

COMMENTS

SOURCE TEST DATA SUMMARY

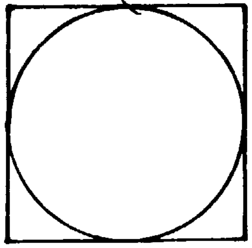
```
                                                COMPANY....OMAHA-PAPILLION
                                                LOCATION...UNIT #2
                                                DATE.......4-18-80
                                                TIME.......1828-1935 HRS
                                                TEST RUN #.2

VOLUME THRU DG METER                  Vm =   36.410 cu-ft
VOLUME OF CONDENSATE                 Vlc =   39.5 ml
BAROMETRIC PRESSURE                 Pbar =   29.30 in,Hg
STATIC PRESSURE                   STATIC =    0.00 in,H2O
ABS. STACK GAS PRESSURE               Ps =   29.30 in,Hg
ABS. GAS METER PRESSURE               Pm =   29.36 in,Hg
ABS. STACK GAS TEMPERATURE            Ts =  550.0 R
ABS. GAS METER TEMPERATURE            Tm =  520.0 R
STACK AREA                            As =    9.621 sq-ft
PITOT TUBE COEFFICIENT                Cp =    0.830
AVE. VELOCITY HEAD OF STACK GAS          =    0.502
NOZZLE AREA                           An = 0.000385 sq-ft

STACK GAS DATA
   TEMPERATURE, F                 90.0
   VELOCITY, ft/sec               28.63
   GAS VOLUME, ACFM            16525.4
   GAS VOLUME, SCFM(WET)       15594.5
   GAS VOLUME, SCFH(DRY)      889903.0
   MOISTURE, %                     4.9
   CARBON DIOXIDE, %(DRY)          7.0
   OXYGEN, %(DRY)                 12.6
   CARBON MONOXIDE, %(DRY)         0.0
   NITROGEN, %(DRY)               80.4
   MOLECULAR WEIGHT, (WET)        29.06

SAMPLING DATA
   TOTAL TIME, min                60.0
   VOLUME, SCF(DRY)               36.407
   ISOKINETIC RATIO, %           102.3

SOLID PARTICULATES
   AMOUNT COLLECTED, mg           42.2
   CONCENTRATION, Grains/SCF       0.0179
   EMISSION RATE, lb/hr            2.2745
```

JMM (NDEC)

COMPANY OMAHA
LOCATION UNIT #2
DATE 04-18-80
TEST RUN # 2
STACK AREA 42"ϕ
OPERATOR

AMBIENT TEMPERATURE 80
BAROMETRIC PRESSURE 29.3
ASSUMED MOISTURE, % 5
HEATER BOX SETTING 250
PROBE HEATER SETTING 250
FILTER NUMBER .8640

SAMPLE BOX # BLUE
METER BOX # GREEN
METER H@ 1.
C FACTOR — .531
PROBE LENGTH 4' SS
NOZZLE DIAMETER 17/64


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)	
18:28	SW1	5		90	.25	.500	.80	881.74	60		270	4.0	
36' 15 ~~41.15~~	2	5		90	.30	.548	.95	84.81			270	4.5	
	3	5	0	90	.30	.548	.95	88.10			260	4.5	
	4	5		90	.35	.591	1.15	91.35			250	5.0	
	5	5		90	.25	.500	.80	94.95			250	4.0	
1903	6	5		90	.25	.500	.80	97.92			250	4.0	
1905	SE 1	5		90	.15	.387	.45	900.97			260	3.0	
	2	5		90	.25	.500	.80	03.31			260	4.0	
	3	5	0	90	.25	.500	.80	06.37			260	4.0	
	4	5		90	.25	.500	.80	09.39			270	4.0	
	5	5		90	.25	.500	.80	12.43			270	4.0	
	6	5		90	.20	.447	.60	15.50			260	3.5	
TOTAL	☒		0	1080	☒	6.021	9.70	918.15			☒	☒	
AVERAGE	☒	☒	0	90.0	☒	.502	.808	36.41	60		☒	☒	

WATER COLLECTED	IMPINGERS 1	2	3	4
FINAL	65	145		229.5
INITIAL	100	100		200.0
NET H_2O	-35	45		29.5
TOTAL H_2O COLLECTED, ml				39.5

PARTICULATE COLLECTED	FILTER	PROBE WASH
FINAL		
TARE	.8640	
NET GAIN		
TOTAL WEIGHT, mg		

ORSATS TIME	CO_2	O_2	CO	N_2
1840	7.0	12.6		
1910	7.0	12.6		
AVERAGE	7.0	12.6	80.	4

COMMENTS:
Leak Ck .02
at 7" in Hg

LABORATORY DATA

LOCATION OMAHA - PAPILLION DATE 4-18-80 RUN #2

UPSTREAM WASH # 9

FINAL 68,605.8

TARE -68,596.0

195 x .008 = BLANK - 1.6

NET 8.2 mg

THIMBLE # —

FINAL

TARE -

NET

FILTER # —

FINAL 898.0

TARE - 864.0

NET 34.0

DOWNSTREAM WASH #

FINAL

TARE -

x = BLANK -

NET

CONDENSATE #

FINAL

TARE -

x = BLANK -

NET

TOTAL WEIGHT OF PARTICULATES 42.2 mg

COMMENTS

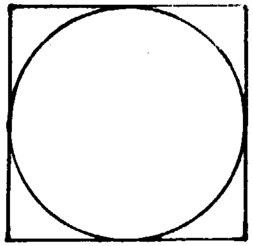
```
                 SOURCE  TEST  DATA  SUMMARY
                 ----------------------------------------------

                                        COMPANY....OMAHA-PAPILLION
                                        LOCATION...UNIT #2
                                        DATE.......4-18-80
                                        TIME.......2033-2135 HRS
                                        TEST RUN #.3

VOLUME THRU DG METER                 Vm =   35.710 cu-ft
VOLUME OF CONDENSATE                Vlc =   42.4 ml
BAROMETRIC PRESSURE                Pbar =   29.30 in,Hg
STATIC PRESSURE                  STATIC =    0.00 in,H2O
ABS. STACK GAS PRESSURE              Ps =   29.30 in,Hg
ABS. GAS METER PRESSURE              Pm =   29.36 in,Hg
ABS. STACK GAS TEMPERATURE           Ts =  553.3 R
ABS. GAS METER TEMPERATURE           Tm =  520.0 R
STACK AREA                           As =    9.621 sq-ft
PITOT TUBE COEFFICIENT               Cp =    0.830
AVE. VELOCITY HEAD OF STACK GAS         =    0.499
NOZZLE AREA                          An = 0.000385 sq-ft

STACK GAS DATA
   TEMPERATURE, F                 93.3
   VELOCITY, ft/sec               28.56
   GAS VOLUME, ACFM            16483.8
   GAS VOLUME, SCFM(WET)       15462.5
   GAS VOLUME, SCFH(DRY)      878312.0
   MOISTURE, %                     5.3
   CARBON DIOXIDE, %(DRY)          7.3
   OXYGEN, %(DRY)                 12.0
   CARBON MONOXIDE, %(DRY)         0.0
   NITROGEN, %(DRY)               80.7
   MOLECULAR WEIGHT, (WET)        29.03

SAMPLING DATA
   TOTAL TIME, min                60.0
   VOLUME, SCF(DRY)               35.706
   ISOKINETIC RATIO, %           101.7

SOLID PARTICULATES
   AMOUNT COLLECTED, mg           47.3
   CONCENTRATION, Grains/SCF       0.0204
   EMISSION RATE, lb/hr            2.5655
```

J.F. LEO

COMPANY OMAHA
LOCATION UNIT #2
DATE 4-18-80
TEST RUN # 3
STACK AREA 42"ϕ
OPERATOR 88

AMBIENT TEMPERATURE 85
BAROMETRIC PRESSURE 29.3
ASSUMED MOISTURE, % 4
HEATER BOX SETTING 260
PROBE HEATER SETTING 250
FILTER NUMBER .8380

SAMPLE BOX # BLUE
METER BOX # GREEN
METER H@ —
C FACTOR —
PROBE LENGTH 4' SS
NOZZLE DIAMETER 17/64


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)	
2033	SE 1	5		90	.20	.447	.65	921.44	60		260	35	
	2	5		90	.25	.500	.80	24.33			260	4.0	
	3	5	0	90	.25	.500	.80	27.44			260	4.0	
	4	5		90	.25	.500	.800	30.52			260	4.0	
	5	5		95	.25	.500	.800	33.60			260	4.0	
	6	5		95	.25	.50	.80	36.64			260	4.0	
2105	SW 1	5		90	.20	.447	.65	39.71			260	35	
	2	5		95	.25	.500	.800	42.46			260	4.0	
	3	5	0	95	.30	.548	.950	45.47			260	45	
	4	5		100	.30	.548	.95	48.95			270	45	
	5	5		95	.25	.500	.80	52.24			260	4.0	
2135	6	5		95	.25	.500	.80	55.32			240	4.0	
TOTAL	☒	60	0.0	1120	☒	5.990	9.60	958.35			☒	☒	
AVERAGE	☒	☒	0.0	93.3	☒	.499	.80	36.91	60		☒	☒	

WATER COLLECTED	IMPINGERS 1	2	3	4
FINAL	75	140		227.4
INITIAL	100	100		200
NET H_2O	-25	40		27.4
TOTAL H_2O COLLECTED, ml				42.4

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

ORSATS TIME	CO_2	O_2	CO	N_2
2040	6.4	13.0		
2110	8.2	11.0		
AVERAGE	7.3	12.0		80.7

COMMENTS:

Leak Ck @ .04 CFM

LABORATORY DATA

LOCATION OMAHA - PAPILLION DATE 4-18-80 RUN #3

UPSTREAM WASH # 10

FINAL 67,219.1

TARE -67,197.5

270 x .008 = BLANK - 2.2

NET 19.4

THIMBLE # —

FINAL

TARE -

NET

FILTER # —

FINAL 865.9

TARE - 838.0

NET 27.9

DOWNSTREAM WASH #

FINAL

TARE -

x = BLANK -

NET

CONDENSATE #

FINAL

TARE -

x = BLANK -

NET

TOTAL WEIGHT OF PARTICULATES 47.3 mg

COMMENTS

Calibration Data

During an aborted test run on the morning of April 18, 1980, water and silica gel were drawn into the metering system. Some of this material affected the calibrated orifice resulting in a change in $\Delta H@$. A field calibration curve was determined for use during testing. Upon return to the PDL Laboratory, a complete meter system calibration was performed which verified the field diagnosis. These data are also presented in the following pages.

DRY GAS METER CALIBRATION

METER BOX IDENTIFICATION GREEN METER # ____

DATE 02-12-80 CALIBRATED BY S.E. SUNDBERG

BAROMETRIC PRESSURE, P_b = 29.10 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
0.5	5.0	2.579	520	29.14	2.612	530	29.02
1.0	5.0	3.631	520	29.17	3.701	530	28.95
1.5	5.0	4.549	520	29.21	4.643	530	28.90
2.0	5.0	5.178	520	29.25	5.308	530	28.88
3.0	5.0	6.502	520	29.32	6.784	530	28.81

CALCULATIONS

	Υ	$\Delta H_@$
ΔH	$\frac{V_w P_w T_d}{V_d P_d T_w} =$	$\frac{0.0317\ \Delta H}{P_w\ T_d}\left[\frac{T_w\ \theta}{V_w}\right]^2 =$
0.5	.989	1.038
1.0	.993	1.080
1.5	1.001	1.031
2.0	.993	1.052
3.0	1.006	.969
AVERAGE	.996	1.034

ORIFICE MAGNEHELIC	MANOMETER
.48	.50
.98	1.00
1.50	1.51
2.00	2.01
3.00	3.02

PITOT TUBE CALIBRATION

Pitot tube identification number 4' SS w/ 1/4 NOZZLE

Date 02-12-80 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 = 1.30 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	.69	.97	.7113	.835	.004
2	.66	.94	.7021	.830	.001
3	.65	.93	.6989	.828	.003
			$\bar{C}_p(A)$ =	.831	σ = .003

"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	.65	.92	.7065	.832	.004
2	.63	.91	.6923	.823	.005
3	.65	.93	.6989	.828	.000
			$\bar{C}_p(B)$ =	.828	σ = .003

$$C_{p(s)} = 0.99\sqrt{\frac{\Delta p_{std}}{\Delta p_{(s)}}} \qquad \sigma\,(A \text{ or } B) = \frac{\sum_{1}^{3} \left|C_{p(s)} - \bar{C}_p(A \text{ or } B)\right|}{3}$$

THERMOCOUPLE CALIBRATION

ICE WATER	30°F
BOILING WATER	210°F
AIR TEMP	70°F

DRY GAS METER CALIBRATION

METER BOX IDENTIFICATION GREEN METER #

DATE 4-22-80 CALIBRATED BY SE. SUNDBERG

BAROMETRIC PRESSURE, P_b = 29.25 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
0.5	5.0	2.556	520	29.29	2.597	530	29.19
1.0	5.0	3.404	520	29.32	3.494	530	29.12
1.5	5.0	4.039	520	29.36	4.184	530	29.08
2.0	5.0	4.560	520	29.40	4.756	530	29.05
3.0	5.0	5.707	520	29.47	5.987	530	28.98

CALCULATIONS

	Υ	$\Delta H_@$
ΔH	$\frac{V_w P_w T_d}{V_d P_d T_w} =$	$\frac{0.0317 \ \Delta H}{P_w \ T_d} \left[\frac{T_w \ \theta}{V_w}\right]^2 =$
0.5	.993	1.087
1.0	1.000	1.204
1.5	1.007	1.261
2.0	1.011	1.303
3.0	1.012	1.236
AVERAGE	1.005	1.218

A13

an
omatest
subsidiary

2917 Douglas Street
Omaha, Nebraska 68131
402/341-5181

Report Number

E 1535

report made for

Henningson, Durham and Richardson
Attn: Mr. Steve Nielson
8404 Indian Hills Drive
Omaha, Nebraska 68114

Report Date

30 April 1980

Report on

Sampling and testing performed for the Papillion Creek Wastewater Plant Sludge Incinerator 302 Performance Test on 17 and 18 April 1980.

Re: HDR No. 17501606

Sampling:

Our representative was on site at Incinerator 302 on 17 and 18 April 1980. Data and/or samples were collected hourly from the following sampling points:

Sampling Point	Description
1	Sludge Cake, Vacuum Filter No. 2
2	Grease, Pump No. 4 (Valve)
3	Scrubber Effluent (Valve)
4	Venturi Recirculating Water (Tank)
5	Ash Slurry (Valve)
6a	Scrubber Water Supply (Valve)
6b	Fluidizing Air.

Sludge cake samples were collected in a large pan, mixed and homogenized before securing the portions for analysis.

Samples from Points 2, 3, 5 and 6a were collected from valves. At each sampling period, the valves were bled before collecting the sample so as to avoid catching any sediment build up within the valves. The samples from Point 4 were collected by bailing.

All samples were then transferred to our Laboratory for analysis. The attached tabulations list the analytical test results.

OMAHA CHEMICAL AND ENVIRONMENTAL TESTING, INC.

Norman H. Hanson

Norman H. Hanson
President

NHH/ee

O: File
3xc: Henningson, Durham and Richardson
Attn: Mr. Steve Nielson

SLUDGE CAKE, VACUUM FILTER NO. 2

Sampling Times During 4/18/80	Total Solids to 103°C, Wt.,%	Ash to 750°C, % DWS	Volatile Solids to 600°C, % DWS	Fixed Carbon, % DWS	Carbon, % DWS	Hydrogen, % DWS	Nitrogen, % DWS	Oxygen, % DWS	Sulfur, % DWS	Btu per lb. of DVS	Sludg Temp. °F*
09:00 hrs	30.74	59.56	39.54	0.90	22.91	3.26	1.98	11.77	0.52	11169	62
10:00 hrs	30.02	64.49	34.15	1.36	N.T.**	N.T.	N.T.	N.T.	N.T.	11185	68
11:00 hrs	29.67	66.06	32.78	1.16	18.05	2.86	2.42	10.19	0.42	11321	78
12:00 hrs	28.66	66.62	32.17	1.21	N.T.	N.T.	N.T	N.T.	N.T.	11429	81
13:00 hrs	28.31	67.46	31.29	1.25	19.59	2.84	2.60	7.05	0.46	11715	80.5
14:00 hrs	32.72	69.78	28.91	1.31	N.T.	N.T.	N.T.	N.T.	N.T.	12000	78
15:00 hrs	29.46	65.56	33.14	1.30	19.72	2.91	2.42	8.93	0.46	11654	79
16:00 hrs	29.50	65.46	33.14	1.40	N.T.	N.T.	N.T.	N.T.	N.T.	11372	78
17:35 hrs	29.64	65.68	32.72	1.60	19.82	2.93	2.34	8.73	0.50	11843	82
18:00 hrs	29.67	65.24	33.25	1.51	N.T.	N.T.	N.T.	N.T.	N.T.	11159	77
19:00 hrs	30.43	64.82	33.70	1.48	17.83	2.98	2.27	11.63	0.47	11435	76
20:00 hrs	29.87	65.51	33.09	1.40	N.T.	N.T.	N.T.	N.T.	N.T.	11556	76
21:00 hrs	29.40	65.22	33.31	1.47	18.31	2.90	2.39	10.65	0.53	11432	75.

* Temperatures taken on site.

** N.T. = Not Tested.

GREASE, PUMP NO. 4

Sampling Times During 4/18/80	Total FOG, % of Total Sample	Total Solids to 103°C, Wt %	FOG, % of Total Solids	Ash to 750°C, % DWS	Volatile Solids to 600°C, % DWS	Fixed Carbon, % DWS	Carbon, % DWS	Hydrogen, % DWS	Nitrogen, % DWS	Oxygen, % DWS	Sulfur, % DWS	Btu per lb, DWS	Grease Temp., °F*
09:04 hrs	30.34	36.91	82.20	7.44	91.95	0.61	66.37	10.80	0.69	14.59	0.11	14654	155
10:04 hrs	73.71	78.16	94.31	2.56	97.12	N.T.**	N.T.	N.T.	N.T.	N.T.	N.T.	15998	136
11:02 hrs	53.36	61.43	86.86	3.96	95.67	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	15426	144
12:05 hrs	49.50	55.37	89.40	4.19	95.27	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	15867	134
13:03 hrs	77.09	78.05	98.77	2.34	97.16	0.50	72.30	11.86	0.20	13.22	0.08	15965	150
14:03 hrs	75.07	77.78	96.52	2.22	97.18	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	15773	128
15:03 hrs	75.70	78.76	96.11	2.41	97.13	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	15912	148
16:03 hrs	74.85	75.98	98.51	2.50	97.10	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	15693	142
17:37 hrs	76.82	78.32	98.09	2.28	97.17	0.55	72.08	12.62	0.20	12.75	0.07	16140	144
18:05 hrs	55.55	61.15	90.84	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	15929	147
19:02 hrs	75.67	77.33	97.85	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	15965	152
20:04 hrs	16.27	22.83	71.26	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	14070	174
21:03 hrs	25.57	28.45	89.89	N.T.	N.T.	N.T.	64.60	10.04	0.72	N.T.	0.11	14076	182.

* Temperatures taken on site.

** N.T. = Not Tested.

SCRUBBER WATER SUPPLY

Sampling Times During 4/18/80	Suspended Solids (Filtered), mg/1	Volatile Solids, % DWS	Temperature, °F (On Site)	Total Solids (Suspended and Dissolved), mg/1
09:06 hrs	56	56.5	63	615
11:07 hrs	40	68.57	63	N.T.*
13:06 hrs	128	47.5	64	N.T.
15:07 hrs	168	46.2	69	N.T.
17:33 hrs	163	47.0	64	N.T.
19:06 hrs	123	47.9	63	N.T.
21:06 hrs	83	47.5	63	N.T.

* N.T. = Not Tested.

SCRUBBER EFFLUENT

Sampling Times During 4/18/80	Suspended Solids (Filtered), mg/l	Total Solids (Suspended and Dissolved), mg/l
09:08 hrs	2241	3002
10:09 hrs	2955	N.T.*
11:08 hrs	2867	N.T.
12:11 hrs	3068	N.T.
13:07 hrs	3233	N.T.
14:08 hrs	2499	N.T.
15:09 hrs	2339	N.T.
16:08 hrs	2750	N.T.
17:27 hrs	2412	N.T.
18:06 hrs	2257	N.T.
19:07 hrs	2484	N.T.
20:08 hrs	2299	N.T.
21:07 hrs	2716	N.T.

* N.T. = Not Tested.

VENTURI RECIRCULATING WATER

Sampling Times During 4/18/80	Suspended Solids (Filtered), mg/l	Total Solids (Suspended and Dissolved) mg/l
09:07 hrs	2741	3507
10:09 hrs	2888	N.T.*
11:08 hrs	3690	N.T.
12:11 hrs	5929	N.T.
13:07 hrs	12794	N.T.
14:08 hrs	4796	N.T.
15:08 hrs	5140	N.T.
16:09 hrs	2796	N.T.
17:29 hrs	2547	N.T.
18:05 hrs	2323	N.T.
19:07 hrs	2372	N.T.
20:09 hrs	2200	N.T.
21:07 hrs	2758	N.T.

* N.T. = Not Tested.

ASH SLURRY

Sampling Times During 4/18/80	Suspended Solids (Filtered), mg/1	Ash, % DWS	Volatile Solids, % DWS	Fixed Carbon, % DWS	Temp., °F*	Total Solids (Suspended and Dissolved), mg/1
09:06 hrs	7404	97.87	1.57	0.56	111	8209
10:06 hrs	9767	N.T.**	N.T.	N.T.	117	N.T.
11:05 hrs	10713	98.25	1.26	0.49	119	N.T.
12:10 hrs	7138	N.T.	N.T.	N.T.	122	N.T.
13:05 hrs	9775	98.03	1.51	0.46	121	N.T.
14:07 hrs	10043	N.T.	N.T.	N.T.	113	N.T.
15:05 hrs	5773	97.71	1.70	0.59	118	N.T.
16:07 hrs	9052	N.T.	N.T.	N.T.	119	N.T.
17:32 hrs	8870	97.75	1.94	0.31	122	N.T.
18:09 hrs	7102	N.T.	N.T.	N.T.	112	N.T.
19:05 hrs	6195	97.50	2.23	0.27	113	N.T.
20:08 hrs	7222	N.T.	N.T.	N.T.	113	N.T.
21:05 hrs	8837	98.40	1.47	0.13	117	N.T.

* Temperatures taken on site.

** N.T. = Not Tested

FLUIDIZING AIR

Sampling Times During 4/18/80	Temperature, °F	Relative Humidity, %
09:13 hrs	83.0	33.0
11:12 hrs	86.5	33.0
13:11 hrs	90.5	27.0
15:14 hrs	91.5	27.5
17:18 hrs	91.5	27.0
19:13 hrs	92.0	26.0
21:10 hrs	90.0	28.0.

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 conditions.

$(\sqrt{\Delta p})_{avg}$ = 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 mercury.

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:

$$M_s = (1-B_{wo})(0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%CO + \%N_2)) + 18\ B_{wo}$$

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.

0.44 = Molecular weight of CO_2 divided by 100.

0.32 = Molecular weight of O_2 divided by 100.

0.28 = 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 O, $\%O_2 = 21$ 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 inches 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 must 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, variation within the range of 90%-110% 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) is 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 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 dry gas meter temperature, $^\circ$R.

P_m = Average absolute meter pressure, inches Hg.

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

where: V_{l_c} = Total volume of liquid 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 a contaminant in the stack gas, grains/scf, dry basis.

M_n = Total amount of contaminant collected, milligrams.

The concentrations of certain gaseous components of an effluent 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 stack gas. Conversion from ppm (vol) to pound makes 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:

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

where: c_sQ_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 or in the preceeding discussion of Source Testing.

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 basis (scf (dry)).
DSCFH = Cubic feet at standard conditions, dry basis, per hour (scfh (dry)). On the computer out puts this is given in exponential form, e.g., .534774E 06 = $.534774 \times 10^6$ or 534,774.
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,H_2O = Inches of water (in, H_2O or 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)).