ENVISAGE ENVIRONMENTAL INCORPORATED
P. O. Box 152, Richfield, Ohio 44286
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STAPPA / ALAPCO
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REPORT NO. 85-9192 54
COMPANY NEORSD
TITLE Compliance
DATE 8-28-85

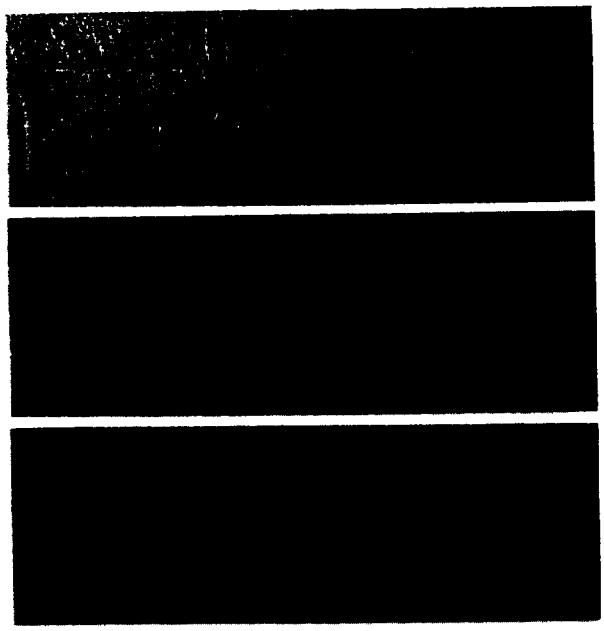
#124 11/12/86

SOUTHERLY SEWAGE PLANT

INCINERATOR #1

EPA METHODS 1-5 PARTICULATE COMPLIANCE EMISSIONS TEST

CONDUCTED - AUGUST 28, 1985



Envisage Environmental Incorporated P.O. Box 152 Richfield, Ohio 44286
Phone (216) 526-0990

[redacted]

August 30, 1985

Mr. Robert Dominak, P.E.
Northeast Ohio Regional Sewer District
1127 Euclid Avenue
Cleveland, Ohio 44115

Dear Mr. Dominak:

The following report is the result of the E.P.A. Methods 1-5 Compliance stack test conducted on August 28, 1985. The test for particulate emissions was conducted at the Southerly Sewage Treatment Plant, Incinerator #1, Cleveland, Ohio.

These results are true and accurate to the degree specified in the pertinent sections of the Federal Register, in force at the time of testing, concerning Source Sampling for Particulate Matter.

Respectfully submitted,

Tom E. Holder

Tom E. Holder
Environmental Engineer
ENVISAGE ENVIRONMENTAL INC.

INTRODUCTION

MH/I per Gary Nied 1-8-87.

INTRODUCTION

On August 28, 1985, Envisage Environmental Inc. conducted a Particulate Emission Compliance test at the Northeast Ohio Regional Sewer District, Southerly Sewage Treatment Plant, Cleveland, Ohio. The testing consisted of three (3) test runs of EPA Methods 1-5 to determine the particulate emission rate. The purpose of this test was to determine the emission rates from the exhaust stack venting Sludge Incinerator #1 in order to ascertain compliance with EPA regulations.

The incinerator was monitored throughout the test by Northeast Ohio Regional Sewer District personnel. Ohio Environmental Protection Agency representative, Mr. Zoltan Rajnay and Mr. Jim Krause were present during testing. The signature on the field data sheets of Mr. Krause of the Cleveland Division of Air Pollution Control shows his approval of the on-site procedures.

The results in this report are the particulate emission rates for the three test runs and the various temperature, volumetric, and velocity measurements taken with these tests.

DESCRIPTION OF PROGRAM

DESCRIPTION OF PROGRAM

This testing was conducted in the exhaust stack through two sample ports located approximately twenty-five (25) feet above the roof level. Twelve (12) sample points were utilized in each sample port making a total of twenty-four (24) sample points per test run. The sample was drawn for two and one half (2.5) minutes at each sample point for a total test time of sixty (60) minutes per test run. A diagram of the sample point locations is included in this report.

The samples were drawn from the gas stream isokinetically through a one quarter (0.25) inch diameter nozzle and a three (3) foot Pyrex lined probe. This probe was heated its entire length and was attached to a Standard EPA Method Five Sample Train. The sample box was heated to approximately two hundred and fifty (250) degrees Fahrenheit and was monitored throughout each test to ensure that no condensation formed in the sample train before the impingers. The impingers were maintained below 70 degrees Fahrenheit with an ice bath. The nozzle, probes, and connecting glassware were cleaned prior to the first run and at the conclusion of each run. All leak checks were acceptable by EPA regulations.

Flue gas analysis was conducted by drawing an integrated air bag sample and was analyzed with a Hays Republic Model 621A "Orsat" Portable Gas Analyzer. The average of these readings for each test run were used in calculating the emission rates.

Description of Program - con't

Calibration of equipment used, including the dry gas meter, orifice meter, and the "S" type pitot tube was conducted August 1, 1985. Calibration data is included in this report.

All analytical procedures were performed in accordance with the methods specified in the Federal Register, Title 40, Part 60, Volume 43, as published March 3, 1978 and its amendments. During the laboratory analysis, a blank was performed on the residue left from the acetone and distilled water used in the evaluation. The acetone blank was recorded and incorporated into the results. The distilled water blank was less than could be measured on a one-tenth (0.1) milligram analytical balance and therefore was considered to be zero.

A set of sample stack testing equations used for data reduction and evaluation is included in this report for convenience and to aid in understanding the presented data. Figures included as sample calculations are from Test Run #1.

TEST RESULTS

SUMMARY

TEST RESULTS SUMMARY

North East Ohio Regional Sewer District

Southerly Sewage Treatment Plant

Sludge Incinerator # 1

EPA Methods 1-5

Particulate Emissions

Compliance Test

Conducted - August 28, 1985

PARAMETER	Run # 1	Run # 2	Run # 3
Particulate Emissions			
Pounds/hour	2.81	2.74	3.20
Grains/dscf	0.0175	0.0185	0.0205
System Flow Rates			
Feet/second	52.36	48.86	51.30
ACFM	22,208	20,723	21,756
SCFM	18,702	17,320	18,183
Moisture Content			
Volume percent	4.04	4.24	4.25
Sample Location Temperature			
Degrees Fahrenheit	136	139	138

TEST RESULTS

DETAILED

TEST RESULTS

North East Ohio Regional Sewer District

Southerly Sewage Treatment Plant

Sludge Incinerator # 1

	Date: August 28, 1985		Units	RUN # 1	RUN # 2	RUN # 3
	Time of Day			9:00am-10:01am	10:15am-11:17am	11:32am-12:34pm
1	Gas Volume-dry,std.	Vmstd	cu. ft.	56.41	50.97	53.78
2	Condensate Vapor Vol.	Vwstd	cu. ft.	2.37	2.25	2.39
3	Gas Stream Moisture	Bws	vol.dec.	0.0404	0.0424	0.0425
4	Mol.Wt-flue gas (dry)	Msd	lb/lb mo.	29.37	29.44	29.47
5	Mol.Wt-flue gas (wet)	Ms	lb/lb mo.	28.91	28.96	28.98
6	Flue Gas Velocity	Vs	ft/sec.	52.36	48.86	51.30
7	Flue Gas Volume-Actual	ACFM	cu. ft.	22,208	20,723	21,756
8	Flue Gas Volume-Std.	SCFM *	cu. ft.	18,702	17,320	18,183
9	Particulate Conc.	Cs				
	- Probe		gr/scf	0.0011	0.0011	0.0015
	- Filter		gr/scf	0.0164	0.0174	0.0190
	- Impingers		gr/scf	0.0007	0.0001	0.0011
	- Total *		gr/scf	0.0175	0.0185	0.0205
10	Emission Rate	E				
	- Probe		lb/hr	0.18	0.16	0.23
	- Filter		lb/hr	2.64	2.58	2.96
	- Impingers		lb/hr	0.11	0.02	0.18
	- Total *		lb/hr	2.81	2.74	3.20
11	Isokinetic Rate	I	%	104.2	101.7	102.2

* Totals DO NOT include impinger weights.

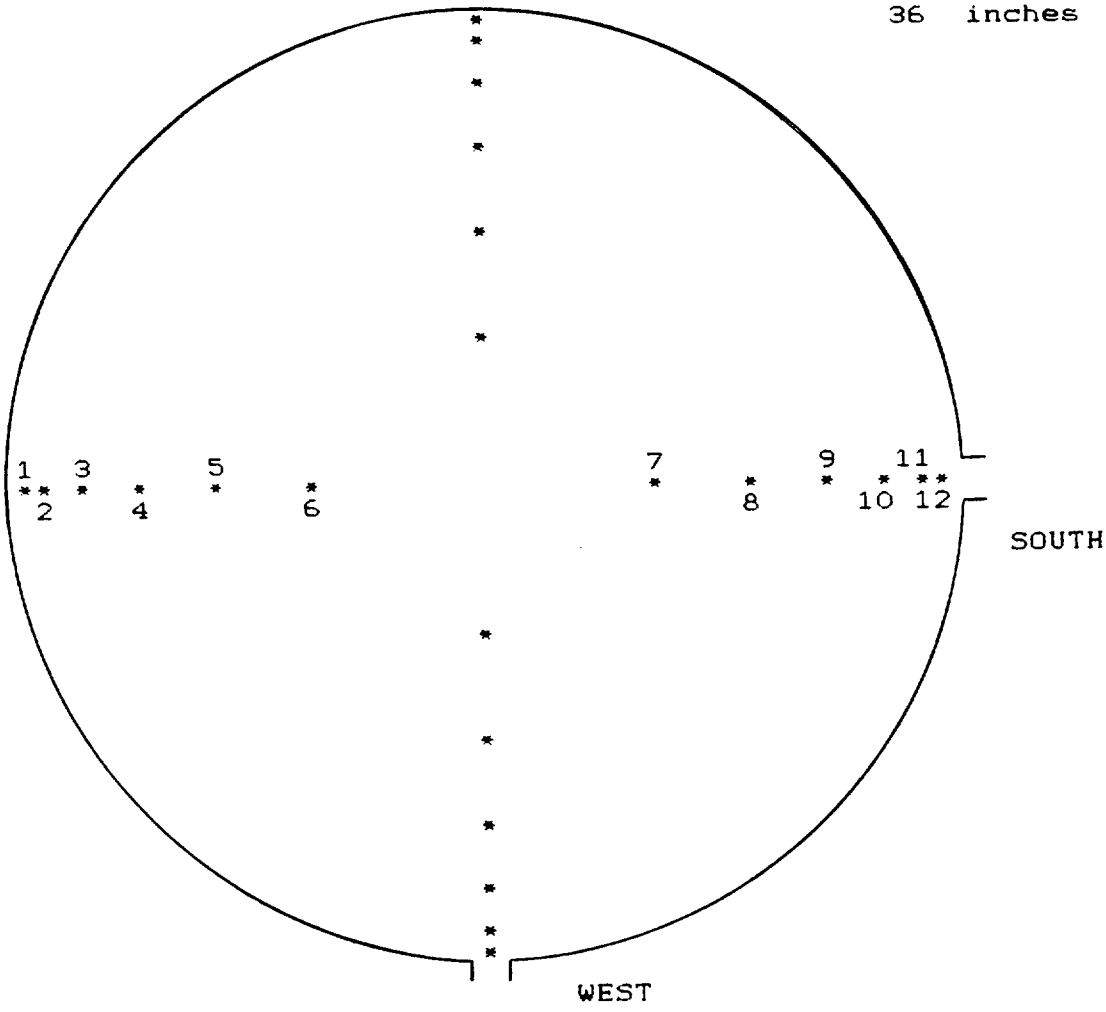
* dry per p. 42

SAMPLE POINT
LOCATION DIAGRAM

SAMPLE POINT LOCATIONS

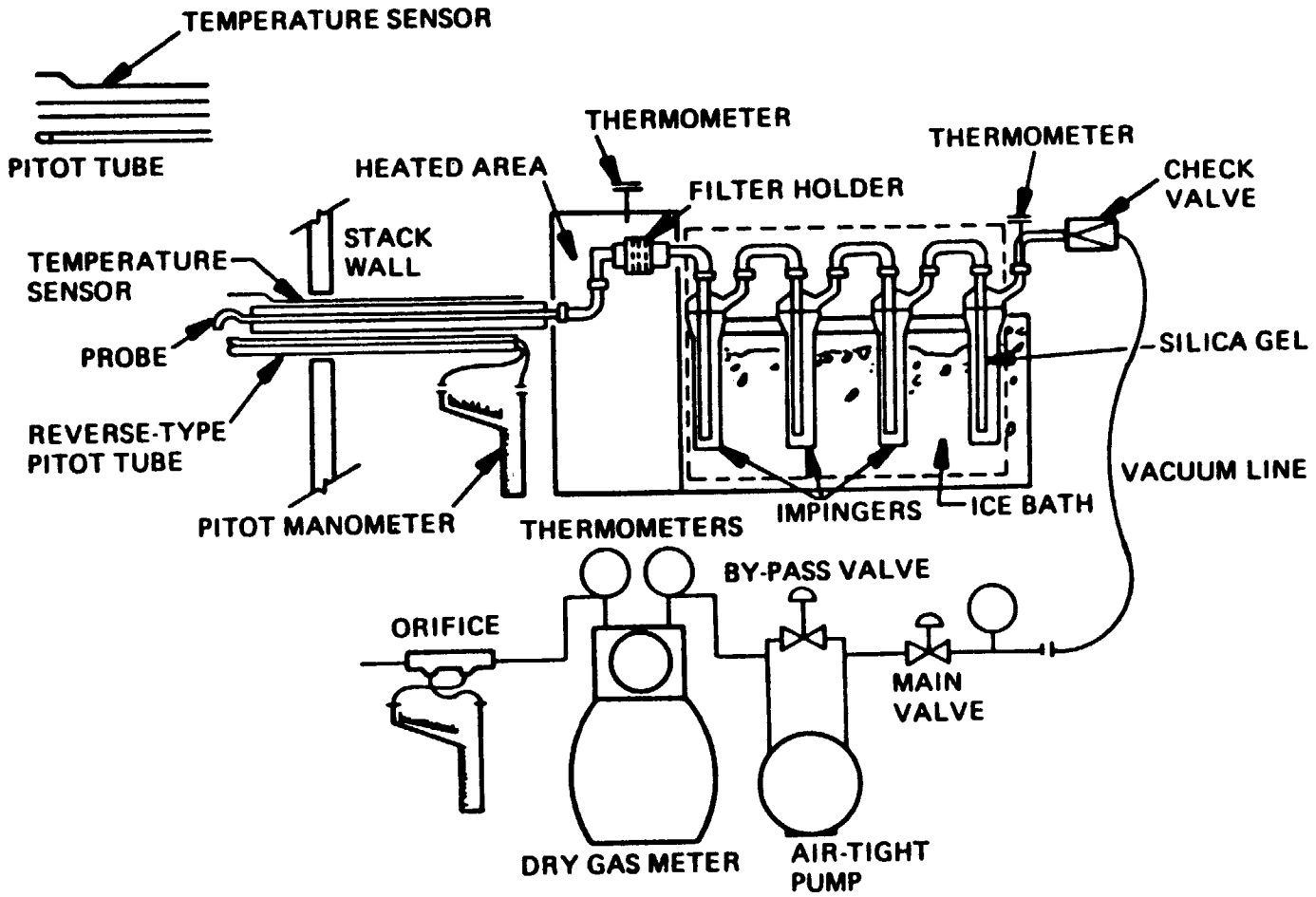
Northeast Ohio Regional Sewer District
Southerly Sewage Treatment Plant
Sludge Incinerator # 1
Exhaust Stack

Inside Diameter:
36 inches



Point #	Distance From Inside Wall	Point #	Distance From Inside Wall
1	35.0 inches	7	12.8 inches
2	33.6 inches	8	9.0 inches
3	31.8 inches	9	6.4 inches
4	29.6 inches	10	4.2 inches
5	27.0 inches	11	2.4 inches
6	23.2 inches	12	1.0 inches

SAMPLING TRAIN DIAGRAM



EPA METHOD 5 PARTICULATE SAMPLE APPARATUS

STACK TESTING

EQUIPMENT SPECIFICATIONS

EQUIPMENT AND SPECIFICATIONS
U.S.E.P.A. REFERENCE METHODS 1-5

Control Unit (Meter box)	Equipment designation
Envisage Environmental Inc. (E.E.I.)	Control Unit #'s MB-01 & 02
Andersen Samplers	Control Unit # MB-03
Remanufactured R.A.C.	Control Unit #'s MB-04 - 08

Sample Box	
E.E.I.	SB-01, 02 & 05 - 07
Remanufactured R.A.C.	SB-03 & 04
E.E.I. (special design)	SB-08 - 11

Impingers - per sample train (each set changed for each test run)

E.E.I.	3 Modified Smith-Greenburg type
E.E.I.	1 Smith-Greenburg type

Probes	Length	Lining types
E.E.I.	3 foot	SS, Pyrex, Quartz, Teflon
E.E.I.	5 foot	SS, Pyrex, Quartz, Teflon
E.E.I.	3 foot	SS, Pyrex, Teflon
E.E.I.	7 foot	SS, Pyrex, Teflon
E.E.I.	10 foot	SS, Pyrex, Teflon
E.E.I.	12 foot	Pyrex, Teflon
E.E.I.	15 foot	SS, Pyrex, Teflon
E.E.I.	24 foot	SS, Teflon

Temperature Sensors	Equipment designation - Type
Omega Engineering (K type thermocouple)	PY-01 & 02
Thermo Electric (K type thermocouple)	PY-03 - 08
Fisher Scientific	Mercury Thermometer
Fisher Scientific	Bimetalic Thermometer

Pressure Gages	Type
Dwyer Incline Manometer	Oil, 0 - 10 inch water
Dwyer Magnehelic	Magnetic/Mechanical 0 - 1 inch water
Dwyer Magnehelic	Magnetic/Mechanical 0 - 10 inch water
Dwyer "U" Tube Manometer	Mercury, 36 inch
Dwyer "U" Tube Manometer	Water, 72 inch
Dwyer Microtector (Micro-manometer)	Water, 0 - 1 inch water

Chemicals & Reagents	
Water	Deionized/distilled
Acetone	Reagent grade ($<$ 0.001 % residue)
Silica Gel	6 - 16 mesh
Stopcock Grease	Acetone-insoluble & Heat stable

LABORATORY SECTION

LABORATORY SUMMARY SHEET

North East Ohio Regional Sewer District

Southerly Sewage Treatment Plant

Sludge Incinerator # 1

Date: August 28, 1985	Symbol	Units	RUN # 1	RUN # 2	RUN # 3
1 Sampling Time	t	minutes	60.0	60.0	60.0
2 Barometric Pressure	Pb	in. Hg	29.66	29.64	29.63
3 Static Pressure	Pg	in. H2O	-0.50	-0.50	-0.50
Stack Pressure	Ps	in. Hg	29.62	29.60	29.59
4 Gas Meter Volume	Vm	cu. ft.	58.64	54.06	57.73
5 Stack Area	A	sq. ft.	7.07	7.07	7.07
6 Nozzle Diameter	Dn	dec. in.	0.25	0.25	0.25
7 Meter Temperature		degrees F	88.2	98.1	105.4
	Tm	degrees R	548.2	558.1	565.4
8 Stack Temperature		degrees F	135.7	138.6	138.3
	Ts	degrees R	595.7	598.6	598.3
9 Velocity Head	^P	in. H2O	0.918	0.855	0.898
10 Orifice Pressure	^H	in. H2O	3.07	2.46	2.92
11 Carbon dioxide	CO2	%	4.8	5.6	5.8
12 Oxygen	O2	%	15.0	13.7	13.5
13 Carbon monoxide	CO	%	0.0	0.0	0.0
14 Nitrogen	N2	%	80.2	80.7	80.7
15 Pitot Coefficient	Cp		0.80	0.80	0.80
16 Water Collected	Vlc	ml	50.4	47.9	50.7
Sample Weight:	Mn				
17 - Probe		g	0.0040	0.0035	0.0052
18 - Filter		g	0.0601	0.0575	0.0663
19 - Impingers		g	0.0024	0.0004	0.0040

PLANT	Southerly Sewage # 1
DATE	August 28, 1985
RUN NO.	1
CASE NO.	5

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CONTAINER NUMBER	WEIGHT OF PARTICULATE COLLECTED			
	FINAL WEIGHT	TARE WEIGHT	WEIGHT GAIN	
19	0.7008	0.6407	0.0601	FILTER
203	144.9278	144.9254	0.0024	IMPINGERS
125	104.0035	103.9995	0.0040	PROBE *

* Corrected for Acetone Blank

VOLUME OF LIQUID WATER COLLECTED			
	IMPINGER VOLUME (ml)	SILICA GEL WEIGHT (g)	
FINAL	230	255.3	
INITIAL	200	234.9	
NET LIQUID COLLECTED	30	20.4	
TOTAL NET VOLUME	50.4	g *	ml

* Convert weight of water to volume by dividing weight increase by density of water:

$$\frac{\text{Increase g}}{(1\ \text{g/ml})} = \text{Volume Water, ml}$$

PLANT	Southerly Sewage # 1
DATE	August 28, 1985
RUN NO.	2
CASE NO.	6

CONTAINER NUMBER	WEIGHT OF PARTICULATE COLLECTED			
	FINAL WEIGHT	TARE WEIGHT	WEIGHT GAIN	
18	0.6963	0.6388	0.0575	FILTER
206	140.4845	140.4841	0.0004	IMPINGERS
128	98.1201	98.1166	0.0035	PROBE *

* Corrected for Acetone Blank

VOLUME OF LIQUID WATER COLLECTED			
	IMPINGER VOLUME (ml)	SILICA GEL WEIGHT (g)	
FINAL	235	247.8	
INITIAL	200	234.9	
NET LIQUID COLLECTED	35	12.9	
TOTAL NET VOLUME	47.9	g *	ml

* Convert weight of water to volume by dividing weight increase by density of water:

$$\frac{\text{Increase g}}{(1\ \text{g/ml})} = \text{Volume Water, ml}$$

PLANT	Southerly Sewage # 1
DATE	August 28, 1985
RUN NO.	3
CASE NO.	11

CONTAINER NUMBER	WEIGHT OF PARTICULATE COLLECTED			
	FINAL WEIGHT	TARE WEIGHT	WEIGHT GAIN	
23	0.7005	0.6342	0.0663	FILTER
707	142.1245	142.1205	0.0040	IMPINGERS
500	99.8420	99.8368	0.0052	PROBE *

* Corrected for Acetone Blank

VOLUME OF LIQUID WATER COLLECTED			
	IMPINGER VOLUME (ml)	SILICA GEL WEIGHT (g)	
FINAL	236	249.6	
INITIAL	200	234.9	
NET LIQUID COLLECTED	36	14.7	
TOTAL NET VOLUME	50.7	g *	ml

* Convert weight of water to volume by dividing weight increase by density of water:

$$\frac{\text{Increase g}}{(1\ \text{g/ml})} = \text{Volume Water, ml}$$

CALIBRATION SECTION

METER BOX CALIBRATION

Meter Box Number: MB - 03

Calibration Date: August 1, 1985

$$Y = \frac{V_t \; P_b \; (T_m + 460)}{V_m \left[P_b + \frac{\Delta H}{13.6} \right] (T + 460)}$$

$$\Delta H_@ = \frac{0.0317 \; \Delta H}{P_b \; (Tm + 460)} \left[\frac{(T_t + 460) \; t}{V_t} \right]$$

Delta H (ΔH)	in. H2O	0.5	1.0	3.0	5.0	7.0
Pres.Barometer (P_b)	in. Hg	29.42	29.42	29.42	29.42	29.42
Vol.Meter Box (V_m)	cu. ft.	4.310	5.860	9.940	12.820	15.030
Vol.Test Meter(V_t)	cu. ft.	4.080	5.700	9.790	12.580	14.710
Temp. Meter Box (T_m)	^oF	98.9	80.6	94.9	97.6	100.4
	^oR	558.9	540.6	554.9	557.6	560.4
Temp. Test Meter (T_t)	^oF	73.4	73.0	73.0	74.0	73.6
	^oR	533.4	533.0	533.0	534.0	533.6
Time (t)	minutes	10.0	10.0	10.0	10.0	10.0
METER FACTOR (Y)		0.991	0.984	1.018	1.012	1.010
- Average				1.00		
METER COEFFICIENT ($\Delta H_@$)		1.648	1.743	1.727	1.741	1.771
- Average				1.73		

"S" TYPE PITOT TUBE CALIBRATION

"S" Type Pitot Tube (Probe) # 3 foot Probe # 3

Calibration Date: August 1, 1985

$$C_p = C_{std} \sqrt{\frac{\Delta P_{std}}{\Delta P_p}}$$ (EPA Equation 2-2)

where:

C_p = Coefficient of Type S pitot tube, dimensionless

C_{std} = Coefficient of Standard Pitot Tube (0.99), dimensionless

ΔP_{std} = Velocity head measured by standard pitot tube, inches H_2O

ΔP_p = Velocity head measured by Type S pitot tube, inches H_2O

	ΔP_{std}	ΔP_p	C_p
Side A	0.20	0.31	0.795
Side B	0.20	0.31	0.795
Side A	0.60	0.92	0.799
Side B	0.60	0.92	0.799
Side A	1.10	1.65	0.808
Side B	1.10	1.65	0.808

Average - 0.80

NOZZLE DIAMETER CALIBRATION

I.D. of nozzles are checked periodically by inside micrometer on at least 12 different diameters. If deviation exceeds +0.001" on an average or 0.002" maximum, nozzle is reworked. Sharpening occurs after each test.

CALIBRATION FREQUENCY

The frequency of calibration is dictated by the Federal Register, Volume 42, Number 160, August 18, 1977. The regulations state that you must "use methods and equipment which have been approved by the Administrator to calibrate the orifice meter, pitot tube, dry gas meter, and probe heater. Recalibrate after each test".

The methods of calibration are determined from "Maintenance, Calibration, and Operation of Isokinetic Source Sampling Equipment," published by the U.S. EPA Office of Air Program Publications APTD-0576. Per the above listed regulations, the equipment was checked after the stack test and the values of Y, Cp (Test) and nozzle diameter had not appreciably changed from the acceptable tolerances.

FIELD DATA SHEETS

FIELD DATA

PLANT NEO Southerly WWTP
DATE Aug 28, 1985
SAMPLING LOCATION Incinerator #1
SAMPLE TYPE EPA Methods 1-5
OPERATOR TH Du
AMBIENT TEMPERATURE 70's
BAROMETRIC PRESSURE
STATIC PRESSURE -.50
HEATER BOX SETTING 250

Incinerator #1
36" Dia

PROBE LENGTH & TYPE 3 Pyrex
NOZZLE I.D. 0.25
ASSUMED MOISTURE % 4
METER BOX NUMBER And
METER ΔH @ 1.73
C FACTOR 1.00
PITOT CORRECTION FACTOR 0.
PRE-TEST LEAK CHECK 0 CFM@ 15 "Hg
POST-TEST LEAK CHECK ____ CFM@ ____ "Hg

SCHEMATIC OF TRAVERSE POINT LAYOUT

READ AND RECORD ALL DATA EVERY 2.5 MINUTES

TRAVERSE POINT NUMBER	ELAPSED SAMPLING TIME min.	GAS METER READING	VELOCITY HEAD		ORIFICE PRESSURE DIFFERENTIAL	STACK TEMPERATURE	GAS METER TEMPERATURE INLET	GAS METER TEMPERATURE OUTLET	PUMP VACUUM	FILTER HOLDER TEMP.	IMPINGER TEMP.
1	0 /9:00 Am	432.60	.90	.141	3.20	132	69	66	4.0	240	<70
2	2.5	435.40	.95	.975	3.40	130	84	66	4.0		
3	5	437.60	1.00	1.00	3.60	135	88	66	4.0		
4	7.5	440.50	.98	.990	3.50	134	95	67	4.0	237	
5	10	443.50	1.10	1.049	4.00	128	99	68	5.0		
6	12.5	446.20	1.00	1.00	3.60	130	102	69	4.0		
7	15	448.30	.92	.959	3.30	136	104	70	4.0	238	
8	17.5	450.60	.88	.938	3.10	136	105	71	3.0		
9	20	453.20	.75	.866	2.70	140	105	72	3.0		
10	22.5	455.60	.70	.837	2.50	136	105	73	3.0	228	
11	25	457.70	.50	.707	1.80	134	104	74	2.0		
12	27.5	460.00	.45	.671	1.60	137	102	75	1.5		
1	30	461.45	.70	.837	2.50	126	98	75	3.0	237	
2	32.5	463.20	.75	.866	2.70	130	101	76	3.0		
3	35	465.80	.84	.917	3.00	126	103	76	3.5		
4	37.5	468.70	.80	.894	2.90	130	105	77	3.0	242	
5	40	471.00	.95	.975	3.40	132	106	78	4.0		
6	42.5	473.80	1.00	1.00	3.60	136	107	78	4.0		
7	45	476.20	1.10	1.049	4.00	142	109	79	5.0	241	
8	47.5	477.90	1.10	1.049	4.00	140	110	80	5.0		
9	50	481.50	1.10	1.049	4.00	137	112	81	5.0		
10	52.5	484.60	.85	.922	3.00	150	113	82	4.0	246	
11	55	486.90	.70	.837	2.50	146	112	82	3.0		
12	57.5	489.30	.50	.707	1.80	154	110	83	2.0		
	60/10:01 Am	491.24									
		5.84		.113	3.07						

Run #1
Case #5

M: 7.10
8/28/85

KCK @10'

12

PLANT Southerly DATE 8-28-85 LEAK CHECK 0 CFM@ 14 "Hg PAGE 2 OF 3

Run#2
Case#6

TRAVERSE POINT NUMBER	ELAPSED SAMPLING TIME min.	GAS METER READING	VELOCITY HEAD		ORIFICE PRESSURE DIFFERENTIAL	STACK TEMPERATURE	GAS METER TEMPERATURE INLET	GAS METER TEMPERATURE OUTLET	PUMP VACUUM	FILTER HOLDER TEMP.	IMPINGER TEMP.
1	0 / 10:15	492.00	.71	.843	2.55	126	90	80	3	231	<70°
2	2.5	494.1	.71	.843	2.55	126	97	80	3		
3	5	496.6	.72	.849	2.6	131	103	80	3		
4	7.5	499.1	.72	.849	2.6	128	105	81	3	238	
5	10	501.1	.72	.849	2.6	131	107	81	3		
6	12.5	503.4	.72	.849	2.6	134	108	82	3		
7	15	505.[illegible]	.80	.894	2.8	144	110	82	3	247	
8	17.5	507.7	.85	.922	3.2	147	112	83	3		
9	20	510.2	.82	.906	2.6	146	113	84	4		
10	22.5	512.7	.75	.866	2.4	149	114	85	4	238	
11	25	515.2	.68	.825	2.2	151	113	85	3		
12	27.5	517.3	.45	.671	1.5	153	113	85	3		
1	30	519.25	.88	.938	2.8	136	105	85	4	235	
2	32.5	521.6	.72	.849	[illegible]	138	113	86	3		
3	35	523.9	.74	.860	2.4	139	115	87	3		
4	37.5	526.2	.74	.860	2.4	136	115	87	3	243	
5	40	528.4	.78	.883	2.5	134	115	87	3		
6	42.5	530.6	.86	.927	2.75	136	115	88	4		
7	45	533.0	.84	.917	2.7	137	116	88	4	256	
8	47.5	535.4	.84	.917	2.7	142	117	89	4		
9	50	537.6	.78	.883	2.5	143	117	89	3		
10	52.5	539.9	.65	.806	2.1	141	117	90	3	255	
11	55	542.1	.58	.762	1.85	140	117	90	3		
12	57.5	544.1	.56	.748	1.8	139	116	90	3		
	60/11:17AM	546.06									
		54.06		.855	2.46	138.6	98.1				

Nomograph change Ts → (at point 9)

M Kr[illegible]
8-28-85

Leak Check
0 @ 11 in Hg

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PLANT Southerly DATE 8-28-85 LEAK CHECK 0 CFM@ 15 "Hg PAGE 3 OF 3

Run 3 one 11

TRAVERSE POINT NUMBER	ELAPSED SAMPLING TIME min.	GAS METER READING	VELOCITY HEAD		ORIFICE PRESSURE DIFFERENTIAL	STACK TEMPERATURE	GAS METER TEMPERATURE INLET	GAS METER TEMPERATURE OUTLET	PUMP VACUUM	FILTER HOLDER TEMP.	IMPINGER TEMP.
1	0/11:32 am	546.50	.90	.949	3.20	132	95	88	6.0	230	<70
2	2.5	548.00	.95	.975	3.40	137	104	88	6.5		
3	5	551.60	1.00	1.00	3.60	138	110	88	7.0		
4	7.5	554.00	1.00	1.00	3.60	132	114	88	7.0	233	
5	10	556.70	.95	.975	3.40	134	117	88	6.0		
6	12.5	559.70	.95	.975	3.40	132	119	90	6.0		
7	15	562.10	1.00	1.00	3.60	140	121	90	7.0	232	
8	17.5	564.80	1.00	1.00	3.60	146	121	90	7.0		
9	20	567.40	.90	.949	3.20	148	122	91	6.0		
10	22.5	570.00	.70	.837	2.50	146	122	91	5.0	248	
11	25	572.30	.50	.707	1.80	140	120	91	3.0		
12	27.5	574.60	.45	.671	1.50	136	118	92	2.0		
1	30	576.14	.70	.837	2.50	126	111	91	5.0	256	
2	32.5	578.50	.70	.837	2.50	126	117	92	5.0		
3	35	580.60	.75	.866	2.70	129	119	92	5.0		
4	37.5	584.00	.75	.866	2.70	132	121	93	5.0	242	
5	40	586.00	.80	.894	2.90	130	122	93	5.0		
6	42.5	587.70	.85	.922	3.00	133	123	93	5.5		
7	45	590.00	.90	.949	3.20	144	124	94	6.0	260	
8	47.5	592.20	1.00	1.00	3.60	143	126	95	7.0		
9	50	594.95	1.00	1.00	3.60	148	127	95	7.0		
10	52.5	597.70	.80	.894	2.90	152	127	96	5.5	252	
11	55	600.00	.55	.742	1.90	151	128	97	3.5		
12	57.5	602.20	.50	.707	1.80	144	125	98	3.0		
	60/12:34 pm	604.23									
		57.73		.898	2.92	138.3	118.9	91.8			
							105.4				

J. M. Kon 8/28

KCK @10"

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PARTICULATE SAMPLING

NOMENCLATURE

PARTICULATE SAMPLING NOMENCLATURE

A = Cross sectional area of stack or duct, ft^2.

A_n = Cross sectional area of nozzle, ft^2.

B_{ws} = Water vapor in gas stream, proportion by volume.

C = Nomograph correction factor, dimensionless.

C_p = Pitot tube coefficient, dimensionless.

C_s = Concentration of particulate matter in gas stream, dry basis-corrected to standard conditions, gr/dscf.

D_n = Nominal diameter of probe nozzle tip, inches.

E = Particulate Emission Rate, lb/hr.

ΔH = Average pressure differential across orifice, in. H_2O.

$\Delta H_@$ = Orifice meter calibration factor, in. H_2O.

I = Percent of Isokinetic sampling, %.

K_p = Pitot tube constant, $85.49 \left[\frac{ft}{sec} \left| \frac{(lb/lb\text{-}mole)(in.Hg)}{(^\circ R)(in.H_2O)} \right| \right]$

M_d = Molecular weight of gas, dry basis, lb/lb-mole.

M_n = Total amount of particulate matter collected, g.

M_s = Molecular weight of gas, wet basis, lb/lb-mole.

Particulate Sampling Nomenclature - continued

M_w = Molecular weight of water, 18 lb/lb-mole.

P_{bar} = Barometric Pressure, in. Hg.

P_g = Pressure differential from gas stream to atmosphere, (static pressure) in.H_2O.

P_s = Absolute gas stream pressure, $(P_{bar} + P_g/13.6)$ in.Hg.

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

P_w = Density of water, 0.0022 lb/ml.

$\hat{p}_{avg}$ = Average of the square roots of the velocity head readings, $(\overline{\sqrt{\hat{p}}})$ (in.H_2O).

Q = Volumetric flow rate at gas stream conditions, A.C.F.M.

Q_{sd} = Dry volumetric gas flow rate corrected to standard conditions, S.C.F.M.

R = Ideal gas constant, 21.85 in. Hg-ft^3/ ^oR-lb-mole.

t = Total sampling time, minutes.

T_m = Average dry gas meter temperature, ^oR.

T_s = Average absolute gas stream temperature, ^oR.

T_{std} = Standard absolute temperature, 528^o Rankine.

V_{lc} = Volume of water collected in impingers & silica gel, ml.

Particulate Sampling Nomenclature - continued

V_m = Volume of gas sample measured at meter box (meter conditions), ft^3.

$V_{m(std)}$ = Volume of gas sample measured at meter box (corrected to standard conditions), ft^3.

V_s = Average gas stream velocity, ft/sec.

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

13.6 = Specific gravity of mercury (Hg).

% CO_2 = Percent by volume of CO_2 in gas stream (dry basis).

% O_2 = Percent by volume of O_2 in gas stream (dry basis).

% CO = Percent by volume of CO in gas stream (dry basis).

% N_2 = Percent by volume of N_2 in gas stream (dry basis).

SAMPLE STACK TESTING EQUATIONS

1) Volume of dry gas sampled through meter box at standard conditions,

$$V_{m(std)} = V_m \left[\frac{T_{std}}{T_m} \right] \left[\frac{P_b + \frac{\Delta H}{13.6}}{P_{std}} \right]$$

(EPA Equation 5-1)

Where:

$V_{m(std)}$ = Volume of gas sample measured at meter box (corrected to standard conditions), ft^3.

V_m = Volume of gas sample measured at meter box (meter conditions), ft^3.

T_{std} = Standard absolute temperature, 528° Rankine.

T_m = Average dry gas meter temperature, $^{\circ}R$.

P_{bar} = Barometric Pressure, in. Hg.

ΔH = Average pressure differential across orifice, in. H_2O.

13.6 = Specific gravity of mercury (Hg).

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

Example: Run 1

V_m = 58.64 ft^3

T_m = 548.2 $^{\circ}R$

ΔH = 3.07 in. H_2O

P_{bar} = 29.66 in. Hg

$$V_{m(std)} = 58.64 \left[\frac{528.0}{548.2} \right] \left[\frac{29.66 + \frac{3.07}{13.6}}{29.92} \right]$$

$$= 58.64 \quad (0.9631) \quad (0.9988)$$

$$= \underline{56.41} \quad ft^3$$

2) Volume of water vapor collected at standard conditions,

$$V_{w(std)} = V_{lc} \left[\frac{P_w}{M_w} \right] \left[\frac{(R)(T_{std})}{P_{std}} \right]$$

(EPA Equation 5-2)

Where:

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

V_{lc} = Volume of water collected in impingers & silica gel, ml.

P_w = Density of water, 0.0022 lb/ml.

M_w = Molecular weight of water, 18 lb/lb-mole.

R = Ideal gas constant, 21.83 in. Hg-ft^3/ ^oR-lb-mole.

T_{std} = Standard absolute temperature, 528 ^{o} Rankine.

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

Example: Run 1

V_{lc} = 50.4 ml

$$V_{w(std)} = 50.4 \left[\frac{0.0022}{18.0} \right] \left[\frac{(21.83)(528.0)}{29.92} \right]$$

= 2.37 ft^3

3) Moisture content of gas stream,

$$B_{ws} = \frac{V_{w(std)}}{V_{m(std)} + V_{w(std)}}$$

(EPA Equation 5-3)

Where:

B_{ws} = Water vapor in gas stream, proportion by volume.

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

$V_{m(std)}$ = Volume of gas sample measured at meter box (corrected to standard conditions), ft^3.

Example: Run 1

$V_{w(std)} = 2.37 \ ft^3$

$V_{m(std)} = 56.41 \ ft^3$

$$B_{ws} = \frac{2.37}{56.41 + 2.37}$$

$$= 0.0404$$

4) Dry Molecular Weight of gas in gas stream,

$$M_d = 0.440\ (\%CO_2) + 0.320\ (\%O_2) + 0.280\ (\%N_2 + \%CO)$$

(EPA Equation 3-2)

Where:

M_d = Molecular weight of gas, dry basis, lb/lb-mole.

0.440 = Molecular weight of CO_2 divided by 100.

0.320 = Molecular weight of O_2 divided by 100.

0.280 = Molecular weight of N_2 or CO (same for both compounds) divided by 100.

$\%\ CO_2$ = Percent by volume of CO_2 in gas stream (dry basis).

$\%\ O_2$ = Percent by volume of O_2 in gas stream (dry basis).

% CO = Percent by volume of CO in gas stream (dry basis).

$\%\ N_2$ = Percent by volume of N_2 in gas stream (dry basis).

Example: Run 1

$\%\ CO_2$ = 4.8

$\%\ O_2$ = 15.0

% CO = 0.0

$\%\ N_2$ = 80.2

$M_d = 0.440\ (\ 4.8\ ) + 0.320\ (\ 15.0\ ) + 0.280\ (\ 80.2\ )$

$= 2.112 + 4.800 + 22.456$

$= 29.37$ lb/lb-mole

5) Molecular Weight of gas in gas stream,

$$M_s = M_d (1 - B_{ws}) + M_w (B_{ws})$$

(EPA Equation 2-5)

Where:

M_s = Molecular weight of gas, wet basis, lb/lb-mole.

M_d = Molecular weight of gas, dry basis, lb/lb-mole.

B_{ws} = Water vapor in gas stream, proportion by volume.

M_w = Molecular weight of water, 18 lb/lb-mole.

Example: Run 1

M_d = 29.37 lb/lb-mole

B_{ws} = 0.0404

M_s = 29.37 (1 - 0.0404) + 18 (0.0404)

= 28.183 + 0.727

= 28.91 lb/lb-mole

6) Average Gas Stream Velocity,

$$V_s = K_p C_p \Delta P_{avg} \sqrt{\frac{T_s}{P_s M_s}}$$

(EPA Equation 2-9)

Where:

V_s = Average gas stream velocity, ft/sec.

K_p = Pitot tube constant, 85.49 $\frac{ft}{sec}\left[\frac{(lb/lb\text{-}mole)(in.Hg)}{(^oR)(in.H_2O)}\right]^{1/2}$

C_p = Pitot tube coefficient, dimensionless.

ΔP_{avg} = Average of the square roots of the velocity head readings, $(\sqrt{\Delta p})$ $(in.H_2O)$.

T_s = Average absolute gas stream temperature, ^oR.

P_s = Absolute gas stream pressure, $(P_{bar} + P_g/13.6)$ in.Hg.

P_{bar} = Barometric Pressure, in. Hg.

P_g = Pressure differential from gas stream to atmosphere, (static pressure) $in.H_2O$.

M_s = Molecular weight of gas, wet basis, lb/lb-mole.

Example: Run 1

C_p = 0.80

ΔP_{avg} = 0.918 $(in.H_2O)^{1/2}$

T_s = 595.7 ^oR

$P_s = P_{bar} + P_g/13.6 = 29.66 + -0.50/13.6 = 29.62$ in.Hg

M_s = 28.91 lb/lb-mole

$$V_s = (85.49)(0.80)(0.918)\sqrt{\frac{595.7}{(29.62)(28.91)}}$$

$$= 52.36 \text{ ft/sec}$$

7) Volumetric Flow Rate at Gas Stream Conditions,

$$Q = A \times V_s \times 60$$

Where:

Q = Volumetric flow rate at gas stream conditions, A.C.F.M.

A = Cross sectional area of stack or duct, ft^2.

V_s = Average gas stream velocity, ft/sec.

60 = Conversion factor from seconds to minutes.

Example: Run 1

A = 7.07 ft^2

V_s = 52.36 ft/sec

$Q = (7.07) (52.36) 60$

$= 22,208$ ACFM

8) Volumetric Flow Rate at Standard Conditions,

$$Q_{sd} = 60 \ (1 - B_{ws}) \ V_s \ A \left[\frac{T_{std}}{T_s} \right] \left[\frac{P_s}{P_{std}} \right]$$

(EPA Equation 2-10)

Where:

Q_{sd} = Dry volumetric gas flow rate corrected to standard conditions, S.C.F.M.

60 = Conversion factor from seconds to minutes.

B_{ws} = Water vapor in gas stream, proportion by volume.

V_s = Average gas stream velocity, ft/sec.

A = Cross sectional area of stack or duct, ft^2.

T_{std} = Standard absolute temperature, 528 ^{o} Rankine.

T_s = Average absolute gas stream temperature, ^{o}R.

P_s = Absolute gas stream pressure, $(P_{bar} + P_g/13.6)$ in.Hg.

P_{bar} = Barometric Pressure, in. Hg.

P_g = Pressure differential from gas stream to atmosphere, (static pressure) in.H_2O.

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

Example: Run 1

B_{ws} = 0.0404

V_s = 52.36 ft/sec

A = 7.07 ft^2

T_s = 595.7 ^{o}R

$P_s = P_{bar} + P_g/13.6 = 29.66 + -0.50/13.6 = 29.62$ in.Hg

$$Q_{sd} = 60 \ (1 - 0.0404) \ (52.36) \ (7.07) \ \frac{528.0}{595.7} \ \frac{29.62}{29.92}$$

= 18,702 SCFM

9) Gas Stream Particulate Concentration,

$$C_s = 15.43 \text{ gr./g} \left[\frac{M_n}{V_{m(std)}} \right]$$

(EPA Equation 5-6)

Where:

C_s = Concentration of particulate matter in gas stream, dry basis-corrected to standard conditions, gr/dscf.

M_n = Total amount of particulate matter collected in probe wash and on filter, g.

$V_{m(std)}$ = Volume of gas sample measured at meter box (corrected to standard conditions), ft^3.

1

Example: Run 1

$$M_n = \underset{\text{(probe)}}{0.0040} + \underset{\text{(filter)}}{0.0601} = 0.0641 \text{ g}$$

$$V_{m(std)} = 56.41 \text{ } ft^3$$

$$C_s = 15.43 \left[\frac{0.0641}{56.41} \right]$$

$$= 0.0175 \text{ gr/dscf}$$

10) Particulate Emission Rate,

$$E = Q_{sd} \; C_s \left[\frac{1 \text{ pound}}{7000 \text{ grains}}\right] \left[\frac{60 \text{ minutes}}{1 \text{ hour}}\right]$$

Where:

E = Particulate Emission Rate, lb/hr.

Q_{sd} = Dry volumetric gas flow rate corrected to standard conditions, S.C.F.M.

C_s = Concentration of particulate matter in gas stream, dry basis-corrected to standard conditions, gr/dscf.

Example: Run 1

Q_{sd} = 18,702 ft^3

C_s = 0.0175 gr/dscf

$$E = (18,702) (0.0175) \left[\frac{60}{7000}\right]$$

$$= 2.81 \text{ lb/hr}$$

11) Percent of Isokinetic Sampling,

$$I = \frac{100\ T_s \left[K_3\ V_{lc} + \left[\frac{V_m}{T_m} \right] \left[P_{bar} + \frac{\Delta H}{13.6} \right] \right]}{60\ A_n\ V_s\ P_s\ t}$$

(EPA Equation 5-7)

Where:

I = Percent of Isokinetic sampling, %.

T_s = Average absolute gas stream temperature, ^{o}R.

K_3 = Constant, 0.002669 in.Hg-ft^3/ml-^{o}R.

V_{lc} = Volume of water collected in impingers & silica gel, ml.

V_m = Gas sample volume measured at meter box (meter conditions), ft^3.

T_m = Average dry gas meter temperature, ^{o}R.

P_{bar} = Barometric Pressure, in. Hg.

ΔH = Average pressure differential across orifice, in. H_2O.

t = Total sampling time, minutes.

V_s = Average gas stream velocity, ft/sec.

P_s = Absolute gas stream pressure, in.Hg.

D_n = Nominal diameter of probe nozzle tip, inches.

A_n = Cross sectional area of nozzle, ft^2.

Example: Run 1

T_s	=	595.7	^{o}R	ΔH	=	3.07	in.H_2O
V_{lc}	=	50.4	ml	t	=	60.0	min.
V_m	=	58.64	ft^3	V_s	=	52.36	ft/sec
T_m	=	548.2	^{o}R	P_s	=	29.62	in.Hg
A_n	=	0.0003408	ft^2	P_{bar}	=	29.66	in.Hg

$$I = \frac{595.7\ (\ 100\ ) \left[0.002669\ (\ 50.4\ ) + \left[\frac{58.64}{548.2} \right] \left[29.66 + \frac{-0.50}{13.6} \right] \right]}{60\ (0.0003408\ )\ (\ 52.36\ )\ (\ 29.62\ )\ (\ 60.0\ )}$$

$$= 104.2\ \%$$