STAPPA/ALAPCO 730053

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12/17/86

INCINERATOR COMPLIANCE TEST
at
THE GLASTONBURY
SEWAGE TREATMENT PLANT
in
GLASTONBURY, CONNECTICUT
for
THE BSP DIVISION
ENVIROTECH SYSTEMS, INC.

Prepared By

YORK RESEARCH CORPORATION
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REPORT NO. Y-8200

August 21, 1973

I. ABSTRACT

On July 25th and 26th, 1973, York Research, an independent consulting firm in the environmental field, began a series of emission sampling tests at the Glastonbury Sewage Treatment Plant in Glastonbury, Connecticut.

The purpose of these tests was to determine compliance with Connecticut State Regulations for particulate emissions from an incinerator. NO_x, SO_x, hydrocarbon and CO were also tested per a State request.

The Connecticut State Regulations as specified in "Administrative Regulations", Department of Environmental Protection, Abatement of Air Pollution, May 23, 1972, Page 14B, Section 19-508-18 "Control of Particulate Emissions" subsection (C)(3)(i) "Emission Standards. Particulates" states:

> No person shall construct, install, use or cause to be used any new (constructed or modified after June 1, 1972) incinerator which will result in particulate matter in the effluent in excess of 0.08 gr/SCF (0.18 gm/NM^3) corrected to 12% CO_2, maximum 2 hour average. No person shall use or cause to be used any existing incinerator which will emit more than 0.4 lb. particulate/1000 lbs. of flue gases adjusted to 50% excess air.

The following Table gives the results of the scrubber outlet sampling in terms as used in the Connecticut State Regulations.

Particulate Test	gr/SCF (12% CO_2)	lbs./1000 lbs. (Flue Gas @ 50% Excess Air)
1	.0306	.0394
2	.0250	.0336
3	.0330	.0428
Average	.0295	.0386
State Limitations	.08 gr/SCF (12% CO_2)	.4 lbs./1000 lbs. (Flue Gas @ 50% Excess Air)

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II. SUMMARY OF RESULTS

OUTLET PARTICULATE

Test	1	2	3
Date	7/25/73	7/25/73	7/26/73
Time	1509-1725	1914-2142	1049-1305
Gas Velocity, FPM	1564	1526	1392
Gas Flow, SCFM	3767	3397	3010
Isokinetic Sampling Rate,%	99.4	93.6	107.8
Particulate Concentration,			
gr/SCF	.0219	.0184	.0228
gr/CF	.0172	.0133	.0160
gr/SCF (12% CO_2)	.0306	.0250	.0330
Particulate Emission Rate,			
lb/hr.	.7079	.5343	.5891
lbs/1000 lbs. (50% E.A.)	.0394	.0336	.0428
Sludge Feed Rate (ton/hr.)	2.20	2.42	2.43

SO_x

Test	1	2	3	4	Average
Date	7/25/73	7/25/73	7/26/73	7/26/73	-
Time	1710-1725	1940-2000	1132-1147	1225-1240	-
SO_2 (ppm)	20.2	9.00	19.3	47.8	24.0
SO_3 (ppm)	1.15	2.25	.865	2.09	1.59

NO_x

Test	1	2	3	4	5	6	7	8	9	10	Average
Date	7/25/73	7/25/73	7/25/73	7/25/73	7/25/73	7/25/73	7/26/73	7/26/73	7/26/73	7/26/73	
Time	1250	1253	1257	1259	1302	1304	1430	1431	1432	1433	-
NO_2 (ppm)	123	164	68	145	160	111	214	173	230	176	156.4

HYDROCARBONS

Test	1	2	3	4	5	6	Average
Date	7/26/73	7/26/73	7/26/73	7/26/73	7/26/73	7/26/73	-
ppm*	9.05	9.81	6.14	2.96	4.10	0.54	5.43
CO (ppm)	97	144	138	95	122	128	121

*Based on $C_6 H_{14}$

III. GENERAL TEST METHODS

Particulate Sampling Train - EPA Method 5

The sampling apparatus consisted of a three (3) foot probe, cyclone bypass, filter, four impingers, dry gas meter, vacuum pump and flow meter (See Figure 1). The stainless steel, button-hook type probe tip (1) was connected by a stainless steel coupling (2) with asbestos packing to the probe. The probe (3) consisted of 5/8 inch outside diameter medium wall Pyrex glass tube with a ground balljoint on one end. The probe was logarithmically wound from the entrance end with 26-gauge nickel-chromium wire. During sampling, the wire was connected to a variable transformer to maintain a gas temperature of 300°F in the probe. The wire wound tube was wrapped with fiberglass tape and encased in a 1-inch-OD stainless steel casing for protection. The end of the steel probe casing does not have the balljoint protruding but has a nut welded to it for connection to the stainless steel coupling used to attach the nozzle. The probe connects to a cyclone bypass (4). The cyclone bypass connects to a very coarse fritted glass filter holder (5), which holds a tared glass fiber filter. The cyclone, flask, and filter were contained in an electrically heated enclosed box (6) which is thermostatically maintained at a minimum temperature of 300°F to prevent water condensation. Attached to the heated box was an ice bath (7) containing four impingers connected in series with glass balljoints. The first impinger (8) receives the gas stream from the filter. This impinger is of the Greenburg-Smith design modified by replacing the tip with a 1/2 inch ID glass tube extending to 0.5 inches from the bottom of the flask. This impinger was initially filled with 100 milliliters of distilled water. The second impinger (9) is of the Greenburg-Smith design and like the first was initially filled with 100 milliliters of distilled water. The third impinger (10), which was left dry, is a Greenburg-Smith impinger modified like the first. The fourth impinger (11) is also a Greenburg-Smith type modified like the first and contained dry silica gel.

From the fourth impinger (11) the effluent stream flows through a check valve (13); flexible rubber vacuum tubing (14); vacuum gauge (15); a needle valve (16); a leakless vacuum pump (17), rated at 4 cubic feet per minute at 0 inches of mercury gauge pressure and 0 cubic feet per minute at 26 inches of mercury gauge pressure, and connected in parallel with a bypass valve (18); and a dry gas meter rated at .1 cubic foot per revolution (19). A calibrated orifice (20 completes the train and was used to measure instantaneous flow rates. The three thermometers (21) are dial type with a range of 25° to 125°F. A fourth thermometer in the heated portion of the box has a range up to 500°F. The dual manometer (21) across the calibrated orifice is an inclined-vertical type graduated in hundredths of an inch of water from 0 to 1.0 inch and in tenths from 1 to 10 inches.

The circular outlet stack was measured as 1'-11 3/4" I.D.. Two ports 90° to each other were located approximately 7 feet above the nearest downstream restriction, and approximately 9 feet from the top of the stack. (See Figure 2.) Twelve points were sampled in each port for five minutes each. Readings were taken every five minutes. (See Figure 3). The location of each sampling position was determined by Method 1 of the Federal Register, December 23, 1971.

Readings Taken

During each run the following readings were taken at each point:

1. Point Designation
2. Clock Time
3. Dry gas meter reading (CF)
4. Velocity head (ΔP in inches water)
5. Desired pressure drop across orifice (ΔH in inches of water)
6. Actual pressure drop across orifice (ΔH in inches of water)
7. Dry gas temperature (°F) gas meter inlet
8. Dry gas temperature (°F) gas meter outlet
9. Vacuum pump gauge reading (in. Hg)
10. Filter box temperature (°F)
11. Dry gas temperature (°F) at the discharge of last impinger
12. Stack temperature (°F)
13. Stack pressure (inches water)

The relationship of ΔP reading with the ΔH reading is a function of the following variables:

1. Orifice calibration factor
2. Gas meter temperature
3. % moisture in the flue gas
4. Ratio of flue gas pressure to barometric pressure
5. Stack temperature
6. Sampling nozzle diameter

A nomograph was used to correlate all the above variables such that a direct relationship between ΔP and ΔH could be determined by the sampler within fifteen seconds and isokinetic conditions maintained throughout the test.

Hydrocarbon and Carbon Monoxide Sampling

The Hydrocarbon/Carbon Monoxide sampling train consists of (1) a heated glass probe, (2) a 3 inch coupling, (3) an aluminum box, (4) three 250 Ml hydrocarbon sampling flasks. The flasks are connected to a manifold with 12/5 ball and socket joints, (5) two 350 watt strip heaters (one on the bottom of the box, the other inside the top cover), (6) a thermometer, (7) the exhaust from the box to the pump inlet. (See Figure 2.)

A sample is drawn through one flask at a time, for a minute or two. The valve on the pump end of the flask is closed first then the valve on the probe end. Three samples are taken during each particulate test.

Oxides of Nitrogen (EPA Method No. 7)

A grab sample is collected in an evacuated flask containing a dilute sulfuric acid - hydrogen peroxide absorbing solution.

The sampling procedure consists of pipetting 25 ml of H_2SO_4 - H_2O_2 absorbing solution into a 2 liter sampling flask. The flask is then evacuated to at least 3 in. Hg. absolute pressure. The next step is to evacuate the probe prior to sampling. The sample is then taken over a period of 15 seconds. After the sample has been collected, the flask is shaken for approximately 5 minutes. After this period the flask must be left with the sample for a minimum of 16 hours. After the 16 hours, the flask is reshaken for a period of two minutes. After this the final pressure of the flask is recorded and the sample is transferred to the lab for analysis. The sampling apparatus used to collect oxide of nitrogen samples is shown in Figure 3.

SO_2, SO_3 Analysis (EPA Method No. 6)

The sulfur dioxide sampling train consists of the following components arranged and illustrated schematically (See Figure 4): (1) glass wool filter, (2) an electrically heated glass probe, (3) variac, (4,5,6,7) four midget impingers, (8) ice bath, (9) drying tube containing silica gel, (10) vacuum gauge, (11) control valve, (12) vacuum pump, (13) dry gas meter, and (14) thermometer.

The probe is made of an 18" length of medium wall Pyrex tubing wound with 26 gauge nichrome heating wire. The front end of the probe includes a two-inch long area for insertion of glass wool to be used as a filtering device. The wire is connected to a variable transformer which allows the voltage and hence the heat input to be controlled. The wire is covered with a fiberglass insulation tape.

The probe connects to a coarse frit midget bubbler containing 15 ml of 80% isopropanol, and three midget impingers, the first two of which contained 15 ml of 3% H_2O_2 each with the third left dry, connected in series. The chamber near the bubbler outlet is stuffed with fine glass wool. An ice bath is provided for the bubbler and impingers. Attached to the outlet of the third impinger is a drying tube filled with silica gel of the indicator type. A bypass valve is provided for the leakless pump and a vacuum gauge and needle valve were installed at the inlet of the pump. The dry gas meter has a sensitivity of 0.001 cubic foot and is fitted with thermometers on the meter inlet and outlet.

CO_2 and O_2

CO_2 and O_2 samples were collected by traverse through a sampling tube attached to the particulate sampling probe and aspirated into leveling bottles as illustrated in Figure 5. The gas collected was immediately tested with an Orsat apparatus for CO_2 and O_2 concentration.

Sampling Nozzle Selection

In order to insure accurate results, especially where sizeable particles are present, it is necessary that the gas entering the nozzle be drawn through the sampling nozzle at approximately the same velocity as that of the gas passing the nozzle in the flue at the sampling point. Calculations of meter rates must consider the difference in temperature and pressure between the meter and the nozzle and the moisture content of the gas.

The size of the sampling nozzle depends on the gas velocity and sampling rate to be maintained. It should be large enough to give a suitable dust sample in a reasonable time, one tenth gram being about the minimum desirable. A sampling nozzle size to give an isokinetic sampling rate between .50 to 1.00 cubic feet per minute is best suited to the equipment described.

Determination of Mass Flow and Temperature

Mass flow and temperature are determined by use of a pitot tube and inclined manometer, the two adapters are screwed in tightly and a suitable length of rubber tubing is connected to each. The manometer fluid is then poured in until it reached a level at which the meniscus rests at the zero on the gauge. Slight additional adjustment can be made by moving the scale plate. The Pitot Tube is then connected to the manometer and the zero point read with the Pitot Tube end protected from stray air currents.

This is noted as a zero reading or the manometer was adjusted to read zero. The Pitot Tube is then inserted in the flue at the desired point, taking care to pinch the rubber tubes on entry to avoid blowing or sucking oil from the manometer. When making a reading, the Pitot Tube must always point directly into the flow of gas.

The reading of the manometer is noted at each point of measurement and the differences between this reading and the zero reading is the measure of the velocity pressure at the points of measurement. When the flow of gas is quite regular, it should be possible to estimate the reading to within .005 inches on the manometer.

The temperature of the gas in the flue is noted by means of a pyrometer.

The relation of the pressure of the gas in the flue to atmosphere is usually measured. If within the range of the gauge, it may be referred to the atmospheric pressure outside the flue by the draft gauge and the other end of the gauge open to the atmosphere. If a pressure of more than 2" wc exists, then a "U" tube gauge should be used. Care should be taken to protect the open end of the gauge connection from air currents. This can conveniently be done by placing a loose ball of cotton waste over the opening.

For accurate work, it is also necessary to determine the density of the gas, or its specific gravity referred to some standard gas, such as air. This can be calculated from its chemical composition. For ordinary combustion gases, it is often sufficiently accurate to assume that the density of the gas is the same as that of air, i.e., that is specific gravity referred to air is 1.00.

IV. ANALYTICAL PROCEDURE

Particulate

The filter discs were previously tare weighed and the weights recorded at York Research's Laboratory. Upon return they were dried, cooled in a dessicator, then weighed on an analytical balance. The amount of particulate collected is the difference in the weights. The probe and nozzle acetone wash solution is placed into a tared beaker, evaporated with an Infra-Red Lamp and the beaker weighed again. The difference in weight is the weight of the particulate in the wash. This is combined with the filter catch as the weight of the sample.

Hydrocarbons

The method used to measure the hydrocarbon sample is with a Perkin Elmer 881 gas chromatograph with flame ionization detectors. A 1/8" blank stainless steel column at 200°C with a Perkin Elmer 1cc gas sampling loop is used to inject the sample into the detector.

The samples are heated and displaced from the flask with mercury. Standards are made up from calibrated gases using a PPM Hexane in N_2 standards.

Carbon Monoxide

Carbon Monoxide are analyzed by using the grab flasks used for hydrocarbons and analyzing them by non-dispersive Infra-Red (NDIR) analysis. Detection tubes are also used in the field as a check. The laboratory sample of CO comes from the 250 ml flask used for hydrocarbon collection.

NO_2 Analysis

The amount of nitrogen in the sample is determined by the phenoldisulphonic method. This method is as follows:

The sample is placed in a beaker and NaOH is slowly added until the solution is neutral or slightly basic by litmus paper indication. This solution is then evaporated in the beaker used for neutralization. To the dry residue, two (2) milliliters of phenoldisulphonic acid are added and mixed to dampen all the precipitate. Then add two (2) milliliters of distilled water and mix thoroughly; add twenty (20) more milliliters of distilled water and mix. Add concentrated NH_4OH to this solution in excess of neutralization. Filter solution if necessary and transfer to a volumetric flask. Using a spectrophotometer at 420 Mu, compare results with a standard curve based on standard concentrations, and read milligrams of nitrogen in the sample.

After the amount of nitrogen in the sample is known, the concentration is calculated using the following formula.

$$\text{ppm } NO_x = \frac{(29.63)(\text{Mg } NO_x)(T_f + 460)}{(V_f)(P_i - P_f)}$$

Where:

ppm NO_x = parts per million of NO_x
Mg NO_x = milligrams of NO_x in sample
T_f = flask temperature (°F)
P_i = initial flask pressure (in. Hg.)
P_f = final flask pressure
V_f = flask volume

SO_2 , SO_3 Analysis

The amount of sulfur dioxide and sulfur trioxide are measured as follows:

Dilute solution used for sampling to 50 ml. Pipette 10 ml. of this solution into a 125 ml. Erlenmeyer flask. Add 40 ml. of isopropanol and two to four drops of thorin indicator. Titrate to a pink endpoint using 0.01 N barium perchlorate. Run a blank with each series of samples.

The SO_2 and SO_3 concentration is calculated as follows:

$$C_{SO_2} = (7.05 \times 10^{-5} \frac{\text{lb-l}}{\text{g-ml}}) \frac{(V_t - V_{tb})\ N\ \frac{(V_{soln})}{(V_a)}}{V_{m_{std}}}$$

Where:
V_t = Volume of Barium perchlorate titrant used, ml.
V_{tb} = Volume of Barium perchlorate titrant used in blank, ml.
N = Normality of Barium perchlorate titrant, g-eq./l.
V_{soln} = Total solution volume of SO_2, SO_3, 50 ml.
V_a = Volume of sample aliquot titrated, ml.
$V_{m_{std}}$ = Volume of gas sample through the dry gas meter (std. conditions), cu.ft.

CO_2 and O_2

CO_2 and O_2 samples were collected by traverse through a sampling tube attached to the particulate sampling probe and aspirated into leveling bottles as illustrated in Figure 5. The gas collected was immediately tested with an Orsat apparatus for CO_2 and O_2 concentration.

TEST TEAM

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V. FIGURES

PARTICULATE SAMPLING TRAIN

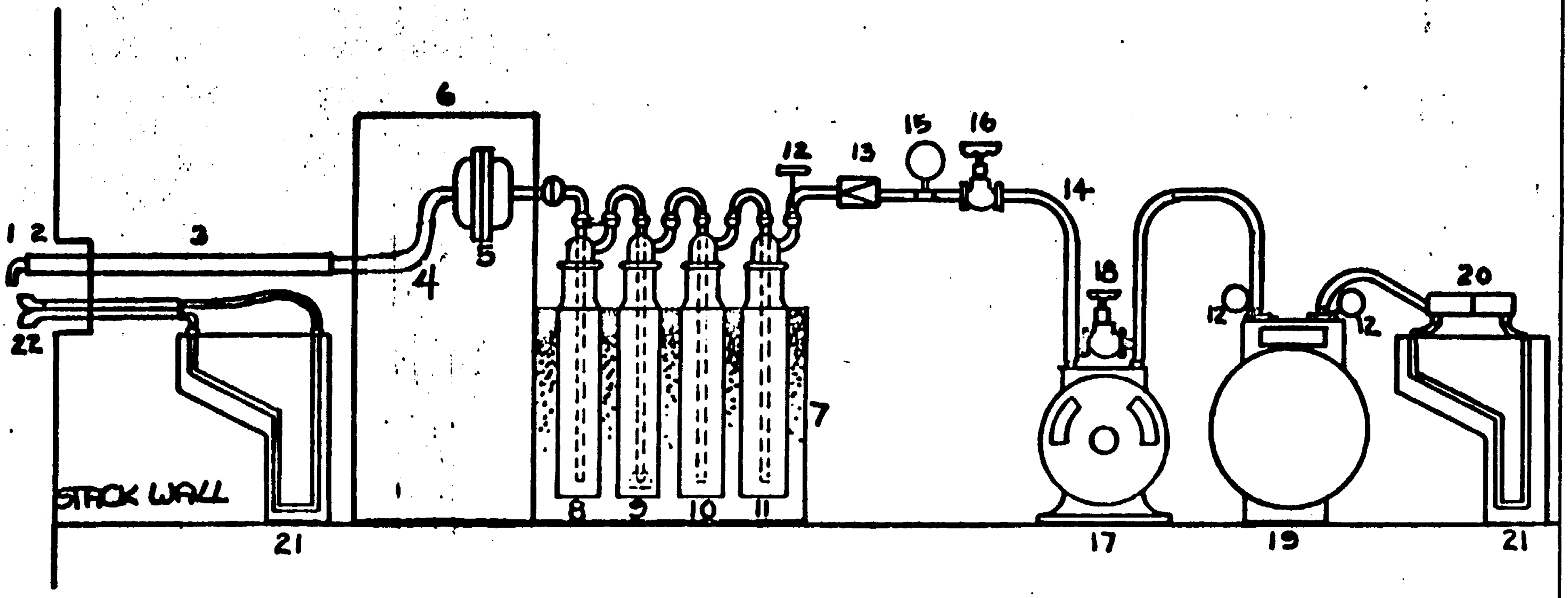
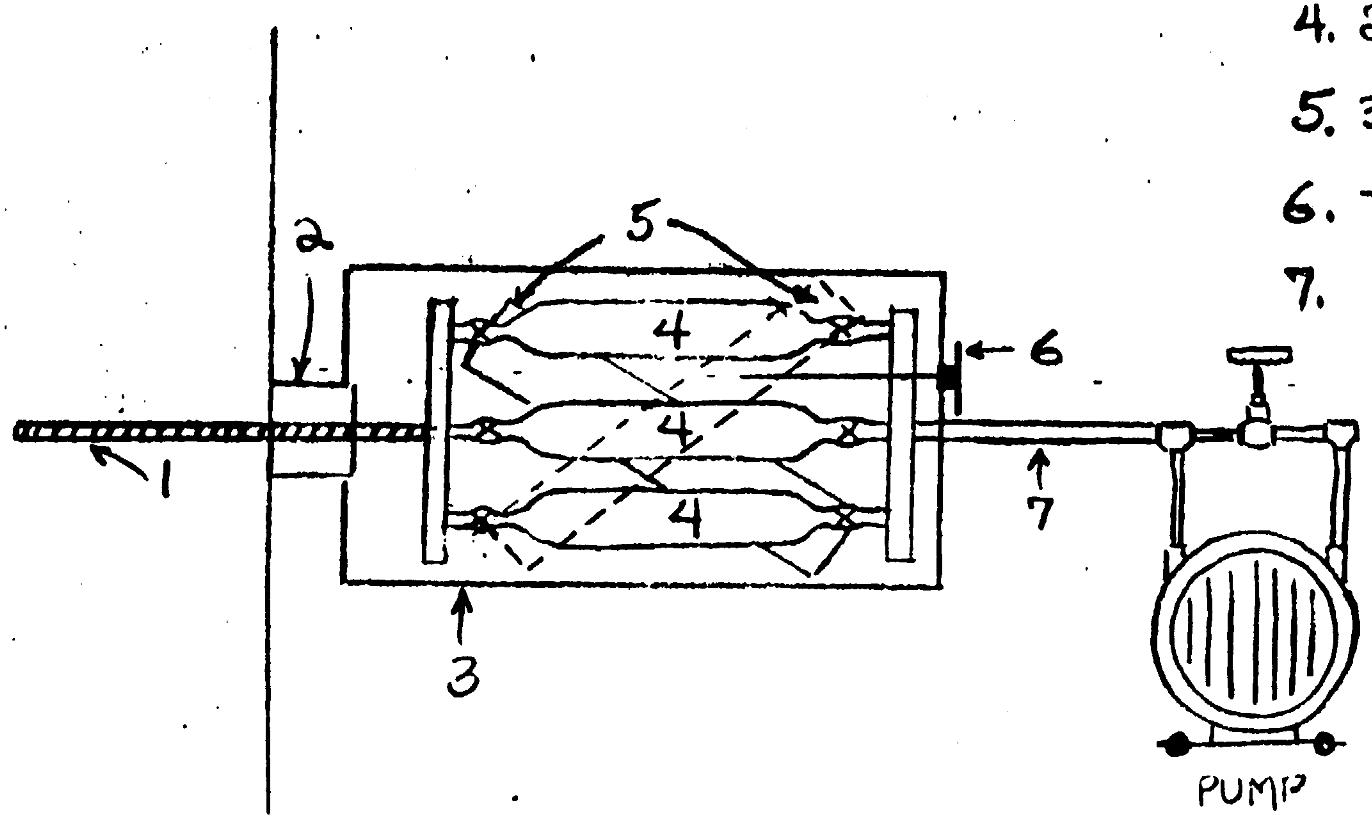


FIGURE #1

HYDROCARBON SAMPLING

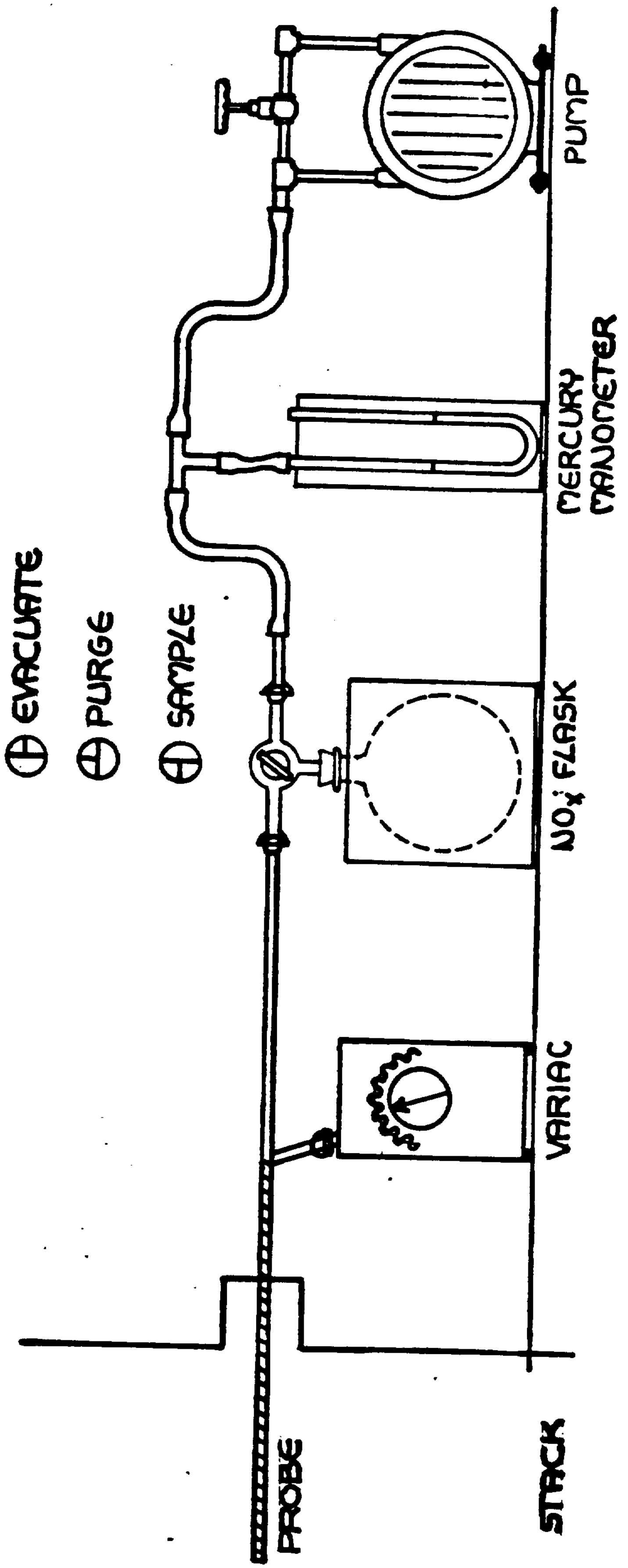
FIGURE #2

1. HEATED GLASS PROBE
2. 3 INCH COUPLING
3. ALUMINUM BOX
4. 250 ml FLASKS
5. 350 WATT HEATERS
6. THERMOMETER
7. EXHAUST LINE



NOx SAMPLING TRAIN

FIGURE #3



SO_x SAMPLING TRAIN

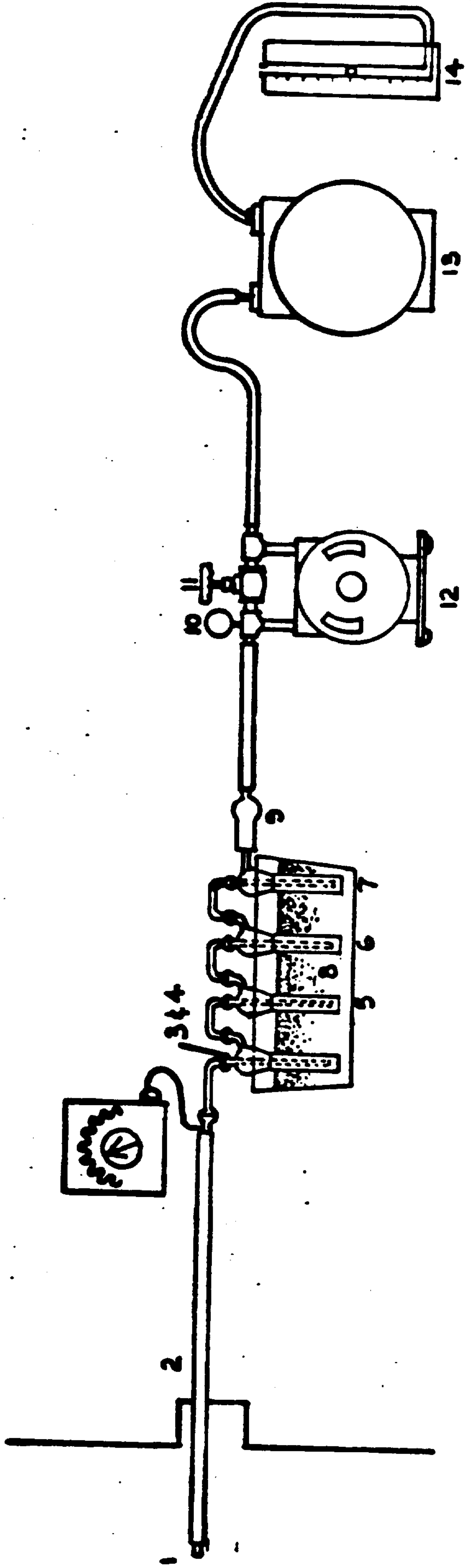
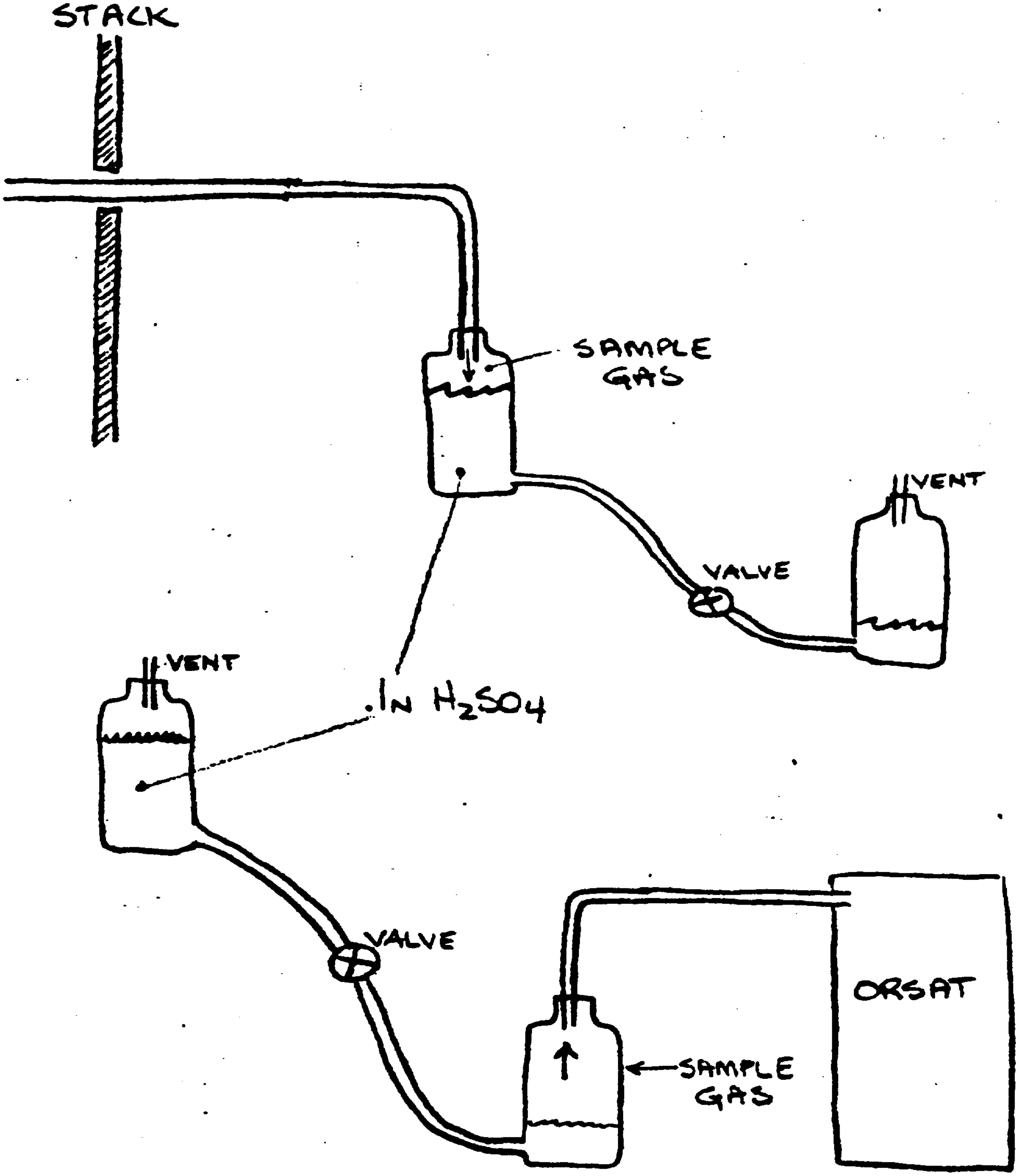
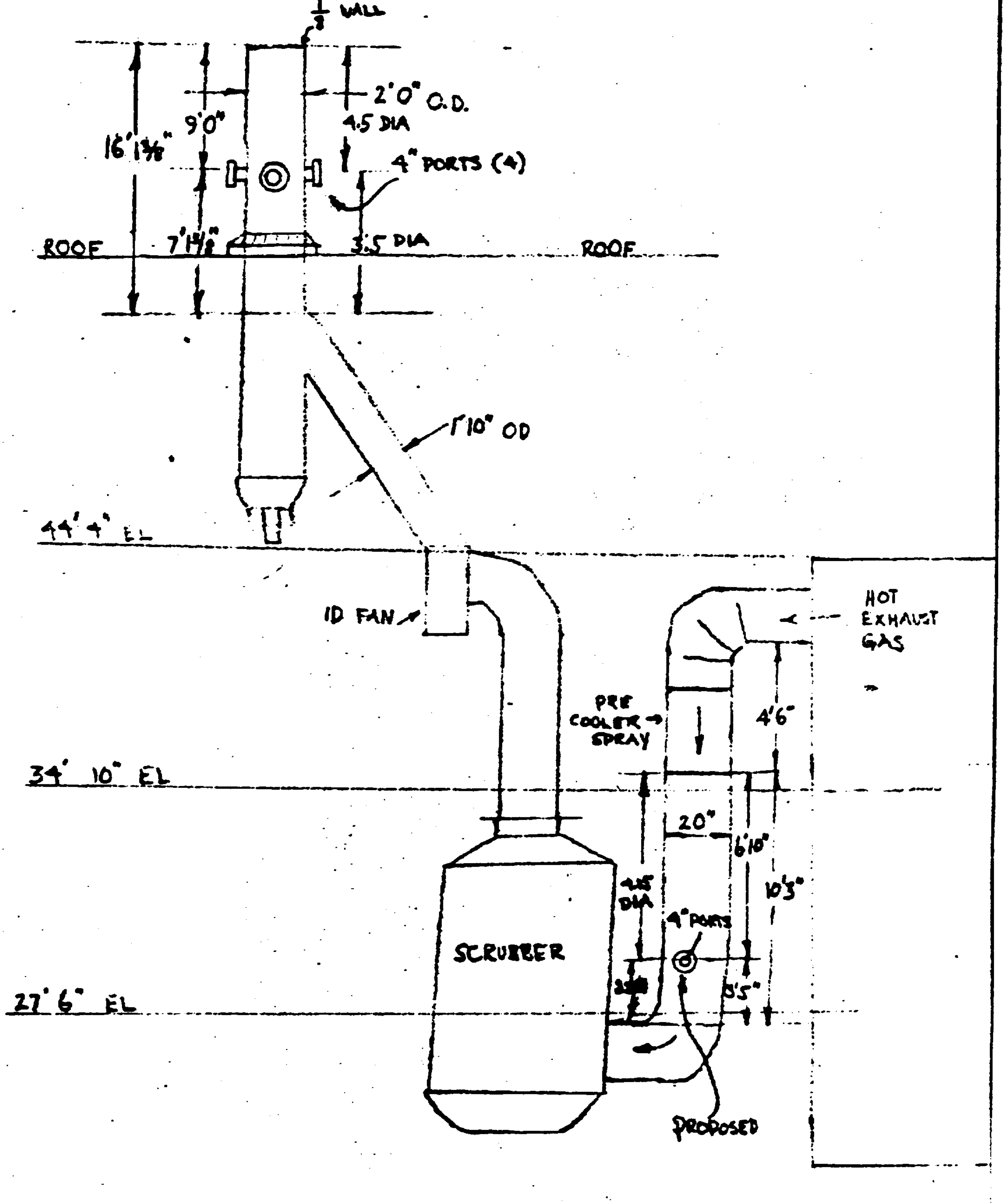


FIGURE #4

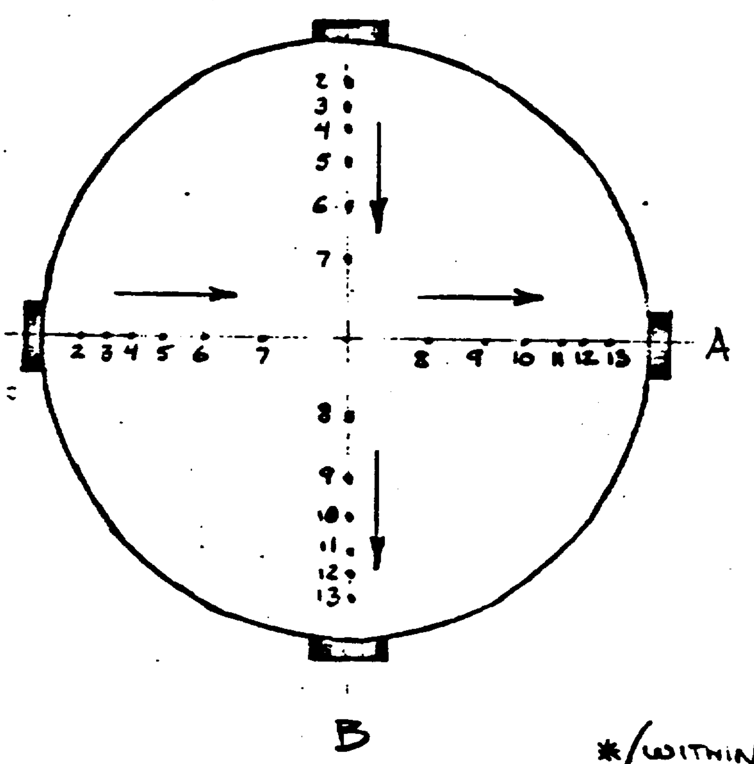
FLUE GAS COLLECTION BY
LEVELING BOTTLE/ORSAT
FIGURE# 5



STACK LOCATION
FIGURE #6



SAMPLING POINT LOCATION
FIGURE # 7



POSITION	DISTANCE
1	*
2	1 5/16"
3	2 5/16"
4	3 1/2"
5	4 3/4"
6	6 3/8"
7	8 11/16"
8	15 1/16"
9	17 3/8"
10	19 "
11	20 5/16"
12	21 3/8"
13.	22 3/8"
14	*

*(WITHIN 1" OF WALL NOT BEING USED)

OUTLET SAMPLING POINT POSITIONS

- I.D. = 1'-11 3/4"
- WALL THICKNESS = 1/8"
- PER FEDERAL REGISTER FIG 1-1

  38 POINTS
  × .67 (UNDER 2'-0")
  25.5 POINTS = ~~26~~ = 28 POINTS
- $\frac{28}{2}$ = 14 POINTS/PORT (USING 2 PORTS)

VI. APPENDIX

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION
STATE OFFICE BUILDING HARTFORD, CONNECTICUT 06115

DAN W. LUFKIN
COMMISSIONER

August 15, 1973

Mr. Robert Epstein
York Research Co.
One Research Drive
Stamford, Connecticut 06906

Dear Mr. Epstein:

This letter shall serve as acceptance of the field test procedures employed by York Research Co. in testing the effluent from the Glastonbury Sewage Sludge incinerator. Because of conflicting schedules the Department could not observe the Field at the Glastonbury plant. The Department has, however, observed the equipment and test procedures used by York in testing two other sewage sludge incinerators and was satisfied with York's performance.

We will continue to spot check York and other consultants performing tests in the state to insure reliable test results.

If there are any questions concerning this letter please do not hesitate to contact me at this office. The telephone number is (203) 566-2690.

Very truly yours,

Carl Dodge

Carleton Dodge
Senior Air Pollution Engineer

CD/lsy

DESCRIPTION OF OPERATIONS

The incinerator is a multiple-hearth furnace which is 16 feet 9 inches in diameter and has 6 hearths. The temperatures in the furnace are regulated by North American burners located on hearths 1, 2, 4, & 5. The total burner system has a maximum capacity of 13,000,000 BTU/HR and consumes 13,000 SCFH of natural gas. The furnace is designed to burn 5,000 lb/hr of a mixture of primary and secondary sludge. The composition of the sludge, skum, and fuel are:

SLUDGE		(estimated)
82	%	Moisture
75	%	Volatile Solids (dry basis)
55.8	%	Carbon (volatile basis)
8.2	%	Hydrogen (volatile basis)
31.0	%	Oxygen (volatile basis)
5.0	%	Nitrogen (volatile basis)
0.0	%	Sulfur (volatile basis)
11,000		BTU/LB Heating Value (volatile basis)

DESCRIPTION OF OPERATIONS (continued)

FUEL (estimated)

Natural Gas

76.1	%	Carbon
23.0	%	Hydrogen
0.0	%	Oxygen
0.9	%	Nitrogen
0.0	%	Sulfur
0.0	%	CO_2
0.0	%	ASH
22,800		Heating Value (BTU/LB)

The combustion air for the sludge and/or other components of the waste will be supplied by air ports such that 75% excess air on the volatiles is maintained.

As the sludge is burned, a relatively large amount of gases are produced. What remains after combustion is a sterile ash which is transported to another location by some suitable means. Along with the combustion gases produced by the sludge and auxiliary fuel (if any) is particulate matter. This particulate matter is passed through a scrubbing system which removes the dust particles. The resulting effluent gas stream then conforms to the local air pollution regulations.

DESCRIPTION OF OPERATIONS (continued)

The scrubber shall be an impingement type using 150 GPM total water for adequate scrubbing of gases. The scrubber will have an outlet volume of 7,800 ACFM (maximum) @ 175°F with a differential pressure of 5" W.C. at the designed scrubber outlet volume with an inlet dust loading of approximately 6 # particulates/ 1000 # dry gases. The emission rate shall not exceed 0.2 #/hour of particulates per 1000 # of dry gases corrected to 50% excess air.

The induced draft fan shall be rated at 7.8" Δ P static pressure and 8,900 ACFM @ 175°F and 0 feet above sea level at operating conditions.

PARTICULATE CALCULATIONS

The following are the basic equations used in calculating final data as found in the final summary.

1. Volume of dry gas sampled at standard conditions - 70°F, 29.92" Hg, ft.^{3}

$$V_{m_{std}} = \frac{17.7 \times V_m \left(P_b + \frac{P_m}{13.6}\right)}{(T_m + 460)} = \text{Ft.}^3$$

2. Volume of water vapor at 70°F and 29.92" Hg, Ft.^{3}

$$V_{w_{gas}} = 0.0474 \times V_w = \text{Ft.}^3$$

3. % Moisture in stack gas

$$\%M = \frac{100 \times V_{w_{gas}}}{V_{m_{std}} + V_{w_{gas}}} = \%$$

4. Mole fraction of dry gas

$$M_d = \frac{100 - \%M}{100}$$

5. Average molecular weight of dry stack gas

$$M\,W_d = (\%\,CO_2 \times \frac{44}{100}) + (\%O_2 \times \frac{32}{100}) + (\%N_2 \times \frac{28}{100})$$

6. Molecular weight of stack gas

$$M\,W = M\,W_d \times M_d + 18\,(1 - M_d)$$

7. Stack velocity at stack conditions, fpm

$$V_s = 4350 \times \sqrt{\Delta P_s \times (T_s + 460)} \left(\frac{1}{P_s \times M\,W}\right)^{1/2} = \text{fpm}$$

8. Stack gas volume at standard conditions, SCFM

$$Q_s = \frac{0.123 \times V_s \times A_s \times M_d \times P_s}{(T_s + 460)} = \text{SCFM}$$

9. Percent isokinetic

$$\%I = \frac{1032 \times (T_s + 460) \times V_{m_{std}}}{V_s \times T_t \times P_s \times M_d \times (D_n)^2} = \%$$

10. Particulate - probe, cyclone and filter, gr/SCF

$$C_{an} = 0.0154 \times \frac{M_f}{V_{m\ std}} = \text{gr/SCF}$$

11. Particulate total, gr/SCF

$$C_{ao} = 0.0154 \times \frac{M_t}{V_{m\ std}} = \text{gr/SCF}$$

12. Particulate - probe, cyclone and filter, gr/CF at stack conditions

$$C_{at} = \frac{17.7 \times C_{an} \times P_s \times M_d}{(T_s + 460)} = \text{gr/CF}$$

13. Particulate - total, gr/CF at stack conditions

$$C_{au} = \frac{17.7 \times C_{ao} \times P_s \times M_d}{(T_s + 460)} = \text{gr/CF}$$

14. Particulate - probe, cyclone and filter, lb/hr.

$$C_{aw} = 0.00857 \times C_{an} \times Q_s = \text{lb/hr.}$$

15. Particulate - total, lb/hr.

$$C_{ax} = 0.00857 \times C_{ao} \times Q_s = \text{lb/hr.}$$

16. % Excess air at sampling point

$$\%\ EA = \frac{100 \times \%\ O_2}{0.264 \times \%\ N_2 - \%\ O_2} = \%$$

17.

$$\frac{\text{Lb.(Part.)}}{10^3\ \text{lb. Flue Gas @ 50\% Ex. Air}} = \frac{\text{gr.(Part.)}}{\text{SCF @ 50\% Ex. Air}} \times \frac{\text{Lb.(Part.)}}{7000\ \text{gr}} \times \frac{10^3\ \text{lb-MOL}}{\text{MW-}10^3\ \text{Lb Flue Gas}} \times \frac{387\ \text{S}}{\text{Lb.-M}}$$

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SOURCE TESTING CALCULATION FORMS

Test No. Y-8200 No. Runs 3

Name of Firm ENVIROTECH SYSTEMS, INC

Location of Plant GLASTONBURY, CONN.

Type of Plant SEWAGE TREATMENT

Control Equipment SCRUBBER

Sampling Point Locations OUTLET

Pollutants Sampled PARTICULATE

Time of Particulate Test:

Run No. 1 Date 7-25-73 Begin 1509 End 1725

Run No. 2 Date 7-25-73 Begin 1914 End 2142

Run No. 3 Date 7-26-73 Begin 1049 End 1305

PARTICULATE EMISSION DATA

Run No.	1	2	3	
P_b barometric pressure, "Hg Absolute	30.03	30.03	30.03	
P_m orifice pressure drop, "H_2O	1.48	1.36	1.00	
V_m volume of dry gas sampled @ meter conditions, ft.^{3}	82.082	68.625	69.819	
T_m Average Gas Meter Temperature, °F	101	92	90	
V_m std. Volume of Dry Gas Sampled @ Standard conditions, ft.^{3}	78.052	66.300	67.640	
V_w Total H_2O collected, ml., Impingers & Silica Gel.	207.4	303.0	378.0	
V_w gas Volume of Water Vapor Collected ft.^{3} @ Standard Conditions*	9.831	14.362	17.917	

* 70°F, 29.92" Hg.

PARTICULATE EMISSION DATA (cont'd)

Run No.	1	2	3	
%M - % Moisture in the stack gas by volume	11.2	17.8	20.9	
M_d - Mole fraction of dry gas	.888	.822	.791	
% CO_2	8.6	8.8	8.3	
% O_2	6.6	6.8	7.2	
% N_2	84.8	84.4	84.5	
MW_d - Molecular weight of dry stack gas	29.64	29.68	29.62	
MW - Molecular weight of stack gas	28.34	27.60	27.18	
ΔP_s - Velocity Head of stack gas, In. H_2O	—	—	—	
T_s - Stack Temperature, °F	143.5	144.2	138.5	
$\sqrt{\Delta P_s X (T_s+460)}$	11.035	10.624	9.621	
P_s - Stack Pressure, "Hg. Absolute	30.04	30.04	30.04	
V_s - Stack Velocity @ stack conditions, fpm	1564	1526	1392	
A_s - Stack Area, in.^{2}	443	443	443	
Q_s - Stack Gas Volume @ Standard Conditions, *SCFM	3767	3397	3010	
T_t - Net Time of Test, min.	120	120	120	
D_n - Sampling Nozzle Diameter, in. 5/16"	.3125	.3125	.3125	
%I - Percent isokinetic	99.4	93.6	107.8	
m_f - Particulate - probe, cyclone and filter, mg.	111.3	79.1	100.6	
m_t - Particulate - total, mg.	—	—	—	
C_{an} - Particulate - probe, cyclone, and filter, gr/SCF	.0219	.0184	.0228	
C_{ao} - Particulate - total, gr/SCF	—	—	—	
C_{at} - Particulate - probe, cyclone, and				

PARTICULATE EMISSION DATA (cont'd)

Run No.	1	2	3	
C_{au} - Particulate, total, gr/cf @ stack cond.	—	—	—	
C_{aw} - Particulate, probe, cyclone, and filter, lb/hr.	.7079	.5343	.5891	
C_{ax} - Particulate - total, lb/hr.	—	—	—	
%EA - % Excess air @ sampling point	41.8	43.9	47.7	

* 70°F. 29.92" Hg.

GR/SCF @ 12% CO_2	.0306	.0250	.0330
LBS/1000 LBS FLUE GAS @ 50% EX. AIR	.0394	.0336	.0428

QUALITY CONTROLLED YORK RESEARCH CORPORATION

PARTICULATE FIELD DATA

JOB NO. Y-8200
lant ENVIROTECH - Glastonbury
un No. 1
ocation OUTLET
ate 7/25/73
perator RAP / RGE
ample Box No. 7-107
eter Box No. S-1049
eter ΔH 1.84
Factor .90

VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

PATHOLOGICAL INCINERATORS- read and record every 5 minutes.

Filter: FL-573

Ref. $= .24\left(\frac{.85}{.808}\right)^2 = .265$

372
-200
172 ml
+ 35.4 g
207.4 ml
H_2O Collected

Ambient Temp °F 90
Bar.Press. "Hg 30.03
Assumed Moisture % 16.5
Heater Box Setting, °F 300°
Probe Tip Dia., In. 5/16" (.3125)
Probe Length 3'
Probe Heater Setting 300
Avg. ΔP — Avg. ΔH —

Point	Clock Time	Dry Gas Meter, CF	Pitot in. H_2O ΔP	Orifice ΔH in H_2O		Dry Gas Temp. °F		Pump Vacuum In. Hg Gauge	Box Temp. °F	Impinger Temp °F	+.17" H_2O Stack Press in.Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
A-1	1509	85.154	.16	1.18	1.18	91	91	3	300	75	—	140
	1514	88.16	.15	1.10	1.10	95	92	3	↓	70	—	140
2	1519	91.11	.20	1.45	1.45	98	93	4		70	—	145
	1524	94.44	.20	1.45	1.45	100	93	4		70	—	145
3	1529	91.78	.20	1.45	1.45	105	94	4		70	—	145
	1534	101.14	.21	1.50	1.50	106	96	4		70	—	145
4	1539	104.60	.21	1.50	1.50	108	97	4		70	—	145
	1544	107.87	.26	1.86	1.86	108	98	4		70	—	145
5	1549	111.68	.21	1.50	1.50	110	99	4		70	—	140
	1554	115.15	.19	1.38	1.38	110	100	4		70	—	145
6	1559	118.53	.16	1.18	1.18	110	100	4		70	—	140
	1604	121.66	.16	1.18	1.18	110	100	3		70	—	140
END	1609	124.119	—	—	—	—	—	—	—	—	—	—
B-1	1625	124.124	.19	1.38	1.38	98	98	7		70		140
	1630	128.08	.19	1.38	1.38	102	98	4		70	—	140

JOB NO. Y-8200 Test 1 7/25/73 Outlet

Point	Clock Time	Dry Gas Meter, CF	Pitot in.H_2O ΔP	Orifice ΔH in H_2O		Dry Gas Temp. °F		Pump Vacuum In. Hg Gauge	Box Temp. °F	Impinger Temp °F	Stack Press in.Hg	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
B-2	1635	131.47	.22	1.66	1.66	125	98	4	300	70	—	145
	1640	135.16	.21	1.50	1.50	106	99	4	300	70	—	145
3	1645	138.70	.22	1.66	1.66	104	99	4	300	75	—	145
	1650	141.3	.22	1.66	1.66	106	100	4	300	75	—	145
4	1655	145.85	.21	1.50	1.50	106	98	4	300	70	—	145
	1700	149.50	.21	1.50	1.50	108	98	4	300	70	—	145
5	1705	152.85	.22	1.66	1.66	108	98	4	300	70	—	145
	1710	156.45	.22	1.66	1.66	108	100	4	300	70	—	150
6	1715	160.00	.22	1.66	1.66	108	100	4	300	70	—	145
	1720	163.72	.22	1.66	1.66	109	100	4	300	70	—	145
END	1725	167.271	—	—	—	—	—	—	—	—	—	—

YORK RESEARCH CORPORATION

PARTICULATE FIELD DATA

B NO. 8200

ant ENVIROTECH GLASTONBURY

n No. 2

cation OUTLET

te 7-25-73

erator RP, RJE

nple Box No. 7-107

ter Box No. S-1049

ter Δ H 1.84

Factor .90

VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

PATHOLOGICAL INCINERATORS-
read and record every 5 minutes.

FL ~~[illegible]~~ # G13

Rf:.265

Total 472.4ml

Ambient Temp °F 90

Bar.Press. "Hg 30.03

Assumed Moisture % 16.5

Heater Box Setting, °F 300

Probe Tip Dia., In. .3125 (5/16)

Probe Length 3'

Probe Heater Setting 300

Avg. ΔP — Avg. ΔH —

oint	Clock Time	Dry Gas Meter, CF	Pitot in. H_2O ΔP	Orifice ΔH in H_2O Desired	Orifice ΔH in H_2O Actual	Dry Gas Temp. °F Inlet	Dry Gas Temp. °F Outlet	Pump Vacuum In. Hg Gauge	Box Temp. °F	Impinger Temp °F	Stack Press in.Hg	Stack Temp °F
1	1914	169.120	.21	1.50	1.50	86	87	5	300	70	+.17	145
1	1919	172.08/.28	.21	1.50	1.50	88	87	5		70		145
2	1924	175.37	.20	1.45	1.45	90	87	4		75		145
2	1929	178.38	.20	1.45	1.45	94	87	4		75		145
3	1934	181.67	.21	1.50	1.60	97	88	4		75		145
3	1939	184.36	.21	1.50	1.50	97	88	4		75		140
9	1944	187.25	.21	1.50	1.50	98	89	4		75		140
4	1949	190.26	.19	1.38	1.38	99	89	4		75		140
5	1954	193.19	.17	1.22	1.22	99	89	4		75		140
5	1959	195.02	.18	1.28	1.28	98	89	4		75		140
6	2004	199.56	.14	1.00	1.00	98	89	3		75		140
6	2009	205.76	.13	.94	.94	97	89	3		75		140
ND	2014	203.699										
1		203.699	.16	1.08	1.08	83	84			70		150
1		206.13	.17	1.22	1.22	89	86			70		145

JOB NO. 8200 Test 2 Outlet 7/25/73

Point	Clock Time	Dry Gas Meter, CF	Pitot in.H_2O ΔP	Orifice ΔH in H_2O		Dry Gas Temp. °F		Pump Vacuum In. Hg Gauge	Box Temp. °F	Impinger Temp °F	Stack Press in.Hg	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2	2052	208.82	.19	1.38	1.38	92	85	4	300	70		150
2	2057	211.98	.19	1.38	1.38	94	86	4		65		140
3	2102	214.60	.20	1.46	1.45	95	86	4		65		145
3	2107	217.60	.20	1.45	1.45	94	86	4		65		145
4	2112	220.60	.20	1.46	1.45	94	86	4		65		145
4	2117	223.60	.20	1.45	1.45	94	86	4		65		145
5	2122	226.55	.20	1.45	1.45	94	86	4		70		145
5	2127	227.52	.18	1.50	1.30	94	85	4		70		145
6	2132	231.67	.18	1.30	1.30	94	86	4		70		145
6	2137	234.83	.18	1.30	1.30	94	86	4		70		145
END	2142	237.745										

YORK RESEARCH CORPORATION QUALITY CONTROLLED

PARTICULATE FIELD DATA

JOB NO. 8200

lant GLASTONBURY

un No. 3

ocation OUTLET

ate 7-26-73

perator MH, RP

ample Box No. 7-107

eter Box No. 3-1049

eter Δ H 1.84

Factor .80

VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

PATHOLOGICAL INCINERATORS- read and record every 5 minutes.

FL 593

Ref = .29Δp

$.26\left(\frac{.85}{.808}\right)^2 = .29$

334
202
- 200
336 ml Tot.

Ambient Temp °F 80

Bar.Press. "Hg 30.03

Assumed Moisture % 20

Heater Box Setting, °F 400/300

Probe Tip Dia., In. .3125" (5/16)

Probe Length 3'

Probe Heater Setting 300

Avg. ΔP — Avg. ΔH —

oint	Clock Time	Dry Gas Meter, CF	Pitot in. H_2O ΔP	Orifice Δ H in H_2O Desired	Orifice Δ H in H_2O Actual	Dry Gas Temp. °F Inlet	Dry Gas Temp. °F Outlet	Pump Vacuum In. Hg Gauge	Box Temp. °F	Impinger Temp °F	Stack Press in.Hg	Stack Temp °F
A 1	1049	252.238	.14	.91	.91	81	73	2	400	70	+.18"	140
1	1054	255.03	.14	.91	.91	87	74	3	"	70	H2O	140
2	1059	257.79	.16	1.03	1.03	88	76	3	"	65	"	140
2	1104	260.72	.16	1.03	1.03	93	79	3	"	70	"	145
3	1109	263.66	.16	1.03	1.03	82	80	15	"	70	"	140
3	1114	267.20	.16	1.03	1.03	89	82	5	"	70	"	140
4	1119	270.19	.17	1.11	1.11	92	83	3	"	70	"	135
4	1124	273.12	.17	1.11	1.11	94	84	3	"	70	"	145
5	1129	276.05	.18	1.16	1.16	94	85	3	"	75	"	140
5	1134	279.06	.17	1.11	1.11	94	86	3	"	75	"	140
6	1139	282.03	.17	1.11	1.11	95	86	3	"	80	"	140
6	1144	285.10	.17	1.11	1.11	96	87	3	"	80	"	140
ND	1149	288.037	—	—								
B1	1205	288.051	.12	.78	.78	91	87	3	406	85	"	135
1	1210	290.582	.17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	85	"	[illegible]

Test 3 JOB NO. Y-8200 7/26/73 Outlet

Point	Clock Time	Dry Gas Meter, CF	Pitot in.H_2O ΔP	Orifice ΔH in H_2O		Dry Gas Temp. °F		Pump Vacuum In. Hg Gauge	Box Temp. °F	Impinger Temp °F	Stack Press in.Hg	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
B-2	1215	293.14	.16	1.03	1.03	94	90	3	300	85	+.18 H_2O	135
	1220	296.05	.16	1.03	1.03	95	90	3	"	50	"	135
3	1225	298.98	.16	1.03	1.03	97	90	3	"	75	"	140
	1230	301.90	.16	1.03	1.03	98	90	3	"	75	"	140
4	1235	304.83	.15	.97	.97	98	91	3	"	75	"	140
	1240	307.70	.16	1.03	1.03	98	91	3	"	75	"	140
5	1245	310.70	.14	.91	.91	99	92	3	"	75	"	135
	1250	313.54	.14	.91	.91	100	92	3	"	75	"	135
6	1255	316.29	.15	.97	.77	101	93	3	"	75	"	135
	1300	319.18	.15	.97	.97	102	94	3	"	75	"	135
END	1305	322.057	—	—	—	—	—	—	—	—	—	—

OXIDES OF NITROGEN FIELD DATA

JOB NO. Y-8200

Date 7-25-73

Plant GLASTONBURY

Sample Collected By RSE/RP

Run No. 1-5

Power Stat Setting 75%

Field Data

TEST*	1	2	3	4	5
Clock Time	1250	1253	1257	1259	1302
Flask Number	11	6	46	12	28
Volume of flask less correction (liter)	2.023	2.003	2.057	2.033	2.050
Pressure before sampling in Hg.	-27.9	-27.8	- 27.9	-27.7	-27.9
Pressure after sampling in Hg.	-.71	-2.2	-2.9	-3.3	-2.9
Flask temperature, °F	70	70	70	70	70

Remarks:

OXIDES OF NITROGEN FIELD DATA

JOB NO Y-8200

Date 7-26-73

Plant GLASTONBURY

Sample Collected By RSE/RP

Run No. 6-10

Power Stat Setting 75%

Field Data

TEST#	6	7	8	9	10
Clock Time	7/25/73 1304	1430	1431	1432	1433
Flask Number	7	18	1	55	24
Volume of flask less correction (liter)	2.016	2.052	2.033	1.908	2.033
Pressure before sampling in Hg.	-28.0	-27.6	-27.6	-27.8	-27.9
Pressure after sampling in Hg.	-2.2	-.5	-.5	-.5	-.5
Flask temperature, °F	70	70	70	70	70

Remarks:

NO_x EMISSION DATA

RUN NO.	1	2	3	4	5		
Date	7/25	7/25	7/25	7/25	7/25		
mg NO_2	.4321	.5364	.2218	.4587	.5288		
T_f - Flask Temperature, °F	70	70	70	70	70		
V_f - Flask Volume, liters	2.023	2.003	2.057	2.033	2.050		
P_i - Initial Flask Vacuum, "Hg.	-27.9	-27.8	-27.9	-27.7	-27.9		
P_f - Final Flask Vacuum, "Hg.	-.7	-2.2	-2.9	-3.3	-2.9		
ppm NO_2	123	164	68	145	160		

$$\text{ppm } NO_2 = \frac{29.63 \times \text{mg } NO_2 \times (T_f + 460)}{V_f \times (P_i - P_f)}$$

① $$\frac{29.63 \times .4321 \times 530}{2.023 \times 27.2} = 123$$

④ $$\frac{29.63 \times .4587 \times 530}{2.033 \times 24.4} = 145$$

② $$\frac{29.63 \times .5364 \times 530}{2.003 \times 25.6} = 164$$

⑤ $$\frac{29.63 \times .5228 \times 530}{2.050 \times 25.0} = 160$$

③ $$\frac{29.63 \times .2218 \times 530}{2.057 \times 25.0} = 68$$

NO_x EMISSION DATA

RUN NO.	6	7	8	9	10		
Date	7/25	7/26	7/26	7/26	7/26		
mg NO_2	.3620	.7581	.6065	.7638	.6254		
T_f - Flask Temperature, °F	70	70	70	70	70		
V_f - Flask Volume, liters	2.016	2.052	2.033	1.908	2.033		
P_i - Initial Flask Vacuum, "Hg.	-28.0	-27.6	-27.6	-27.8	-27.9		
P_f - Final Flask Vacuum, "Hg.	-2.2	-.5	-.5	-.5	-.5		
ppm NO_2	111	214	173	230	176		

$$\text{ppm } NO_2 = \frac{29.63 \times \text{mg } NO_2 \times (T_f + 460)}{V_f \times (P_i - P_f)}$$

⑥ $\frac{29.63 \times .3620 \times 530}{2.016 \times 25.8} = 111$

⑨ $\frac{29.63 \times .7638 \times 530}{1.908 \times 27.3} = 23$

⑦ $\frac{29.63 \times .7581 \times 530}{2.052 \times 27.1} = 214$

⑩ $\frac{29.63 \times .6254 \times 530}{2.033 \times 27.4} = 176$

⑧ $\frac{29.63 \times .6065 \times 530}{2.033 \times 27.1} = 173$

SO_2 EMISSION DATA

RUN NO.	1	2	3	4		
Date	7/25/73	7/25/73	7/26/73	7/26/73		
mg SO_2	1.682	1.281	2.322	4.004		
T_m - Average Gas Meter Temperature, °F	82	82	82	82		
P_b - Barometric Pressure, "Hg abs.	30.03	30.03	30.03	30.03		
V_m - Volume of dry gas sampled @ meter conditions, $ft.^3$	1.129	1.930	1.630	1.140		
ppm SO_2	20.2	9.00	19.3	47.6		

$$\text{ppm } SO_2 = \frac{0.751 \text{ X mg } SO_2 \text{ X } (T_m + 460)}{P_b \text{ X } V_m}$$

① $$\frac{0.751 \times 1.682 \times 542}{30.03 \times 1.129} = 20.2$$

③ $$\frac{0.751 \times 2.322 \times 542}{30.03 \times 1.630} = 19.$$

② $$\frac{0.751 \times 1.281 \times 542}{30.03 \times 1.930} = 9.00$$

④ $$\frac{0.751 \times 4.004 \times 542}{30.03 \times 1.140} = 47.$$

SO_3 EMISSION DATA

RUN NO.	1	2	3	4				
Date	7/25/73	7/25/73	7/26/73	7/26/73				
mg SO_3	.1201	.4003	.1301	.2202				
T_m - Average Gas Meter Temperature, °F	82	82	82	82				
P_b - Barometric Pressure, "Hg abs.	30.03	30.03	30.03	30.03				
V_m - Volume of dry gas sampled @ meter conditions, $ft.^3$	1.129	1.930	1.630	1.140				
ppm SO_3	1.15	2.25	.865	2.09				

$$\text{ppm } SO_3 = \frac{0.6008 \times \text{mg } SO_3 \times (T_m + 460)}{P_b \times V_m}$$

① $$\frac{.6008 \times .1201 \times 542}{30.03 \times 1.129} = 1.15$$

② $$\frac{.6008 \times .4003 \times 542}{30.03 \times 1.930} = 2.25$$

③ $$\frac{.6008 \times .1301 \times 542}{30.03 \times 1.630} = .865$$

④ $$\frac{.6008 \times .2202 \times 542}{30.03 \times 1.140} = 2.09$$

GAS SAMPLING FIELD DATA

JOB NO. Y-8200

Material Sampled for SO_2/SO_3

Date 7-25-73

Plant GLASTONBURY Location OUTLET

Bar. Pressure 30.03 "Hg Comments:

Ambient Temp. 85°F

Run No. 1

Power Stat Setting 80%

Filter Used: Yes X No

Operator RSE

CLOCK TIME	METER (Ft^3)	FLOW METER SETTING (CFM)	METER TEMPERATURE TM
1710	33.968	—	82
1715	34.266	—	82
1720	34.712	—	82
1725	35.097	—	82
	(1.129 CF)		

Comments:

Impinger Bucket No.

Meter Box No.

GAS SAMPLING FIELD DATA

JOB NO. Y-8200

Material Sampled for SO_2/SO_3

Date 7-25-73

Plant GLASTONBURY

Location OUTLET

Bar. Pressure 30.03 "Hg

Comments:

Ambient Temp. 82

Run No. 2

Power Stat Setting 80%

Filter Used: Yes X No

Operator RSE

CLOCK TIME	METER (Ft^3)	FLOW METER SETTING (CFM)	METER TEMPERATURE TM
1940	5.240	—	82
1945	5.721	—	82
1950	6.211	—	82
1955	6.708	—	82
2000	7.170	—	82
	(1.930 CF)		

Comments:

Impinger Bucket No.

Meter Box No.

GAS SAMPLING FIELD DATA

JOB NO. Y-8200

Material Sampled for SO2/SO3

Date 7-26-73

Plant GLASTONBURY Location OUTLET

Bar. Pressure 30.03 "Hg Comments:

Ambient Temp. 82

Run No. 3

Power Stat Setting 75%

Filter Used: Yes X No

Operator RSE

CLOCK TIME	METER (Ft^3)	FLOW METER SETTING (CFM)	METER TEMPERATURE TM
1132	7.170	—	82
1137	7.526	—	82
1142	8.211	—	82
1147	8.800	—	82
	(1.630 CF)		

Comments:

Impinger Bucket No.

Meter Box No.

GAS SAMPLING FIELD DATA

JOB NO. Y-8200

Material Sampled for SO_2/SO_3

Date 7-26-73

Plant GLASTONBURY **Location** OUTLET

Bar. Pressure 30.03 "Hg **Comments:**

Ambient Temp. 82

Run No. 4

Power Stat Setting 75%

Filter Used: Yes X No

Operator RSE

CLOCK TIME	METER (Ft^3)	FLOW METER SETTING (CFM)	METER TEMPERATURE TM
1225	9.806	—	82
1230	10.112	—	82
1235	10.468	—	82
1240	10.946	—	82
	(1.140 cf)		

Comments:

Impinger Bucket No.

Meter Box No.

HYDROCARBON EMISSION DATA

Job No. Y-8200

Date 7/26/73

Plant ENVIROTECH Location Glastonbury

Ambient Temp. 80

Operator RSE

Test No.	Time	Flask Temp.	PPM HYDROCARBON ~~Comments~~
1	1305	300°F	9.05
2	1306	300°F	9.81
3	1307	300°F	6.14
4	1340	300°F	2.96
5	1341	300°F	4.10
6	1342	300°F	0.54

YORK RESEARCH CORPORATION

PITOT TUBE CALIBRATION

$$\frac{STD}{S} = \frac{.44}{.69} = \sqrt{.6376} = .798$$

$$\frac{.17}{.26} = \sqrt{.6538} = .808$$

$$\frac{.07}{.09} = \sqrt{.7777} = .881$$

$$\frac{\quad}{\quad} = \sqrt{\quad} = \_\_\_\_$$

Standard Pitot
Factor = 1.00

Calibrated By

Date 7/23/73

Pitot Tube # 16

Date 6/25/73 Box No. 1577

Pump ✓

Pump Oil ✓

Clean Quick Connects ✓ Valves

Manometers ✓

Dry Test Meter ✓

Thermometers ✓

Lights ✓

Electrical Check - Amphenol ✓

Variac ✓

Vacuum Gauge ✓

Leak Check at 27" hg. - ✓ Cl

Remarks

Initial each item when checked and write in any remarks.

Calibration - Orifice and Meter

Date 6/26/73 Box No. 1577 P_b 29.84

Man Orifice	CF_w	CF_d	T_W	IT_d	OT_d	T_d Avg.	Time t
0.5	5	5.016	72	77.6	72.4	75	12.91
1.0	5	5.042	73	84.6	77.2	80	9.48
2.0	10	10.095	73	89.5	79.5	84.5	13 60
4.0	10	10.104	73	96	81.5	87.3	9.26
6.0	10	10.042	73	98.5	83.5	91.0	7.56
8.0	10						

Calculate Y & $H_@$ at man. 2.0

Y =

$$Y = \frac{CF_w \; P_b \; (T_d \text{ avg.} + 460)}{CF_d \; (P_b + 0.147(T_w + 460)}$$

$$Y = \frac{(\quad + 460)}{(\quad + 0.147)(\quad + 460)}$$

$$\Delta H_@ = \frac{0.0634}{P_b(OT_d + 460)} \left(\frac{(T_w + 460)}{CF_w} \right)^2$$

$$\Delta H_@ = \frac{0.0634}{(\quad + 460)} \left(\frac{(\quad + 460)t}{} \right)^2$$

Tolerances

Y = 0.99 - 1.00 - 1.01

$\Delta H_@$ = 1.6 - 1.84 - 2.1

	Man.	H@
$\Delta H_@ = \frac{0.317\ (\text{Man. Orifice})}{P_b\ (OT_d + 460)} \left(\frac{(T_w + 460)t}{CF_w}\right)^2$		
$\Delta H_@ = \frac{0.01585}{29.84\ (72.4 + 460)} \left(\frac{(72 + 460)\ 12.51}{5}\right)^2$	.5	1.88
$\Delta H_@ = \frac{0.0317}{29.84\ (72.2 + 460)} \left(\frac{(23 + 460)\ 9.48}{5}\right)^2$	1.0	2.02 ~~1.87~~
$\Delta H_@ = \frac{0.0634}{29.84\ (72.5 + 460)} \left(\frac{(23 + 460\ 13.00}{10}\right)^2$	2.0	1.89
$\Delta H_@ = \frac{0.1268}{29.84\ (84.5 + 460)} \left(\frac{(73 + 460)\ 9.26}{10}\right)^2$	4.0	1.91
$\Delta H_@ = \frac{0.1902}{29.84\ (83.5 + 460)} \left(\frac{(73 + 460\ 2.56}{10}\right)^2$	6.0	1.90
$\Delta H_@ = \frac{0.2536}{\_\_\ (\_\_ + 460} \left(\frac{(\_\_ + 460)}{\_\_}\right)^2$	8.0	

Calibration Calculations Meter and Pump Box
Date 6/25/73 Box No. 1522

	Man.	Y
$Y = \frac{CF_w\ P_b\ (T_d\ \text{avg.} + 460)}{CF_d\ P_b + \frac{\text{Man. Orifice}}{13.6}\ (T_w + 460)}$		
$Y = \frac{5 \times 29.84\ (75 + 460)}{5.016\ (29.84 + 0.0368)\ (22 + 460)}$	.5	1.00
$Y = \frac{5 \times 29.84\ (80.9 + 460)}{5.042\ (29.84 + 0.0737)\ (23 + 460)}$	1.0	1.00
$Y = \frac{10 \times 29.84\ (84.5 + 460)}{10.085\ (29.84 + 0.147)\ (23 + 460)}$	2.0	1.01
$Y = \frac{10 \times 29.84\ (87.3 + 460)}{10.104\ (29.84 + 0.294)\ (23 + 460)}$	4.0	1.01
$Y = \frac{10 \times 29.84\ (91 + 460)}{10.042\ (29.84 + 0.431)\ (23 + 460)}$	6.0	1.01
$Y = \frac{\_\_ \times \_\_\ (\_\_ + 460)}{\_\_\ (\_\_ + 0.588)\ (\_\_ + 460)}$	8.0	

Date 6/25/73 Box No. S 1049

Pump ✓

Pump Oil ✓

Clean Quick Connects ✓ Valves

Manometers ✓

Dry Test Meter ✓

Thermometers ✓

Lights ✓

Electrical Check - Amphenol ✓

Variac ✓

Vacuum Gauge —

Leak Check at 27" hg. - ✓ CFM

Remarks

Initial each item when checked and write in any remarks.

Calibration - Orifice and Meter

Date 6/25/73 Box No. S-1049 P_b 29.84

Man Orifice	CF_w	CF_d	T_W	IT_d	OT_d	T_d Avg.	Time t
0.5	5	5.101	72	82	73	77.5	12.57
1.0	5	5.102	72.5	93	79	86	8.76
2.0	10	10.093	73	93.5	81.5	87.5	12.84
4.0	10	10.07	73.5	99.5	85	92.5	8.95
6.0	10	10.265	73.5	105.5	87	96.5	7.50
8.0	10						

Calculate Y & $H_@$ at man. 2.0

Y =

$$Y = \frac{CF_w\ P_b\ (T_d\ \text{avg.} + 460)}{CF_d\ (P_b + 0.147(T_w + 460)}$$

$$Y = \frac{(\quad + 460)}{(\quad + 0.147)\ (\quad + 460)}$$

$$\Delta H_@ = \frac{0.0634}{P_b(OT_d + 460)} \left(\frac{(T_w + 460)t}{CF_w}\right)^2$$

$$\Delta H_@ = \frac{0.0634}{(\quad + 460)} \left(\frac{(\quad + 460)t}{\quad}\right)^2$$

Tolerances

Y = 0.99 - 1.00 - 1.01

$\Delta H_@$ = 1.6 - 1.84 - 2.1

$\Delta H_@ =$	Man.	H@
$\dfrac{0.317\ (\text{Man. Orifice})}{P_b\ (OT_d + 460)}\left(\dfrac{(T_w + 460)t}{CF_w}\right)^2$		
$\dfrac{0.01585}{29.84\ (73 + 460)}\left(\dfrac{(72 + 460)\ 12.5}{5}\right)^2$	.5	1.78
$\dfrac{0.0317}{29.84\ (79 + 460)}\left(\dfrac{(72.5 + 460)\ 8.26}{5}\right)^2$	1.0	1.72
$\dfrac{0.0634}{29.84\ (81.5 + 460)}\left(\dfrac{(73 + 460\ 12.84}{10}\right)^2$	2.0	1.84
$\dfrac{0.1268}{29.84\ (85 + 460)}\left(\dfrac{(73.5 + 460)\ 8.95}{10}\right)^2$	4.0	1.78
$\dfrac{0.1902}{29.84\ (82 + 460)}\left(\dfrac{(73.5 + 460\ 7.50}{10}\right)^2$	6.0	1.87
$\dfrac{0.2536}{\_\_\_\ (\_\_\_ + 460}\left(\dfrac{(\_\_\_ + 460)}{\_\_\_}\right)^2$	8.0	

Calibration Calculations Meter and Pump Box

Date 6/25/73 Box No. 1044

	Man.	Y
$Y = \dfrac{CF_w\ P_b\ (T_d\ \text{avg.} + 460)}{CF_d\ P_b + \dfrac{\text{Man. Orifice}}{13.6}\ (T_w + 460)}$		
$Y = \dfrac{5 \times 29.84\ (72.5 + 460)}{5.101\ (29.84 + 0.0368)(72 + 460)}$	.5	.99
$Y = \dfrac{5 \times 29.84\ (86 + 460)}{5.102\ (29.84 + 0.0737)(72.5 + 460)}$	1.0	1.00
$Y = \dfrac{10 \times 29.84\ (82.5 + 460)}{10.053\ (29.84 + 0.147)(73 + 460)}$	2.0	1.01
$Y = \dfrac{10 \times 29.84\ (93.3 + 460)}{10.107\ (29.84 + 0.294)(73.5 + 460)}$	4.0	1.01
$Y = \dfrac{10 \times 29.84\ (96.5 + 460)}{10.265\ (29.84 + 0.431)(73.5 + 460)}$	6.0	1.00
$Y = \dfrac{\_\_\_ \times \_\_\_\ (\_\_\_ + 460)}{\_\_\_\ (\_\_\_ + 0.588)(\_\_\_ + 460)}$	8.0	