AIRTECH
Environmental
Services Inc.

1371 Brummel Ave • Elk Grove Village, IL 60007
Phone: (630) 860-4740 • Fax: (847) 258-3755
www.airtechenv.com

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Report on the Air Emission Test Program
Wartsila Engines Unit 1, Unit 2, and Unit 3
(EU-ENGINE01, EU-ENGINE02, EU-ENGINE03)

Conducted for Marquette Board of Light & Power
at the Marquette Energy Center Located at
2200 Wright Street
Marquette, Michigan

Report No. 6573 Compliance
January 18, 2018

Introduction

General

Airtech Environmental Services Inc. (Airtech) located at 1371 Brummel Ave., Elk Grove Village, IL 60007 was contracted by the Marquette Board of Light & Power (MBLP) to perform an air emissions test program at the Marquette Energy Center located at 2200 Wright Street, Marquette, Michigan. The specific objectives of this test program were as follows:

- Conduct initial compliance test to determine the concentration of NO_X and non-sulfuric acid (NSA) particulate matter (PM) from the exhaust of Units 1 (EU-ENGINE01), 2 (EU-ENGINE02) and 3 (EU-ENGINE03), while fired on "light fuel oil (LFO)"[2]

- Conduct initial compliance test to determine the concentration of NO_X, CO and volatile organic compounds (VOC) from the exhaust of Units 1, 2 and 3, while fired on "natural gas"

Testing was conducted to meet the requirements of MBLP; the Michigan Department of Environmental Quality (MDEQ); Permit to Install (PTI) No. 204-15, the United States Environmental Protection Agency (U.S. EPA); and 40 CFR Parts 60 and 75, as applicable.

Testing while the engines were fired on LFO was performed on June 27 through June 30. Testing while the engines were fired on natural gas was performed on August 15 through August 18, 2017. Coordinating the field aspects of the test program were:

Tom Carpenter	**Brandon Check/Matthew Libman**
Marquette Board of Light & Power	Airtech Environmental Services Inc.
2200 Wright Street	1371 Brummel Ave
Marquette, MI 49855	Elk Grove Village, IL 60007
Ph: (906) 228-0336	Ph: (630) 860-4740
E-Mail: tcarpenter@mblp.com	E-mail: Bcheck@airtechenv.com mlibman@montrose-env.com

ASTM D7036-04(2011)

All applicable Airtech field personnel used on-site for this test program were compliant with ASTM D7036-04(2011) "Standard Practice for Competence of Air Emissions Testing Bodies" for all tests performed. This includes having the appropriate QSTI directly supervise the testing.

The following table summarizes the key personnel that were involved with this project:

Personnel	Position on Project	Date of QSTI Exam
Brandon Check, Q.S.T.I.	Client Project Manager	3/31/2016
Matthew Libman, Q.S.T.I.	Field Project Manager	3/31/2016

Methodology

NOx and CO Methodology

EPA Methods 7E and 10 were used to determine the concentrations of NOx and CO at the test locations. In EPA Methods 7E and 10, a sample of the gas stream was continuously withdrawn from the test location and analyzed using a temporary RM monitoring system. The sample gas was withdrawn from the test location at a constant rate through an in-situ 0.3 micron stainless-steel cintered frit, a stainless-steel probe, and Teflon sample line and vented to the NOx and CO analyzers.

VOC Methodology

EPA Method 18 combined with EPA Method 25A and EPA Method 320 was used to determine the concentration of VOC at the test locations. In EPA Methods 18/25A/320, a sample of the gas stream was continuously withdrawn from the test location and analyzed using a temporary RM monitoring system. Because methane and ethane are exempt VOCs and are included with the Method 25A result, they were calculated with other methods. The methane concentrations were determined with EPA Method 18 and analyzed using a Gas Chromatograph (GC). The ethane concentrations were determined with EPA Method 320 and analyzed with a Fourier Transform Infrared Spectrometer (FTIR). The methane and ethane emission rates were subtracted from the VOC emission rate to give a total non-methane-non-ethane VOC emission rate.

PM Methodology

EPA Method 5B was used to determine the concentration of non-sulfuric acid (NSA) PM at the test locations during the LFO firing. In EPA Method 5B a sample of the gas stream was withdrawn isokinetically from the test location, and the PM in the sample gas was collected in a heated, glass-lined probe and on a heated, quartz fiber filter. The probe and filter were operated at a temperature of 320°F +/-25°F. The weight of particulate collected with the sample train combined with the volume of dry gas withdrawn from the stack was then used to calculate the particulate concentration.

Volumetric Flow Methodology

To convert the concentrations of various pollutants to mass emission rates, the volumetric flow rate was determined concurrently with each test run using EPA Methods 1, 2, 3A and 4/320.

Fuel Samples

During performance testing, various fuel samples were collected and analyzed by MBLP. The results of the analysis were provided to Airtech. Samples were analyzed per 40 CR 60, GG for total sulfur content, using ASTM D129-00, D2622-98, D4294-02, D1266-98, D5453-00 or D1552-01for liquid "fuel oil" samples and using ASTM D1072-80, 90, D3246-81, 92, 96, D4468-85, or D6667-01for gaseous "natural-gas" samples.

Parameters

The following parameters were determined at the exhaust of each engine:

- gas velocity
- gas temperature
- oxygen concentration
- carbon dioxide concentration
- moisture concentration
- non-sulfuric acid particulate matter concentration (fuel oil only)
- nitrogen oxides concentration
- carbon monoxide concentration (natural gas only)
- methane concentration (natural gas only)
- ethane concentration (natural gas only)
- total hydrocarbon concentration (natural gas only)

Summary of Results

	Permit P0668		EU-ENGINE01	EU-ENGINE02	EU-ENGINE03
Pollutant	Permit Limit	Fuel Type	Unit 1	Unit 2	Unit 3
NO$_x$	10.5g/Kw-hr	Oil	0.225	0.398	0.424
NSA PM	0.40 g/kW-hr	Oil	0.0141	0.0144	0.0110
NO$_x$	3.3 lb/hr	Natural Gas	1.77	1.80	1.99
NO$_x$	1.0 g/hp-hr	Natural Gas	0.0629	0.0639	0.0711
NO$_x$	82 ppmdv@15%O$_2$	Natural Gas	3.24	3.28	3.82
CO	5.0 lb/hr	Natural Gas	0.0234	0.0167	0.0213
CO	2.0 g/hp-hr	Natural Gas	0.000833	0.000595	0.000760
CO	270 ppmdv@15%O$_2$	Natural Gas	0.0704	0.0504	0.0670
VOC	0.7 g/hp-hr	Natural Gas	0.678	0.181	0.444
VOC	60 ppmdv@15%O$_2$	Natural Gas	51.5	30.5	44.3

Source Description

MBLP has installed three (3) dual-fired natural gas and fuel oil Wartsila 18V50DF, 4 stroke, lean burn nominal 17 MW (173 mmBtu/hr when firing natural gas as primary fuel, 154 mmBtu/hr when firing emergency backup fuel oil), reciprocating internal combustion engine used for electricity with selective catalytic reduction (SCR) and oxidation catalyst for control.

Test Results and Discussion

A complete summary of test results may be found in Tables 1 through 6 on pages 9 through 14.

Summary of Test Results and Operating Conditions

Pollutant/ Operating Parameter	Permit Limit/ Unit		EU-ENGINE01	EU-ENGINE02	EU-ENGINE03
		Fuel Type	Unit 1	Unit 2	Unit 3
NO_X	10.5g/Kw-hr	Oil	0.225	0.398	0.424
NSA PM	0.40 g/kW-hr	Oil	0.0141	0.0144	0.0110
Fuel oil rate	lb/h	Oil	7031	7074	7037
Reagent flow rate	gal/h	Oil	660	81	87
Reactor inlet temp	F	Oil	691	671	651
Reactor outlet temp	F	Oil	19	699	683
∫ Pressure over reactor	lb/ft^2	Oil	86	20	19
Engine raw	ppm	Oil	1190	1169	1278
NO_X	3.3 lb/hr	Natural Gas	1.77	1.80	1.99
NO_X	1.0 g/hp-hr	Natural Gas	0.0629	0.0639	0.0711
NO_X	82 ppmdv@15%O_2	Natural Gas	3.24	3.28	3.82
CO	5.0 lb/hr	Natural Gas	0.0234	0.0167	0.0213
CO	2.0 g/hp-hr	Natural Gas	0.000833	0.000595	0.000760
CO	270 ppmdv@15%O_2	Natural Gas	0.0704	0.0504	0.0670
VOC	0.7 g/hp-hr	Natural Gas	0.678	0.181	0.444
VOC	60 ppmdv@15%O_2	Natural Gas	51.5	30.5	44.3
Fuel oil rate	lb/h	Natural Gas	6132	6050	6145
Reagent flow rate	gal/h	Natural Gas	9	8	9
Reactor inlet temp	F	Natural Gas	774	780	787
Reactor outlet temp	F	Natural Gas	784	788	798
∫ Pressure over reactor	lb/ft^2	Natural Gas	19	19	19
Engine raw	ppm	Natural Gas	127	119	134

Process Operating Conditions

Process Operating Conditions				PCC011F00 1PV	YCA011F40 2PV	YDB011T50 1PV	YDB011T50 2PV	YDB011T50 1PV	YDB012T51 0PV
				Fuel oil flow rate	Reagent flowrate, LFO mode	Reactor inlet temp.	Reactor outlet temp.	Differential pressure over reactor	Engine raw
Location Title Unit Name	Date	Run	Fuel Type	(lb/h)	(gal/h)	(F)	(F)	(lb/ft^2)	(ppm)
EU-ENGINE01 Unit 1	6/29	1	Oil	7035	666	697	19	85	1178
	6/29	2	Oil	7036	657	688	19	87	1200
	6/30	3	Oil	7021	657	688	19	87	1192
EU-ENGINE02 Unit 2	6/28	1	Oil	7079	84	661	690	19	1197
	6/28	2	Oil	7058	80	673	701	21	1159
	6/28	3	Oil	7084	80	678	706	21	1152
EU-ENGINE03 Unit 3	6/27	1	Oil	7026	87	651	682	19	1271
	6/27	2	Oil	7053	87	652	683	19	1278
	6/27	3	Oil	7032	88	651	683	19	1285
EU-ENGINE01 Unit 1	8/17	1	Natural Gas	6135	9	777	787	19	126
	8/17	2	Natural Gas	6129	9	772	782	19	128
	8/17	3	Natural Gas	6131	9	772	782	19	128
EU-ENGINE02 Unit 2	8/18	1	Natural Gas	6059	8	778	786	19	114
	8/18	2	Natural Gas	6051	8	780	788	19	121
	8/18	3	Natural Gas	6041	9	781	790	19	123
EU-ENGINE03 Unit 3	8/15	1	Natural Gas	6152	10	789	802	19	131
	8/15	2	Natural Gas	6147	9	787	799	19	130
	8/15	3	Natural Gas	6150	9	789	801	19	130
EU-ENGINE03 Unit 3	8/17	1	Natural Gas	6137	10	784	794	19	140
	8/17	2	Natural Gas	6139	9	786	796	19	137
	8/17	3	Natural Gas	6142	9	787	797	18	135

Discussion of Significance of Results

Unit 1, Unit 2 and Unit 3 meet all emission limits.

All units operated at the required operating parameters during testing as demonstrated in the Process Operating Conditions Table.

Discussion of Variations from Normal Sampling Parameters

As per the Frequently Asked Questions of Method 25A, a conversion factor of 3.0 was used to convert as propane concentrations to as methane.

Because the response of an FIA is approximately proportional to the carbon atoms in a compound, the FIA response to a mole of propane is approximately three times its response to a mole of methane (there are three times as many atoms of carbon in a mole of propane as there are in a mole of methane). The volume of a gas is directly proportional to the number of moles, so if the response of one mole of propane is equivalent to three moles of methane, then the response of a liter of propane is proportional to three liters of methane, and because it's a volume/volume fraction, the response of a ppm of propane is equivalent to three ppm of methane. Therefore, you can convert ppm of propane measured by an FIA to equivalent ppm of methane by multiplying by three. Similarly, as you noted, ppm methane would be equal to ppm carbon.

The volumetric flow rate determined by the Method 5B sampling trains was used to calculate emission rates for NO_X during the LFO firing testing.

The volumetric flow rate determined by the Method 5/202 sampling trains was used to calculate emission rates for NO_X, CO and VOC during the natural gas firing testing at Units 1 and 2. At Unit 2 a separate volumetric flow determination was performed. The moisture determined by the FTIR was used to calculate the volumetric flow rate.

Run 1 at Unit 2 was discarded due to a leak check failure. An addition run was performed at this test location. The results from Runs 2 through 4 are reported for all pollutants.

Discussion of Process or Control Equipment Upset Condition

The following pause was noted on the field data sheets due to the unit tripping.

Date	Unit	Run	Pause Time	Resume Time
6/29/17	Engine 1	R1	11:50	14:30

Description of any Major Maintenance

Units 1, 2 and 3 are new dual fired Wartsila 18V50DF, 4 Stroke Lean Burn Reciprocating Internal Combustion engines (Construction Permit P0668). No major maintenance has taken place.

Both qualitative and quantitative factors contribute to field measurement uncertainty and should be taken into consideration when interpreting the results contained within this report. Whenever possible, Airtech personnel reduce the impact of these uncertainty factors through the use of approved and validated test methods. In addition, Airtech personnel perform routine instrument and equipment calibrations and ensure that the calibration standards, instruments, and equipment used during test events meet, at a minimum, test method specifications as well as the specifications of our Quality Manual and ASTM D 7036-04. The limitations of the various methods, instruments, equipment, and materials utilized during this test have been reasonably considered, but the ultimate impact of the cumulative uncertainty of this project is not fully identified within the results of this report.

Compliance Statement

I certify that to the best of my knowledge and belief, Airtech Environmental Services complied with the requirements of current applicable emission test standards in the completion of this test program. I certify that, to the best of my knowledge, after reasonable inquiry of those responsible for collecting the necessary information, the information presented in this report is accurate.

Prepared by:	Reviewed by:
Cathy Busse	Roy Slick
Cathy Busse, Technical Writer	Roy Slick, Technical Writer

Table 1 – Unit 1, Fuel: Oil, NSA PM and NOx Results

Test Parameters	**Run 1**	**Run 2**	**Run 3**	**Average**	**Permit Limit**
Date	6/29/2017	6/29/2017	6/30/2017		
Start Time	10:00	15:48	15:30		
Stop Time	14:53	18:00	17:45		
Process Data					
Genset active power average (kW-hr)	17046	17044	17042		
Flue Gas Conditions					
Temperature (°F)	700	691	691	**694**	
Volumetric Flow Rate (acfm)	155,800	152,300	135,800	**148,000**	
Volumetric Flow Rate (scfm)	68,600	67,600	60,700	**65,600**	
Volumetric Flow Rate (dscfm)	63,600	62,800	55,900	**60,800**	
Carbon Dioxide (% dry)	6.60	6.45	6.45	**6.50**	
Oxygen (% dry)	12.1	12.3	12.3	**12.2**	
Moisture (%)	7.33	7.05	8.02	**7.47**	
Non-Sulfuric Acid Particulate Results					
Concentration (grains/dscf)	0.000967	0.00103	0.00106	**0.00102**	
Emission Rate (lb/hr)	0.527	0.552	0.508	**0.529**	
Emission Rate (g/hr)	239	251	230	**240**	
Emission Rate (g/kW-hr)	0.0140	0.0147	0.0135	**0.0141**	**0.40**
Nitrogen Oxide Results					
Concentration (ppm)	28.6	14.7	14.3	**19.2**	
Emission Rate (lb/hr)	13.0	6.63	5.70	**8.45**	
Emission Rate (g/hr)	5,906	3,009	2,587	**3,834**	
Emission Rate (g/kW-hr)	0.346	0.177	0.152	**0.225**	**10.5**

Table 2 – Unit 2, Fuel: Oil, NSA PM and NOx Results

Test Parameters	Run 1	Run 2	Run 3	Average	Permit Limit
Date	6/28/2017	6/28/2017	6/28/2017		
Start Time	10:18	14:46	18:00		
Stop Time	13:01	16:58	20:09		
Process Data					
Genset active power average (kW-hr)	17031	17014	17034		
Flue Gas Conditions					
Temperature (°F)	694	705	711	**704**	
Volumetric Flow Rate (acfm)	139,000	136,700	138,300	**138,000**	
Volumetric Flow Rate (scfm)	62,100	60,500	60,900	**61,200**	
Volumetric Flow Rate (dscfm)	58,300	56,700	56,500	**57,200**	
Carbon Dioxide (% dry)	6.34	6.45	6.51	**6.43**	
Oxygen (% dry)	12.3	12.3	12.2	**12.2**	
Moisture (%)	6.22	6.32	7.23	**6.59**	
Non-Sulfuric Acid Particulate Results					
Concentration (grains/dscf)	0.00119	0.00105	0.00106	**0.00110**	
Emission Rate (lb/hr)	0.596	0.512	0.513	**0.540**	
Emission Rate (g/hr)	270	232	233	**245**	
Emission Rate (g/kW-hr)	0.0159	0.0136	0.0137	**0.0144**	**0.40**
Nitrogen Oxide Results					
Concentration (ppm)	35.2	36.4	37.9	**36.5**	
Emission Rate (lb/hr)	14.7	14.8	15.3	**15.0**	
Emission Rate (g/hr)	6,675	6,715	6,960	**6783**	
Emission Rate (g/kW-hr)	0.392	0.395	0.409	**0.398**	**10.5**

Table 3 – Unit 3, Fuel: Oil, NSA PM and NOx Results

Test Parameters	Run 1	Run 2	Run 3	Average	Permit Limit
Date	6/27/2017	6/27/2017	6/27/2017		
Start Time	10:00	13:20	16:15		
Stop Time	12:30	15:31	18:30		
Process Data					
Genset active power average (kW-hr)	17028	17028	17030		
Flue Gas Conditions					
Temperature (°F)	683	683	684	**684**	
Volumetric Flow Rate (acfm)	132,400	134,300	135,000	**133,900**	
Volumetric Flow Rate (scfm)	60,000	60,900	61,200	**60,700**	
Volumetric Flow Rate (dscfm)	56,000	56,800	57,200	**56,700**	
Carbon Dioxide (% dry)	6.31	6.33	6.32	**6.32**	
Oxygen (% dry)	12.4	12.4	12.4	**12.4**	
Moisture (%)	6.81	6.74	6.50	**6.68**	
Non-Sulfuric Acid Particulate Results					
Concentration (grains/dscf)	0.00127	0.000658	0.000630	**0.000854**	
Emission Rate (lb/hr)	0.611	0.320	0.309	**0.413**	
Emission Rate (g/hr)	277	145	140	**188**	
Emission Rate (g/kW-hr)	0.0163	0.00853	0.00823	**0.0110**	**0.40**
Nitrogen Oxide Results					
Concentration (ppm)	39.2	40.2	38.2	**39.2**	
Emission Rate (lb/hr)	15.7	16.4	15.7	**15.9**	
Emission Rate (g/hr)	7,137	7,430	7,102	**7223**	
Emission Rate (g/kW-hr)	0.419	0.436	0.417	**0.424**	**10.5**

Table 4 – Unit 1, Natural Gas Results

Test Parameters	**Run 1**	**Run 2**	**Run 3**	**Average**	**Permit Limit**
Date	8/17/2017	8/17/2017	8/17/2017		
Start Time	10:00	13:05	15:39		
Stop Time	12:17	15:15	17:52		
Operating Data					
Genset active power average (kW-hr)	17088	17080	17085		
Average (hp-hr)	12748	12742	12745		
Flue Gas Conditions					
Temperature (°F)	790	787	786	**788**	
Volumetric Flow Rate (acfm)	126,300	124,300	126,400	**125,600**	
Volumetric Flow Rate (scfm)	51,600	50,900	51,800	**51,500**	
Volumetric Flow Rate (dscfm)	45,900	46,400	46,100	**46,100**	
Carbon Dioxide (% dry)	5.43	5.45	5.45	**5.44**	
Oxygen (% dry)	11.1	11.2	11.1	**11.2**	
Moisture (%)	11.2	9.01	11.1	**10.4**	
Nitrogen Oxide Results					
Concentration, C (ppmdv)	5.02	5.38	5.63	**5.34**	
Concentration, C (ppmd@15%O_2)	3.04	3.29	3.39	**3.24**	**82**
Emission rate, E (lb/hr)	1.65	1.79	1.86	**1.77**	**3.3**
Emission rate, E (g/hp-hr)	0.0588	0.0636	0.0662	**0.0629**	**1.0**
Carbon Monoxide Results					
Concentration, C (ppmdv)	0.109	0.109	0.131	**0.116**	
Concentration, C (ppmd@15%O_2)	0.0662	0.0663	0.0788	**0.0704**	**270**
Emission Rate, E (lb/hr)	0.0219	0.0220	0.0263	**0.0234**	**5.0**
Emission rate, E (g/hp-hr)	0.000779	0.000784	0.000937	**0.000833**	**2.0**

Table 4 (continued) – Unit 1, Natural Gas Results

VOC Results	**Run 1**	**Run 2**	**Run 3**	**Average**	**Permit Limit**
THC Concentration, as propane C (ppmwv)	384	366	377	**375**	
THC Concentration, as propane (ppmdv@15%O_2)	262	245	255	**254**	
THC Emission Rate, as propane (lb/hr)	136	128	134	**133**	
Methane Concentration (ppmdv)	1032	1021	828	**960**	
Methane Concentration (ppmdv@15%O2)	624	622	499	**582**	
Methane Concentration, as propane (ppm@15%)	208	207	166	**194**	
Methane Emission Rate (lb/hr)	118	118	95.5	**111**	
Ethane Concentration (ppmwv)	12.1	13.0	12.5	**12.5**	
Ethane Concentration (ppmdv@15%O2)	8.24	8.71	8.44	**8.46**	
Ethane Concentration as propane (ppmdv@15%O2)	5.49	5.81	5.63	**5.64**	
Ethane Emission Rate (lb/hr)	2.92	3.10	3.03	**3.02**	
VOC Concentration, as propane (ppmdv@15%O_2)	45.4	28.7	80.3	**51.5**	**60**
VOC Emission Rate, as propane (lb/hr)	15.0	6.48	35.6	**19.0**	
VOC Emission Rate, as propane (g/hp-hr)	0.535	0.231	1.27	**0.678**	**0.7**

Table 5 – Unit 2, Natural Gas Results

Test Parameters	Run 2	Run 3	Run 4	Average	Permit Limit
Date	8/16/2017	8/16/2017	8/16/2017		
Start Time	13:54	16:52	19:36		
Stop Time	16:14	19:00	21:47		
Operating Data					
Genset active power average (kW-hr)	17087	17087	17091		
Average (hp-hr)	12747	12747	12750		
Flue Gas Conditions					
Temperature (°F)	791	794	795	**793**	
Volumetric Flow Rate (acfm)	126,100	126,400	126,400	**126,300**	
Volumetric Flow Rate (scfm)	52,200	52,300	52,200	**52,200**	
Volumetric Flow Rate (dscfm)	46,900	46,900	47,600	**47,100**	
Carbon Dioxide (% dry)	5.57	5.48	5.31	**5.45**	
Oxygen (% dry)	11.3	11.4	11.3	**11.3**	
Moisture (%)	10.2	10.4	8.88	**9.83**	
Nitrogen Oxide Results					
Concentration, C (ppmdv)	5.54	5.32	5.09	**5.32**	
Concentration, C (ppmd@15%O_2)	3.40	3.31	3.15	**3.28**	**82**
Emission rate, E (lb/hr)	1.86	1.79	1.74	**1.80**	**3.3**
Emission rate, E (g/hp-hr)	0.0663	0.0635	0.0618	**0.0639**	**1.0**
Carbon Monoxide Results					
Concentration, C (ppmdv)	0.113	0.120	0.0119	**0.0817**	
Concentration, C (ppmd@15%O_2)	0.0692	0.0747	0.00736	**0.0504**	**270**
Emission Rate, E (lb/hr)	0.0231	0.0245	0.00248	**0.0167**	**5.0**
Emission rate, E (g/hp-hr)	0.000823	0.000874	0.0000881	**0.000595**	**2.0**

Table 5 (continued) – Unit 2, Natural Gas Results

VOC Results	**Run 2**	**Run 3**	**Run 4**	**Average**	**Permit Limit**
THC Concentration, as propane C (ppmwv)	375	385	356	**372**	
THC Concentration, as propane (ppmdv@15%O_2)	256	269	245	**257**	
THC Emission Rate, as propane (lb/hr)	134	138	128	**133**	
Methane Concentration (ppmdv)	1076	1073	1072	**1073**	
Methane Concentration (ppmdv@15%O2)	659	667	662	**663**	
Methane Concentration, as propane (ppm@15%)	220	222	221	**221**	
Methane Emission Rate (lb/hr)	126	126	127	**126**	
Ethane Concentration (ppmwv)	11.3	12.2	12.1	**11.9**	
Ethane Concentration (ppmdv@15%O2)	7.78	8.43	8.23	**8.15**	
Ethane Concentration as propane (ppmdv@15%O2)	5.18	5.62	5.49	**5.43**	
Ethane Emission Rate (lb/hr)	2.79	2.98	2.97	**2.91**	
VOC Concentration, as propane (ppmdv@15%O_2)	31.5	40.7	19.3	**30.5**	**60**
VOC Emission Rate, as propane (lb/hr)	5.58	9.68	0.00	**5.08**	
VOC Emission Rate, as propane (g/hp-hr)	0.198	0.344	0.000	**0.181**	**0.7**

Table 6 – Unit 3, Natural Gas Results

Test Parameters	**Run 1**	**Run 2**	**Run 3**	**Average**	**Permit Limit**
Date	8/18/2017	8/18/2017	8/18/2017		
Start Time	10:10	11:24	12:46		
Stop Time	11:10	12:25	13:45		
Operating Data					
Genset active power average (kW-hr)	17072	17069	17073		
Average (hp-hr)	12736	12733	12736		
Flue Gas Conditions					
Temperature (°F)	792	796	799	**796**	
Volumetric Flow Rate (acfm)	120,900	125,700	121,700	**122,800**	
Volumetric Flow Rate (scfm)	49,400	51,200	49,500	**50,000**	
Volumetric Flow Rate (dscfm)	44,100	45,800	44,200	**44,700**	
Carbon Dioxide (% dry)	5.45	5.45	5.45	**5.45**	
Oxygen (% dry)	11.3	11.3	11.3	**11.3**	
Moisture (%)	10.7	10.6	10.6	**10.7**	
Nitrogen Oxide Results					
Concentration, C (ppmdv)	6.11	6.14	6.43	**6.23**	
Concentration, C (ppmd@15%O_2)	3.74	3.77	3.95	**3.82**	**82**
Emission rate, E (lb/hr)	1.93	2.01	2.04	**1.99**	**3.3**
Emission rate, E (g/hp-hr)	0.0689	0.0717	0.0726	**0.0711**	**1.0**
Carbon Monoxide Results					
Concentration, C (ppmdv)	0.131	0.124	0.0739	**0.109**	
Concentration, C (ppmd@15%O_2)	0.0799	0.0758	0.0454	**0.0670**	**270**
Emission Rate, E (lb/hr)	0.0251	0.0246	0.0142	**0.0213**	**5.0**
Emission rate, E (g/hp-hr)	0.000895	0.000878	0.000507	**0.000760**	**2.0**

Table 6 (continued) – Unit 3, Natural Gas Results

VOC Results	**Run 1**	**Run 2**	**Run 3**	**Average**	**Permit Limit**
THC Concentration, as propane C (ppmwv)	384	377	373	**378**	
THC Concentration, as propane (ppmdv@15%O_2)	263	259	256	**259**	
THC Emission Rate, as propane (lb/hr)	130	133	127	**130**	
Methane Concentration (ppmdv)	1044	1007	1018	**1023**	
Methane Concentration (ppmdv@15%O2)	639	618	625	**627**	
Methane Concentration, as propane (ppm@15%)	213	206	208	**209**	
Methane Emission Rate (lb/hr)	115	115	112	**114**	
Ethane Concentration (ppmdw)	13.0	13.2	13.4	**13.2**	
Ethane Concentration (ppmdv@15%O2)	8.94	9.06	9.19	**9.06**	
Ethane Concentration as propane (ppmdv@15%O2)	5.96	6.04	6.13	**6.04**	
Ethane Emission Rate (lb/hr)	3.02	3.17	3.10	**3.09**	
VOC Concentration, as propane (ppmdv@15%O_2)	44.2	47.0	41.6	**44.3**	**60**
VOC Emission Rate, as propane (lb/hr)	12.1	14.3	11.0	**12.5**	
VOC Emission Rate, as propane (g/hp-hr)	0.431	0.509	0.393	**0.444**	**0.7**

Sampling and Analytical Procedures

Method Listing

The following test methods and Performance Specifications were used for the test program. These documents can be referenced in 40 CFR Part 60, Appendix A and B.

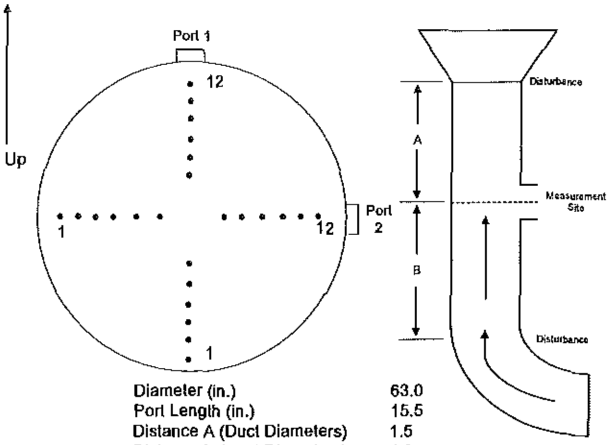
Method 1	Sample and velocity traverses for stationary sources
Method 2	Determination of stack gas velocity and volumetric flow rate (Type S Pitot Tube)
Method 3A	Determination of carbon dioxide and oxygen concentrations in emissions from stationary sources (Instrumental Analyzer Procedure)
Method 4	Determination of moisture content in stack gases
Method 5B	Determination of nonsulfuric acid particulate matter emissions from stationary sources
Method 7E	Determination of nitrogen oxides emissions from stationary sources (Instrumental analyzer procedure)
Method 10	Determination of carbon monoxide emissions from stationary sources (Instrumental Analyzer Procedure)
Method 18	Determination of gaseous organic compound emissions by gas chromatography
Method 25A	Determination of total gaseous organic concentration using a flame ionization analyzer
Method 320	Measurement of vapor phase organic and inorganic emissions by Extractive Fourier Transform Infrared (FTIR) spectroscopy

Method Descriptions

Method 1

EPA Method 1 was used to determine the suitability of each test location and to determine the traverse points used for the velocity determinations. Each test location conformed to the minimum EPA Method 1 requirements of being located at least two diameters downstream and at least 0.5 diameters upstream from the nearest flow disturbances.

The Unit 1, 2, and 3 test locations were round, vertical stacks with a diameter of 63.0 inches. The test ports were located approximately 4.2 equivalent diameters downstream and approximately 1.5 diameters upstream from the nearest flow disturbances. Twelve points in each of the two test ports were traversed for the velocity determinations. A cross section of the test locations showing the sample points is shown below and in Figure 1 of the Appendix.



Diameter (in.)	63.0
Port Length (in.)	15.5
Distance A (Duct Diameters)	1.5
Distance B (Duct Diameters)	4.2

Point	Distance From Wall (in.)
1	1.3
2	4.2
3	7.4
4	11.2
5	15.7
6	22.4
7	40.6
8	47.3
9	51.8
10	55.6
11	58.8
12	61.7

Cross Section of the Engines 1, 2, and 3 Test Locations
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Figure 1

Method 2

EPA Method 2 was used to determine the gas velocity through the test location, using a type S pitot tube and an incline plane oil manometer. The manometer was leveled and "zeroed" prior to each test run. The sample train was leak checked before and after each run by pressurizing the positive side, or "high" side, of the pitot tube and creating a deflection on the manometer equal to at least three (3) inches of water (in. H_2O). The leak check was considered valid if the manometer remained stable for a minimum of fifteen (15) seconds. The velocity head pressure and gas temperature were then determined at each point specified in Method 1. The static pressure of the stack was measured using a water filled U-tube manometer. In addition, the barometric pressure was measured and recorded.

The values measured in Method 2 along with the measurements made in Method 3A were used to calculate the volumetric flow rate through the test location. A diagram of the Method 2 apparatus is shown in Figure 2 and as part of the Method 5B sampling trains in Figure of the Appendix.

Methods 3A, 7E, 10 and 25A

The O_2, CO_2, NO_X, CO and THC concentrations at each test location were determined using EPA Methods 3A, 7E, 10 and 25A. Sample gas was withdrawn from the test location at a constant rate and analyzed using a temporary Continuous Emissions Monitoring System (CEMS). A diagram of the sampling system is shown in Figure 3 of the Appendix.

Sample gas was withdrawn from the test location at a constant rate through a stainless steel probe, a glass fiber filter and a Teflon sample line. The probe, filter and sample line were operated at a temperature of 250°F to prevent the condensation of moisture. The sample was then split into two portions.

The first portion of the sample gas passed through an M & C Type EC gas cooler system. The gas cooler is designed to unobtrusively lower the dewpoint of the sample gas to 35°F, thus removing the moisture. The dry gas was then vented to the O_2, CO_2, NO_X and CO analyzers. Results from these analyzers were determined on a "dry" basis. The second portion of the sample gas was sent directly to a flame ionization analyzer (FIA) for the determination of the THC concentration. The FIA was fueled with hydrogen.

The analyzers that were used for this project are listed in the table below:

Parameter	Manufacturer	Model Number	Operating Principle	Units Reported	Range used
Carbon Dioxide	Teledyne	T803	Infrared	%	0 – 10.14 0-10.06
Oxygen	Teledyne	T803	Paramagnetic	%	0 – 21.14 0-21.06
Nitrogen Oxides	Thermo Environmental	42i-HL	Chemi-luminescence	ppmd	0-91.27 0-48.45
Carbon Monoxide	Thermo Environmental	48i	Infrared	ppmd	0-88.83
Total Hydrocarbons	J.U.M. Engineering	3-300A	Flame Ionization	ppmw	0-1000

Each analyzer was calibrated with zero nitrogen and at least two known concentrations of the appropriate gas constituent in a balance of nitrogen. Each calibration gas was certified according to EPA Protocol 1 procedures.

Prior to sampling, a calibration error test was performed for each analyzer. The zero and high-range calibration gases for each constituent was introduced directly into each analyzer. Each analyzer was then adjusted to the appropriate values. The mid-range gas was then introduced to each analyzer and the measured values were recorded. The measured values for each calibration gas was then compared to the calibration gas values and the differences was less than the method requirement of two (2) percent of the span value.

A calibration error test was also conducted on the FIA. EPA protocol mixtures of propane in a balance of nitrogen were used for all calibrations. The zero and high range calibration gases were introduced into the sampling system prior to the filter and the FIA was adjusted to the appropriate values. Mid range and low range calibration gases were then introduced into the sampling system and the response of the FIA was compared to the cylinder gas value. In both cases the difference in response was less that the minimum requirement of five percent (5%) of the calibration gas value.

A sample system bias check was then performed by introducing the zero and mid-range calibration gases into the sampling system prior to the filter. The gas was drawn through the entire sampling system. The measured responses were then compared to the calibration error test values to determine the bias in response due to the sampling system. The sampling system bias was less than the method requirement of five (5) percent of the span value. In addition, the system response time was determined by measuring the time required for each analyzer to reach 95 percent of its high-range calibration gas value.

After each test run the instrument drift for each analyzer was determined by introducing the zero and mid-range calibration gases into the sampling system prior to the filter. The gas was drawn through the entire sampling system. The measured responses were then compared to the values from the previous test run to determine the analyzer drift. For all test runs, the analyzer drift was less than the method requirement of three (3) percent of the span value.

The CO_2 and O_2 contents were used to calculate the dry molecular weight of the gas stream. The molecular weight was then used, along with the moisture content determined by Method 4, for the calculation of the volumetric flow rate. For these calculations, the remainder of the gas stream was assumed nitrogen since the remaining gas stream components were insignificant for the purposes of calculating molecular weight.

Method 4

The moisture content at the test location was determined using EPA Method 4. A known volume of sample gas was withdrawn from the source and the moisture was condensed and measured. The dry standard volume of the sample gas was compared to the volume of moisture collected to determine the moisture content of the sample gas. The moisture content was then used, along with the measurements made in Methods 2 and 3, to calculate the volumetric flow rate through each test location. A diagram of the Method 4 sampling train is shown in Figure 4 and as part of the Method 5B sampling trains in Figure 5 of the Appendix.

To condense the water vapor, the gas sample was passed through a series of four impingers. The first two impingers each contained 100 ml of water. The third impinger was empty and the fourth contained a known weight of silica gel to absorb any remaining water vapor. The sample train was leak checked prior to the test run by capping the probe tip and pulling a vacuum greater than the highest vacuum expected during the test run. A leak check was considered valid if the leak rate was less than 0.02 cubic feet per minute.

The volume of dry gas exiting the gas condenser system was measured with a dry gas meter. After leaving the dry gas meter, the sample stream passed through an orifice used to meter the flow rate through the sample train. The pressure drop across the orifice was measured with an incline plane, oil manometer. The gas meter reading, gas meter inlet and outlet temperatures, gas meter static pressure and pump vacuum were recorded every five minutes during each test run. Each test run was 60 minutes in duration.

After the test run, the sample train was leak checked at the highest vacuum encountered during the test run. The amount of water collected in the condenser system was measured volumetrically with a graduated cylinder and the silica gel weight gain was determined gravimetrically. The net weight gain of water was converted to a volume of wet gas and compared to the amount of dry gas sampled to determine the moisture content.

Method 5B

Method 5B was used to determine the nonsulfuric acid PM concentration at each test location during LFO firing. A sample of the gas stream was withdrawn isokinetically from the stack and the nonsulfuric acid PM in the sample gas stream was collected in a glass-lined probe and on a glass fiber filter. The weight of nonsulfuric acid PM collected with the sample train combined with the volume of dry gas withdrawn from the stack was used to calculate the nonsulfuric acid PM concentration. A diagram of the Method 5B apparatus is shown in Figure 5 of the Appendix.

The sample probe that was used consisted of a glass liner and a glass nozzle. Sample gas passed through the nozzle and probe assembly and then through a glass fiber filter heated to 320°F (+/-25°F). After exiting the filter, the sample gas passed through the condenser system described in Method 4. The dry gas exiting the moisture condenser system then passed through a sample pump and a dry gas meter to measure the gas volume. After leaving the dry gas meter the sample stream passed through an orifice, which was used to meter the flow rate through the sample train. The pressure drop across the orifice was measured with an incline plane oil manometer.

Whatman glass fiber filters were used as the substrate for the nonsulfuric acid PM sampling. Prior to the test run, the filter was oven dried at 320°F (+/-10°F) for three (3) hours, cooled in a dessicator for two (2) hours and then weighed to the nearest 0.0001 gram (g) until a constant weight was achieved. The weight of the filter was considered constant only when two (2) consecutive weights taken at least six (6) hours apart were within 0.0005g of each other.

The probe was thoroughly pre-cleaned with acetone. The condenser system was then assembled as outlined in Method 4. The sample train was leak checked prior to the test run by capping the probe tip and pulling a vacuum of at least fifteen inches of mercury (15 in.Hg). A leak check was considered valid if the leak rate was below 0.02 cfm. When the sample train was not in operation inside the stack, the nozzle opening was sealed with Teflon tape.

The probe tip was placed at each of the sample points determined by Method 1. The velocity at the sample point was determined using Method 2 by reading the velocity pressure from the manometer. Sample was withdrawn from the source at a rate such that the velocity at the opening of the nozzle matched the velocity of the stack gas at the sample point (isokinetically). The gas velocity pressure (ΔP), gas meter reading, gas meter inlet and outlet temperatures, gas meter orifice pressure (ΔH) and pump vacuum were recorded for each sample point.

After the test run the train was leak checked at the highest vacuum encountered during the test run. The condensate weight gain of the condenser jar contents was determined as outlined in Method 4 and discarded. The probe liner and nozzle were brushed and rinsed with acetone and the collected rinses were saved in a 250 ml amber glass jar fitted with a Teflon lined lid. The filter was sealed in a plastic petri dish and prepared for shipment to the laboratory.

Analysis of the samples for nonsulfuric acid PM was performed at the Airtech Environmental Services Inc. laboratory, located in Elk Grove Village, Illinois. The probe rinses were transferred to tared beakers and evaporated to dryness under ambient temperature and pressure conditions. The dried probe samples were then oven-dried, along with the filters, at a temperature of 320°F (+/-10°F) for six (6) hours, cooled in a dessicator for a minimum of two (2) hours and weighed to a constant weight. The weight gain of the probe rinses and filters resulted in the total weight of the nonsulfuric acid PM collected. To eliminate interference in establishing a constant weight, the analytical balance was equipped with an ion generating polonium strip designed to eliminate static electricity that may have collected on the samples.

Method 18

EPA Method 18 was used to determine the concentration of methane at test location. An integrated gas sample was collected from the source and its major components separated using a gas chromatograph (GC). The individual components were then quantified using a flame ionization detector (FID). Analysis of the samples was performed on-site immediately after each test run was completed.

The Tedlar bag sample from EPA Method 3 was used for the EPA Method 18 analysis. A portion of the gas sample was injected into a Hewlett Packard Model 5890 Series II GC using a gas sample valve. The components of the gas sample were separated using a 30m AT-1 Mega Bore capillary column with a 3μm film thickness. Nitrogen was used as a carrier gas to pass the sample through the column. After exiting the column, the separated sample components, along with the carrier gas, passed through the FID. The output of the FID was monitored using Hewlett Packard Chemstation 3365 computerized integration software. The retention time and area of each peak were determined by the software. The identity of each peak was determined by comparing the retention time of the sample peak with the retention time determined by analyzing known standards.

The GC was calibrated using certified EPA Protocol 1 compressed gas standards that contained known concentration of methane in a balance of nitrogen. At least 3 standards of different concentrations were analyzed. The standards were chosen such that they bracketed the expected concentration at each test location.

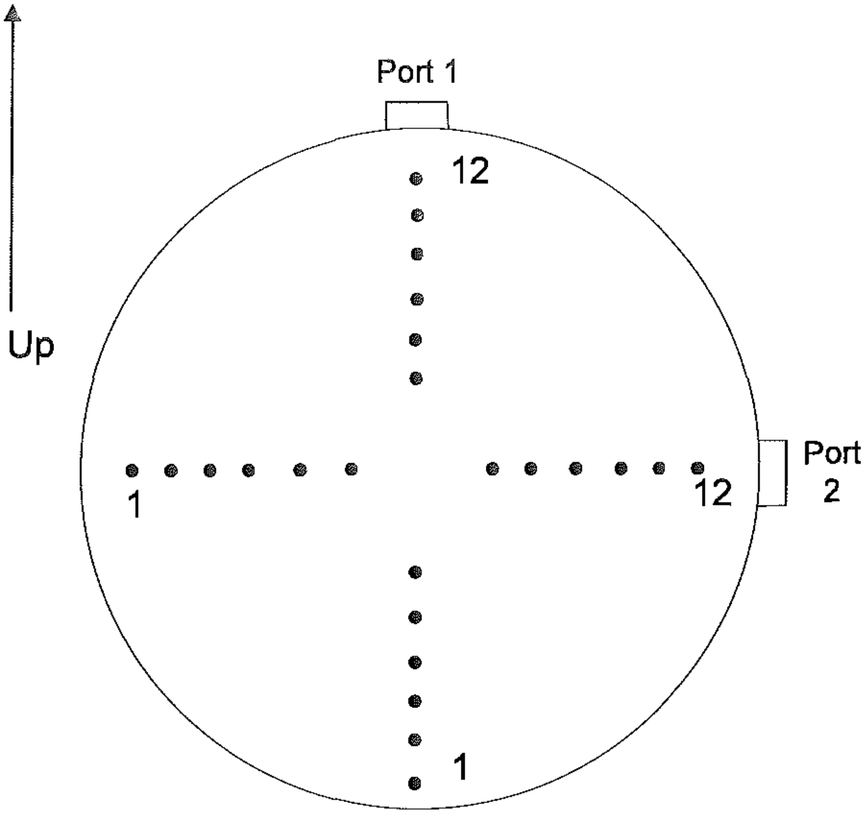
Results were calculated by comparing the areas of the standards to the area of the gas samples using linear regression analysis or an average response factor. Results are expressed in ppm of methane.

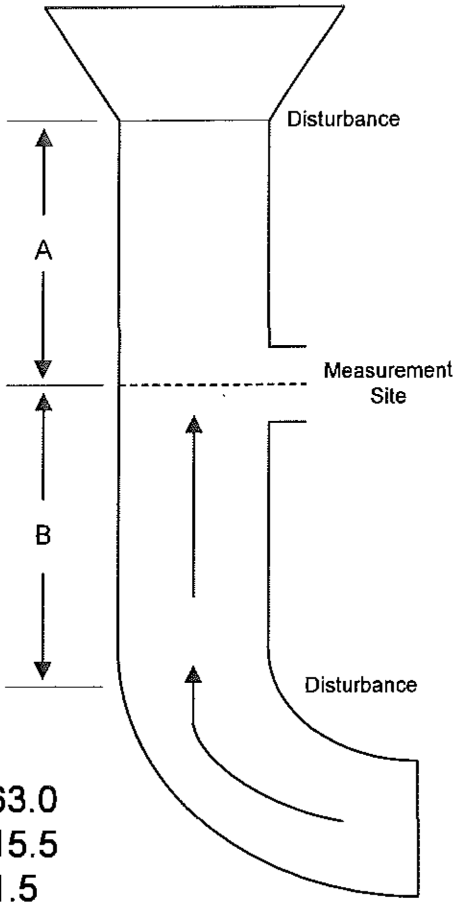
Method 320

The moisture content at the Unit 3 and the ethane concentration at Unit 1, Unit 2, and Unit 3 test location during natural gas firing were determined using EPA Method 320. A sample of the gas stream was continuously withdrawn from the test location and analyzed using a continuous FTIR gas analysis system.

The sample gas was withdrawn from the test location at a constant rate through a stainless steel probe, a heated stainless steel filter and a heated Teflon sample line. The probe, filter and sample line were operated at a temperature of 370 °F to prevent the condensation of moisture. The wet gas was then directed to the FTIR spectrometer gas cell. Results from the analyzer were determined on a "wet" volume basis.

The FTIR gas analyzer that was used for this project is an MKS MultiGas FTIR analyzer and a schematic of the sampling system can be found in Figure 7 in the Appendix.





Diameter (in.)	63.0
Port Length (in.)	15.5
Distance A (Duct Diameters)	1.5
Distance B (Duct Diameters)	4.2

Point	Distance From Wall (in.)
1	1.3
2	4.2
3	7.4
4	11.2
5	15.7
6	22.4
7	40.6
8	47.3
9	51.8
10	55.6
11	58.8
12	61.7

Cross Section of the Engines 1, 2, and 3 Test Locations
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Figure 1

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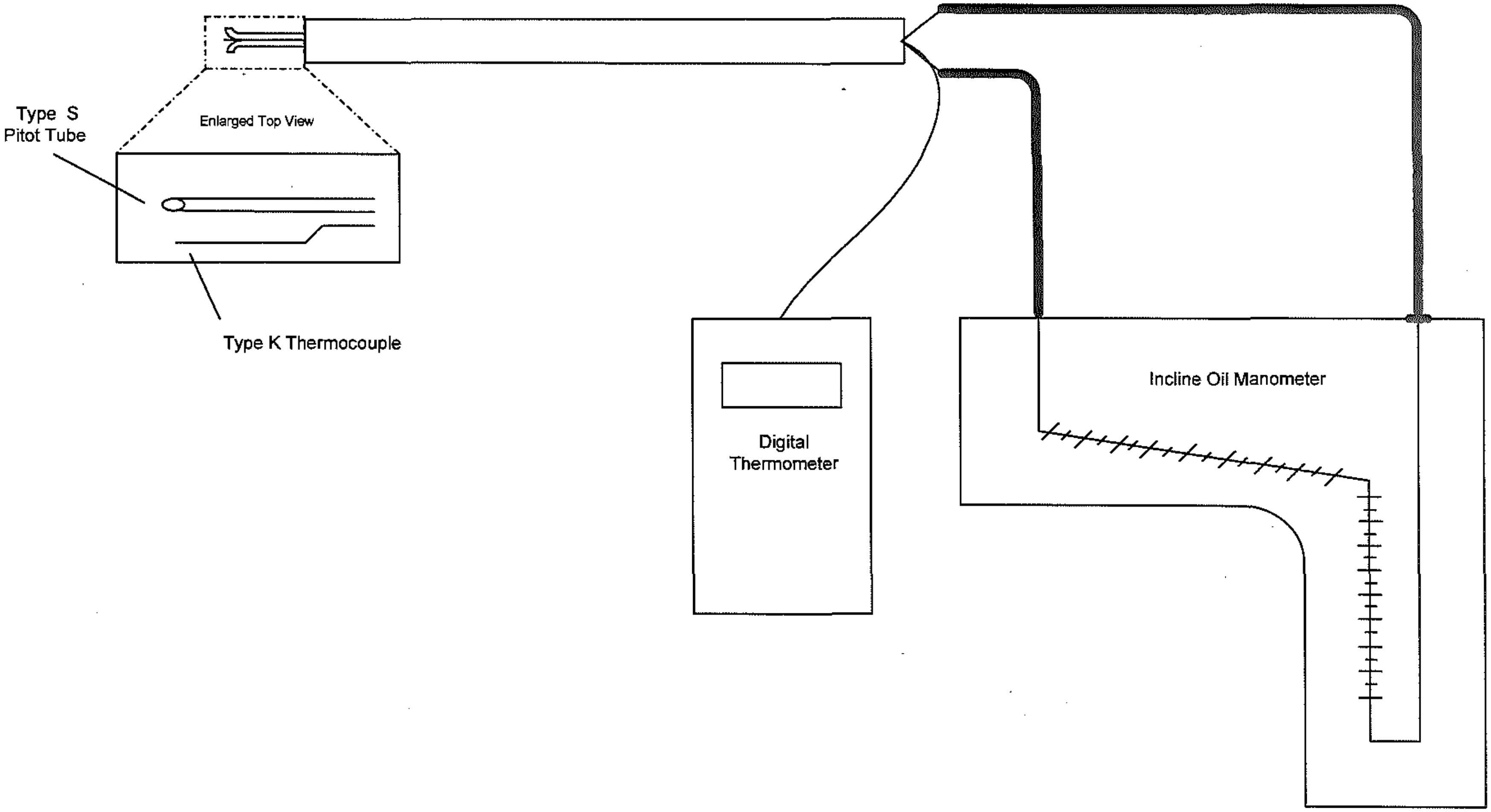

EPA Method 2:
Type S Pitot Tube Assembly with Manometer

Figure 2

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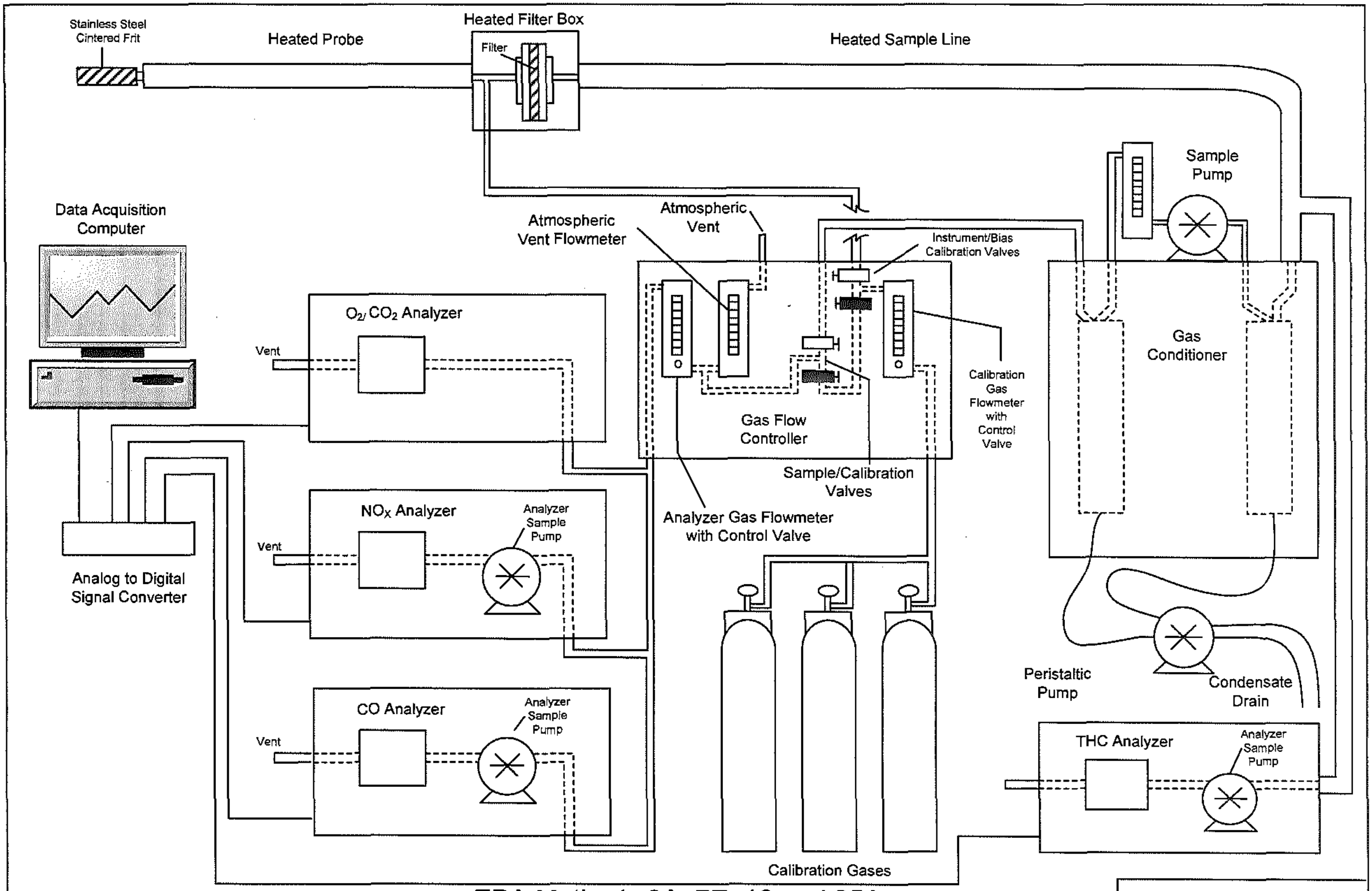

EPA Methods 3A, 7E, 10 and 25A:
O_2/CO_2, NO_X, CO and THC Gas Sampling System

Figure 3

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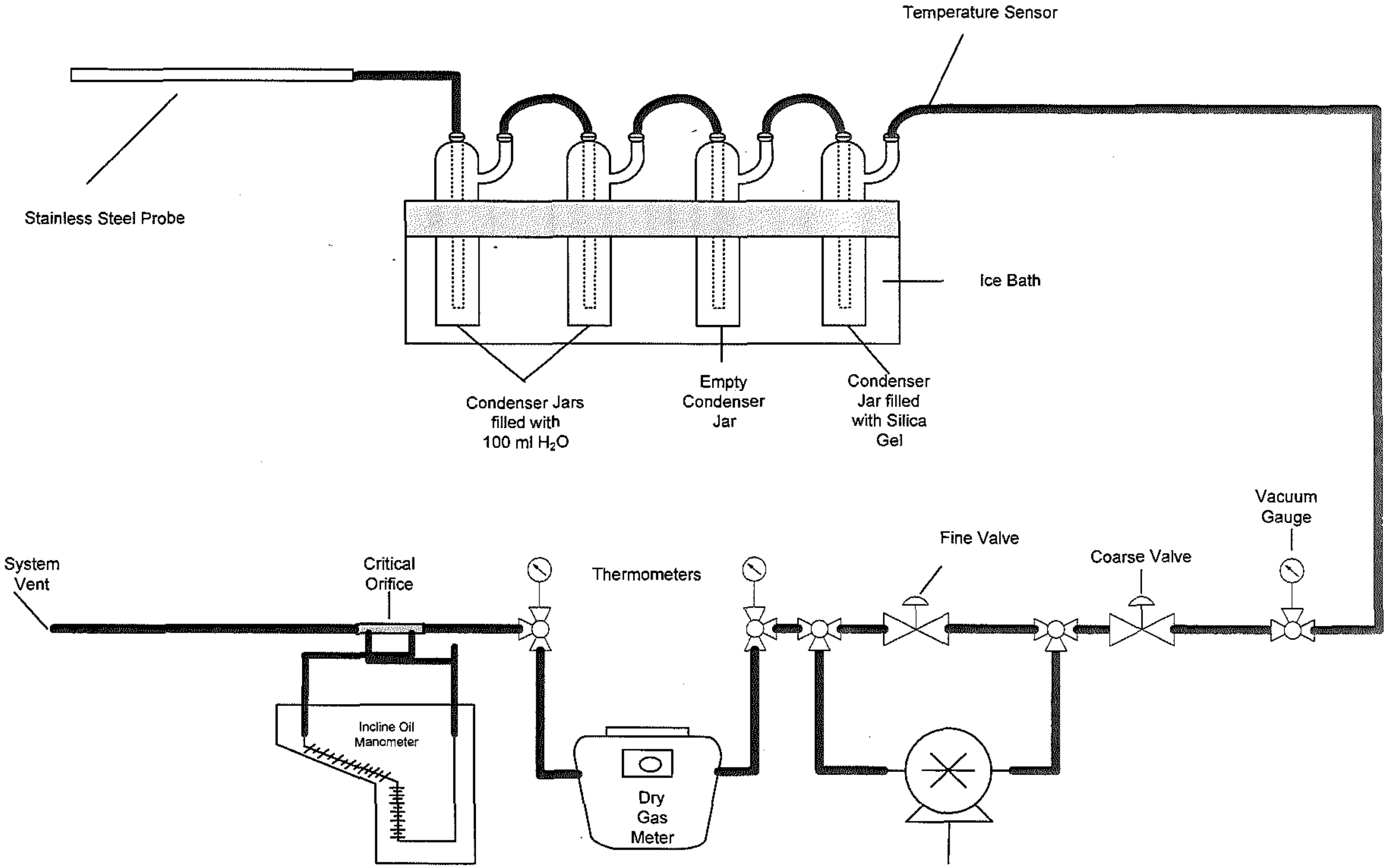

EPA Method 4:
Moisture Sampling Train

Figure 4

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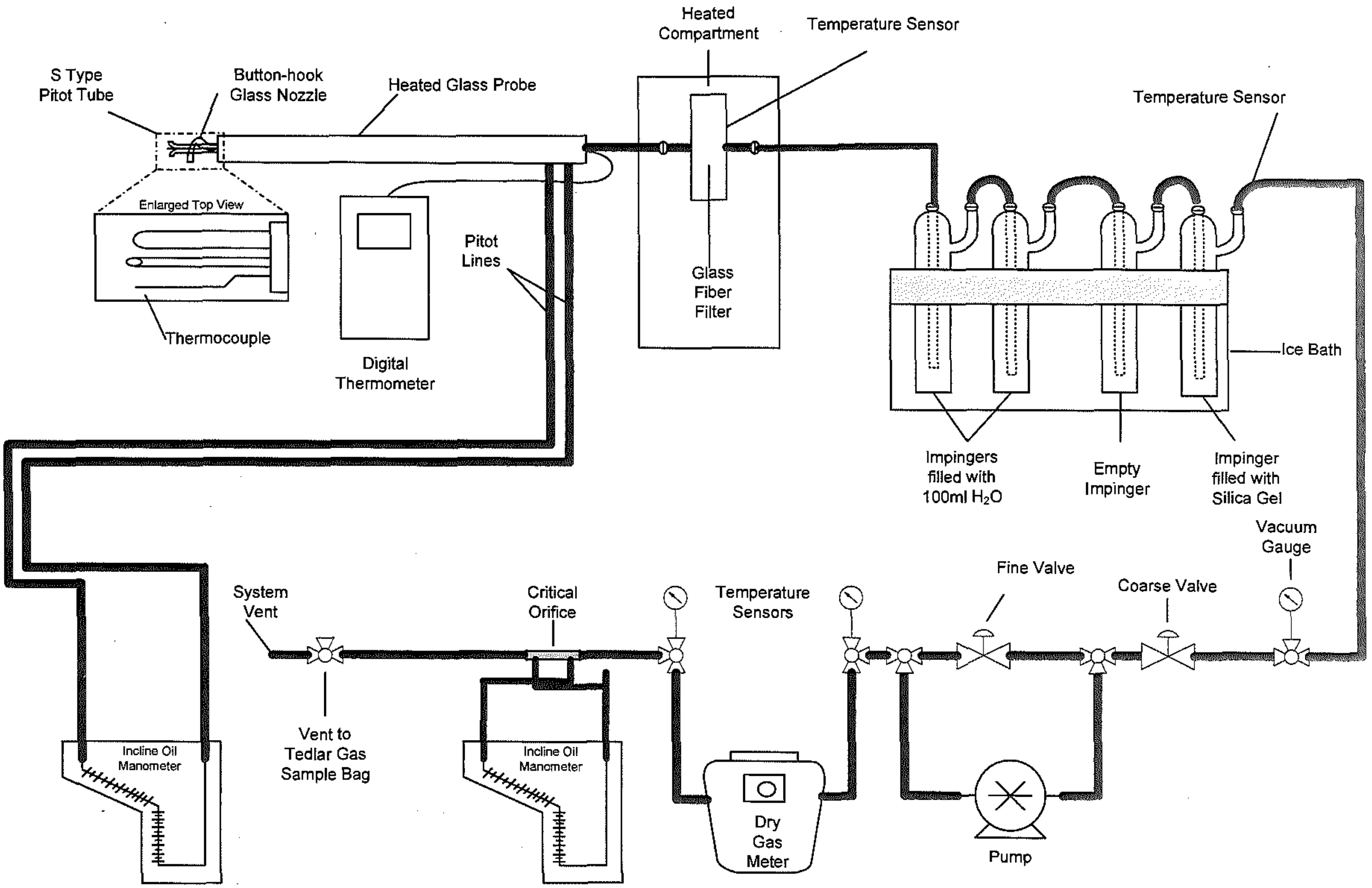

EPA Methods 2, 4 and 5B:
Particulate Matter Sampling Train
Figure 5

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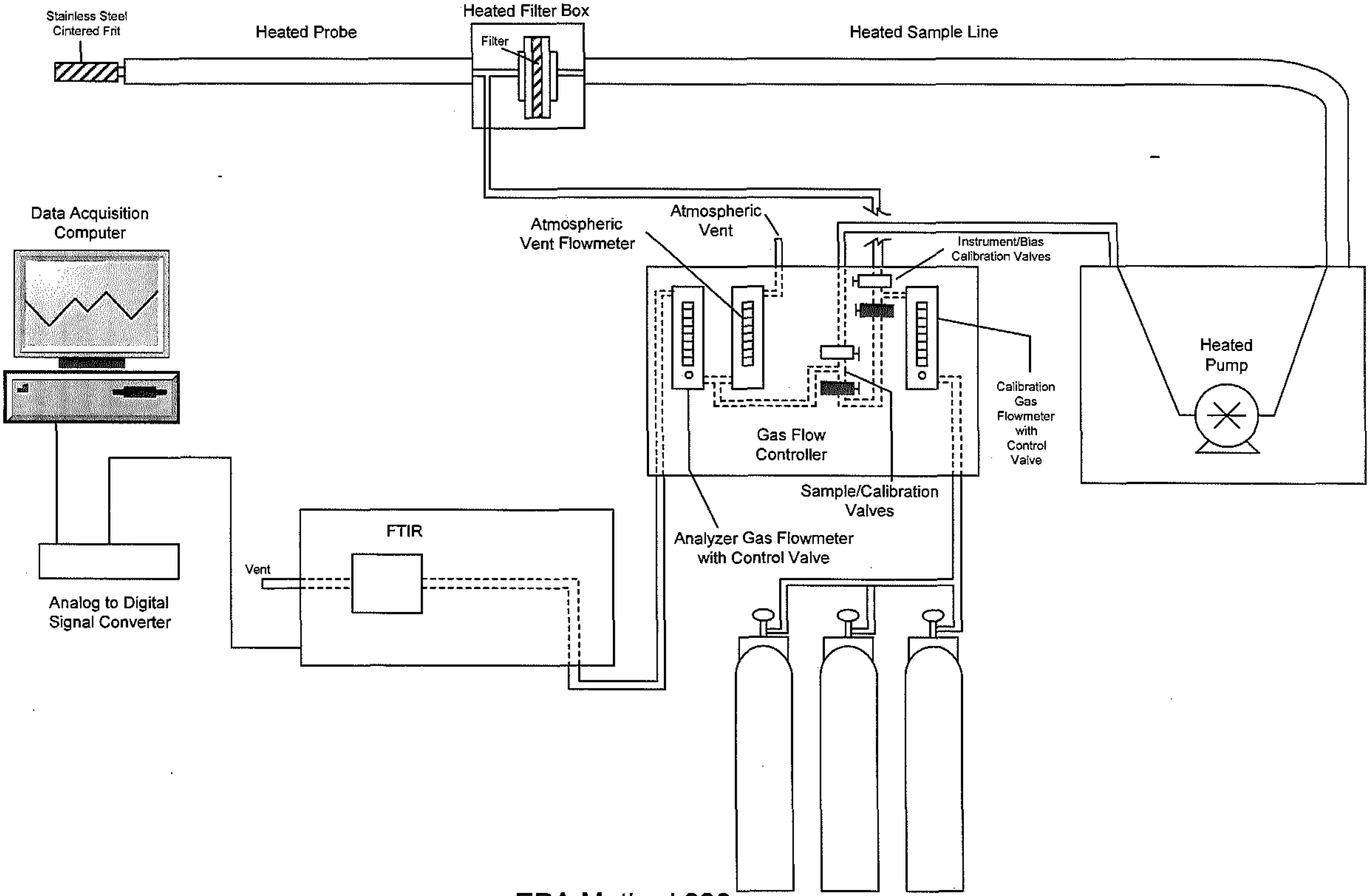

EPA Method 320:
CO_2 and HCl FTIR Sampling Train

Figure 6

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