



The University of Michigan
Ross School of Business
701 Tappan Avenue
Ann Arbor, Michigan 48109

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AIR QUALITY DIV.

Report

**Performed Velocity, Moisture, Temperature, Volumetric Flow Rate,
Oxygen, Carbon Dioxide, Volatile Organic Compounds, Nitrogen Oxide
and Carbon Monoxide Emissions Testing**

Sampling performed on the Cummins Model GTA38 CC Generator Outlet

Ann Arbor, MI

Test Date: 9/30/16



MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR QUALITY DIVISION

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RENEWABLE OPERATING PERMIT
REPORT CERTIFICATION

AIR QUALITY DIV.

Authorized by 1994 P.A. 451, as amended. Failure to provide this information may result in civil and/or criminal penalties.

Reports submitted pursuant to R 336.1213 (Rule 213), subrules (3)(c) and/or (4)(c), of Michigan's Renewable Operating (RO) Permit program must be certified by a responsible official. Additional information regarding the reports and documentation listed below must be kept on file for at least 5 years, as described in General Condition No. 22 in the RO Permit and be made available to the Department of Environmental Quality, Air Quality Division upon request.

Source Name The University of Michigan County Washtenaw

Source Address 1239 Kipke Drive City Ann Arbor

AQD Source ID (SRN) M0675 RO Permit No. MI-ROP-M0675-2014 RO Permit Section No. _____

Please check the appropriate box(es):

Annual Compliance Certification (General Condition No. 28 and No. 29 of the RO Permit)

Reporting period (provide inclusive dates): From _____ To _____

1. During the entire reporting period, this source was in compliance with **ALL** terms and conditions contained in the RO Permit, each term and condition of which is identified and included by this reference. The method(s) used to determine compliance is/are the method(s) specified in the RO Permit.

2. During the entire reporting period this source was in compliance with all terms and conditions contained in the RO Permit, each term and condition of which is identified and included by this reference, **EXCEPT** for the deviations identified on the enclosed deviation report(s). The method used to determine compliance for each term and condition is the method specified in the RO Permit, unless otherwise indicated and described on the enclosed deviation report(s).

Semi-Annual (or More Frequent) Report Certification (General Condition No. 23 of the RO Permit)

Reporting period (provide inclusive dates): From _____ To _____

1. During the entire reporting period, **ALL** monitoring and associated recordkeeping requirements in the RO Permit were met and no deviations from these requirements or any other terms or conditions occurred.

2. During the entire reporting period, all monitoring and associated recordkeeping requirements in the RO Permit were met and no deviations from these requirements or any other terms or conditions occurred, **EXCEPT** for the deviations identified on the enclosed deviation report(s).

Other Report Certification

Reporting period (provide inclusive dates): From 9/30/2016 To 9/30/2016

Additional monitoring reports or other applicable documents required by the RO Permit are attached as described:
Ross School of Business 500 KW natural gas emergency generator emissions test report.

Test was performed on 9/30/2016.

I certify that, based on information and belief formed after reasonable inquiry, the statements and information in this report and the supporting enclosures are true, accurate and complete.

<u>Terrance G. Alexander</u>	<u>Executive Director</u>	<u>734-647-1143</u>
Name of Responsible Official (print or type)	Title	Phone Number

Signature of Responsible Official

11/22/16
Date

The University of Michigan
Ross School of Business
701 Tappan Avenue
Ann Arbor, Michigan 48109

Report

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and Carbon Monoxide Emissions Testing**

Sampling performed on the Cummins Model GTA38 CC Generator Outlet

Ann Arbor, MI

Test Date: 9/30/16

10/21/2016

X *Brian E. Lemasters*

Signed by: Custom Stack Analysis, LLC.
Brian E. Lemasters
Custom Stack Analysis, LLC.

REPORT CERTIFICATION

Custom Stack Analysis, LLC. has used its professional experience and best professional efforts in performing this compliance test. I have reviewed the results of these tests and to the best of my knowledge and belief they are true and correct.

10/21/2016

X *Brian E. Lemasters*

Signed by: Custom Stack Analysis, LLC.
Brian E. Lemasters

EXECUTIVE SUMMARY

Custom Stack Analysis, LLC. conducted emissions sampling using USEPA Methods 1-4, 3A, 7E, 10 and 25A. Testing was conducted on the Cummins Model GTA38 CC Generator Outlet on September 30th, 2016. The testing was conducted at The University of Michigan on the Cummins Model GTA38 CC Generator Outlet at the Ross School of Business to determine compliance status with the applicable state and federal limits, ROP No. MI-ROP-M0675-2014 (see Table 1.2).

The Custom Stack Analysis, LLC. test crew consisted of Mr. Jordan Smith and Mr. Brian Lemasters. The testing procedures were coordinated by Ms. Brandi Campbell of The University of Michigan and Mr. Steve Polloni of Cummins Bridgeway, LLC. (see Table 1.1). All testing procedures were witnessed by Mr. David Patterson of the State of Michigan Department of Environmental Quality Air Quality Division (see Table 1.1).

Contact for this test report:
Mr. Stephen M. O'Rielly
Manager

Occupational Safety & Environmental Health Department
Environmental Protection & Permitting Program
Campus Safety Services Building
1239 Kipke Drive
Ann Arbor, MI 48109
734-763-4642

Table 1.1: Emissions Testing Program Contact Personnel

Name	Company Address	Phone, Fax
Ms. Brandi Campbell	The University of Michigan 1239 Kipke Drive Ann Arbor, Michigan 48109	(734) 647-9017 (Phone)
Mr. Steve Polloni	Cummins Bridgeway, LLC. 54250 Grand River Ave. New Hudson, MI 48165	(248) 573-1978 (Phone) (248) 573-1538 (Fax)
Mr. James Gray	Custom Stack Analysis, LLC. 14614 Cenfield St. N.E. Alliance, OH 44601	(330) 525-5119 (Phone) (330) 525-7908 (Fax)
Mr. David Patterson	State of Michigan Department of Environmental Quality Air Quality Division 525 W. Allegan Street Lansing, Michigan 48909	(517) 284-6782 (Phone) (517) 335-3122 (Fax)

Test results are located on page 3. A description of the testing protocol is included on pages 4-8. All testing calculations are located on pages 15-21. Appendix 1 includes field test data. Appendix 2 contains laboratory data from Custom Stack Analysis, LLC. Appendix 3 contains calibration data for the equipment used on test day. Appendix 4 contains monitoring data. Appendix 5 contains production data.

The MDEQ advised us that we should test each exhaust port for 30 minutes and then average the values for the CEMS results.

Table 1.2 demonstrates how The University of Michigan at The Ross School of Business in Ann Arbor, MI is operating in compliance with the applicable state and federal emission standards at the correct operating parameters for the testing conducted (see Appendix 5).

Table 1.2: Emission Limits and Test Results Summary (State)

Pollutant	Emission Limitations	Test Result Average	Compliance Demonstrated
Carbon Monoxide	540 ppm @ 15% O ²	238.69 ppm @ 15% O ²	Yes
Nitrogen Oxide	160 ppm @ 15% O ²	14.47 ppm @ 15% O ²	Yes
Volatile Organic Compounds	86 ppm @ 15% O ²	41.19 ppm @ 15% O ²	Yes

Test Results

The University of Michigan - Cummins Model GTA38 CC Generator Outlet
 Ross School of Business

9/30/2016

Methods 1-4, 3A, 7E, 10 & 25A

	<u>Run #1</u>	<u>Run #2</u>	<u>Run #3</u>	<u>Avg.</u>	<u>Limit</u>
Moisture %	17.52%	18.40%	18.65%	18.19%	
Carbon Dioxide %	15.50%	15.50%	15.50%	15.50%	
Oxygen %	4.05%	4.11%	4.06%	4.07%	
Nitrogen %	80.45%	80.39%	80.44%	80.43%	
CO (ppm)	875.53	624.99	542.09	680.87	
CO (ppm @ 15%)	306.58	219.61	189.88	238.69	540
Nox (ppm)	45.22	40.59	37.99	41.27	
Nox (ppm @ 15%)	15.83	14.26	13.31	14.47	160
VOC* (ppm)	118.16	117.91	116.36	117.48	
VOC* (ppm @ 15%)	41.38	41.43	40.76	41.19	86
Operating Engine Horsepower	683	683	683	683	
Max Engine Horsepower	670	670	670	670	
Load %	102.00%	102.00%	102.00%	102.00%	
Megawatt	0.5100	0.5100	0.5100	0.5100	

* VOC concentration dry

METHOD 1

Sample and velocity traverses for stationary sources.

To aid in the representative measurement of pollutant emissions and/ or total volumetric flow rate from a stationary source, a measurement site where the effluent stream is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. A traverse point is then located within each of these equal areas.

METHOD 2

Determination of stack gas velocity and volumetric flow rate.

The average gas velocity in a stack is determined from the gas density and from measurement of the average velocity head with a Type S (Stausscheibe or reverse type) pitot tube.

METHOD 3

Gas analysis for the determination of dry molecular weight.

This method is applicable for determining carbon dioxide and oxygen concentrations and dry molecular weight of a sample from a gas stream of a fossil-fuel combustion process.

METHOD 4

Determination of moisture content in stack gases.

A gas sample is extracted at a constant rate from the source. It is determined either volumetrically or gravimetrically.

METHOD 3A TESTING DESCRIPTION

A gas sample is continuously extracted from the stack, and a portion of the sample is conveyed to an instrumental analyzer for determination of O₂ gas concentration. The gases pass through a heated sampling probe and filter to prevent condensation. The gases then pass through a calibration valve to a heated sampling line. After the heated sampling line is a Universal Analyzers Model 530 air cooled single sample thermoelectric water condenser with a perostolic pump for moisture removal. The sample is then passed through to a California Analytical Instruments Model 100F for O₂ concentrations. Before the testing procedures commence the analyzer is left to warm up for a 90 minute period. It is then calibrated according to Method 7E specifications. To the extent practicable, the measured emissions should be between 20 to 100 percent of the selected calibration span. Three calibration gases are selected. The High-Level gas concentrations shall be equivalent to 20 to 100 percent of the calibration span. Mid-Level concentrations shall be equivalent to 40 to 60 percent of the calibration span. The Low-Level Gas concentrations of less than 20 percent of the span. Before the first run an analyzer calibration error check is conducted. If the low-level, mid, or high cal gases expected concentrations differ by more than $\pm 2\%$ of the span then the procedure needs to be repeated until an acceptable 3 point calibration is obtained. After the analyzer calibration check the upscale and low level calibration gases are introduced to the sampling calibration valve and recorded. System bias calibration must be within 5.0% of the analyzer calibration span for low-scale and upscale calibration gases. At the conclusion of each of the test runs the low-level gas and an upscale gas closest to the concentrations are introduced to the calibration valve assembly. If either the low-level or upscale value exceeds $\pm 3\%$ of the span, then the run is considered invalid.

METHOD 7E TESTING DESCRIPTION

A gas sample is continuously extracted from the stack, and a portion of the sample is conveyed to an instrumental analyzer for determination of NO_x gas concentration using a chemiluminescence analyzer. The gases pass through a heated sampling probe and filter to prevent condensation. The gases then pass through a calibration valve to a heated sampling line. After the heated sampling line is a condenser for moisture removal. The sample is then passed through to a Thermo Environmental Instruments Model 42 chemiluminescence analyzer where the gases are analyzed for NO_x concentrations. Before the testing procedures commence the analyzer is left to warm up for a 90 minute period. It is then calibrated according to Method 7E specifications. To the extent practicable, the measured emissions should be between 20 to 100 percent of the selected calibration span. Three calibration gases are selected. The High-Level gas concentrations shall be equivalent to 20 to 100 percent of the calibration span. Mid-Level concentrations shall be equivalent to 40 to 60 percent of the calibration span. The Low-Level Gas concentrations of less than 20 percent of the span. Before the first run an analyzer calibration error check is conducted. If the low-level, mid, or high cal gases expected concentrations differ by more than $\pm 2\%$ of the span then the procedure needs to be repeated until an acceptable 3 point calibration is obtained. After the analyzer calibration check the upscale and low level calibration gases are introduced to the sampling calibration valve and recorded. System bias calibration must be within 5.0% of the analyzer calibration span for low-scale and upscale calibration gases. At the conclusion of each of the test runs the low-level gas and an upscale gas closest to the concentrations are introduced to the calibration valve assembly. If either the low-level or upscale value exceeds $\pm 3\%$ of the span, then the run is considered invalid.

METHOD 10 TESTING DESCRIPTION

A gas sample is continuously extracted from the stack, and a portion of the sample is conveyed to an instrumental analyzer for determination of CO gas concentration using a Luft-type nondispersive infrared analyzer. The gases pass through a heated sampling probe and filter to prevent condensation. The gases then pass through a calibration valve to a heated sampling line. After the heated sampling line is a Universal Analyzers Model 530 air cooled single sample thermoelectric water condenser with a perostolic pump for moisture removal. The sample is then passed through an ascarite tube to a Thermo Environmental Instruments Model 48 Luft-type analyzer where the gases are analyzed for CO concentrations. Before the testing procedures commence the analyzer is left to warm up for a 90 minute period. It is then calibrated according to Method 7E specifications. To the extent practicable, the measured emissions should be between 20 to 100 percent of the selected calibration span. Three calibration gases are selected.

The High-Level gas concentrations shall be equivalent to 20 to 100 percent of the calibration span. Mid-Level concentrations shall be equivalent to 40 to 60 percent of the calibration span. The Low-Level Gas concentrations of less than 20 percent of the span.

Before the first run an analyzer calibration error check is conducted. If the low-level, mid, or high cal gases expected concentrations differ by more than $\pm 2\%$ of the span then the procedure needs to be repeated until an acceptable 3 point calibration is obtained. After the analyzer calibration check the upscale and low level calibration gases are introduced to the sampling calibration valve and recorded. System bias calibration must be within 5.0% of the analyzer calibration span for low-scale and upscale calibration gases. At the conclusion of each of the test runs the low-level gas and an upscale gas closest to the concentrations are introduced to the calibration valve assembly. If either the low-level or upscale value exceeds $\pm 3\%$ of the span, then the run is considered invalid.

METHOD 25A TESTING DESCRIPTION

This method will be used to measure the total VOC concentration expressed in terms of ppm propane. A gas sample is extracted from the source through a stainless steel probe, through a heated sample line (teflon), to a flame ionization analyzer. The main components of Method 25A are the same as Method 204B with the exception of a non heated sample probe.

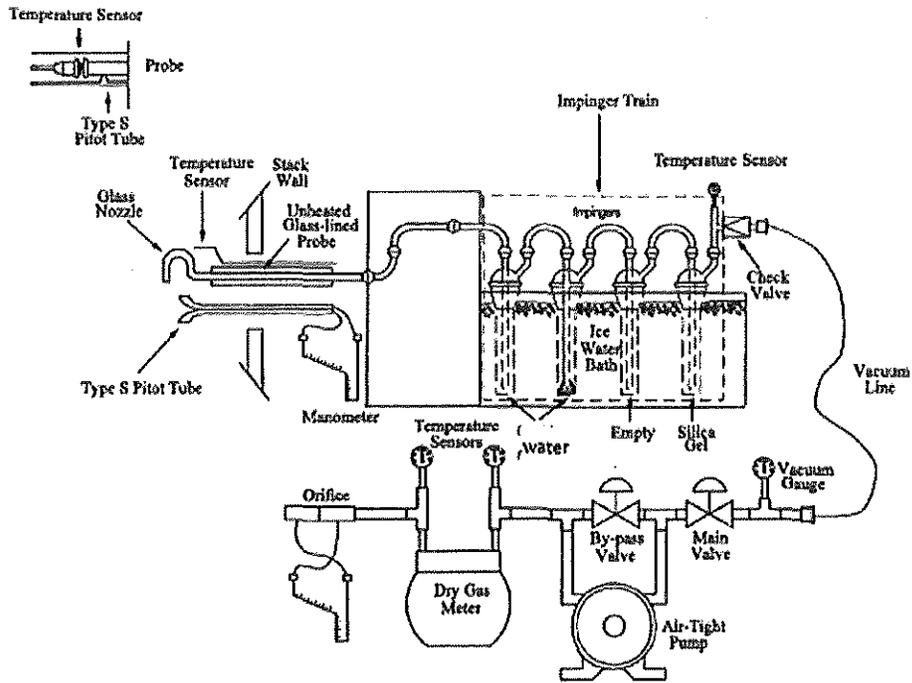
The sampling system is heated up to the proper operating temperature. Within two hours of the start of the test the FIA is calibrated. The calibration range or span is selected to be from 1.5 to 2.5 times the expected concentration. Three calibration ranges are then selected as follows: Low level 25-35% of the span, Mid level 45-55% of the span, and a High level 80-90% of the span. A zero and a high level calibration gas is then injected at the valve assembly and the FIA is adjusted to these levels. Then all four gases are introduced into the analyzer and recorded. If the responses are within 5% of the expected values then the analyzer is responding correctly. The sample probe is located in the center of the stack and sealed in place and the test is started. The test lasts for 60 minutes. At the end of the test run a drift check is ran. The zero gas and the mid level calibration gas is injected at the valve assembly. The analyzer responses are then recorded. The drift check is acceptable if the results are within 3% of the span value. These checks are performed before and after each test run.

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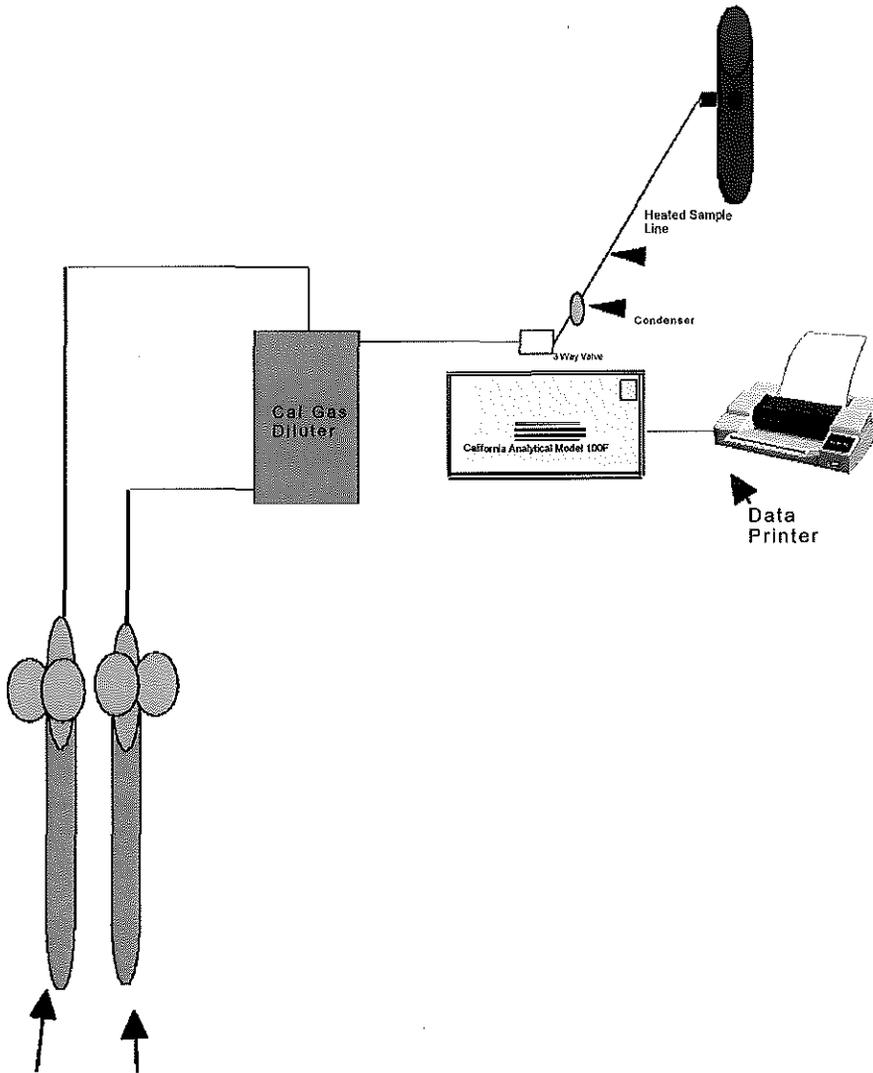
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Method 4 Diagram

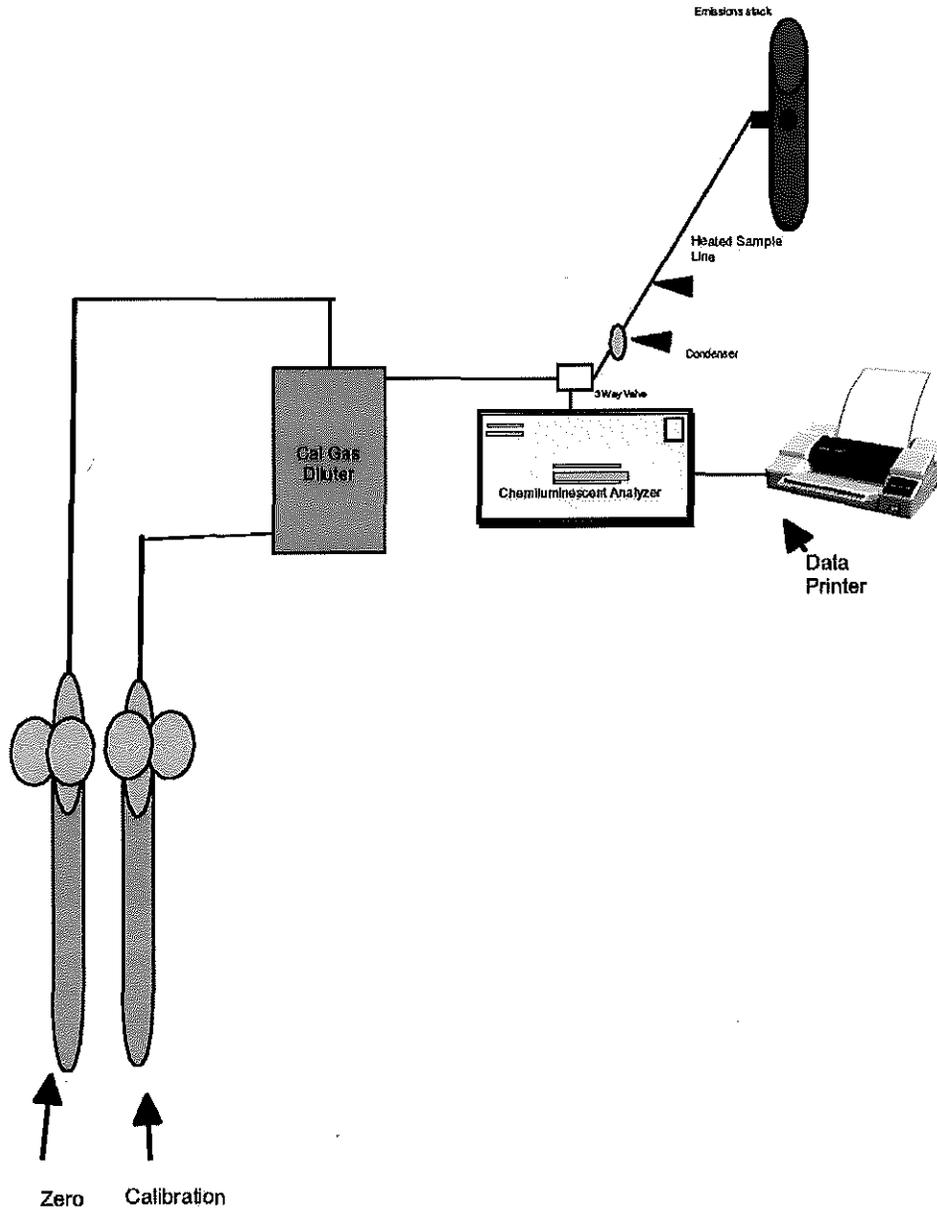


3A Sampling System

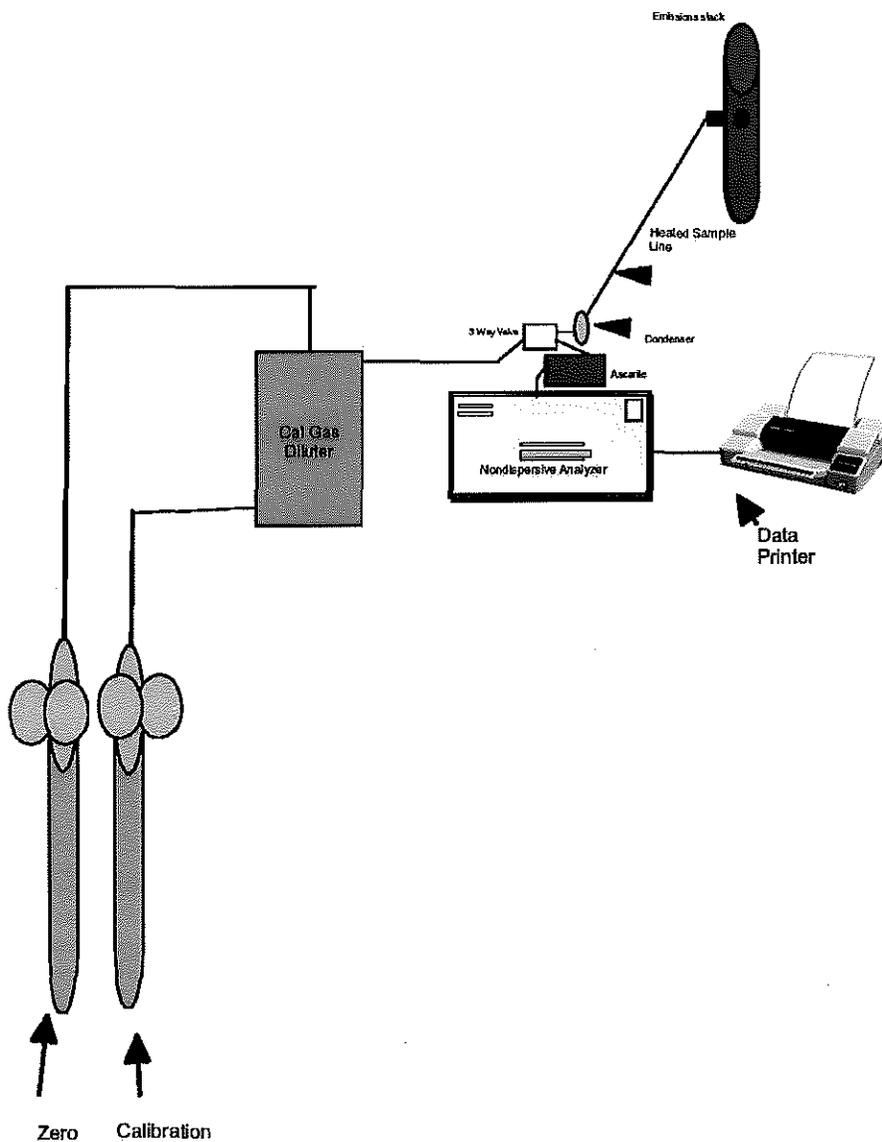
Emissions stack



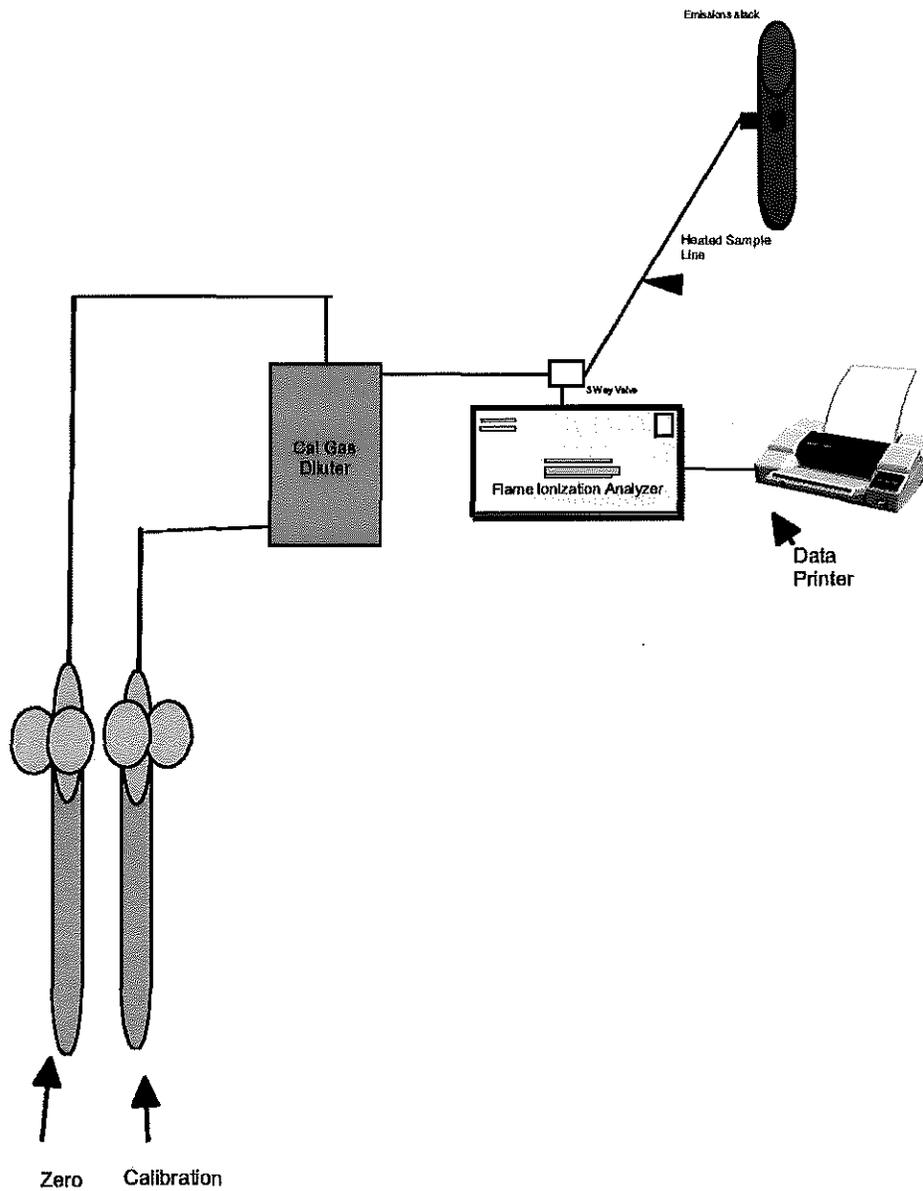
7E Sampling System



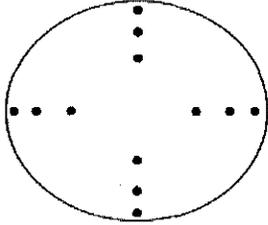
10 Sampling System



25A Sampling System



Location of Sampling Points



<p>Location:</p> <p>Upstream</p> <p>Downstream</p> <p>Stack Diameter</p> <p>Sample Point #</p>	<p>Cummins Model GTA38 CC Generator Outlet</p> <p>12"</p> <p>18"</p> <p>8</p> <p>1</p> <p>2</p> <p>3</p> <p>4</p> <p>5</p> <p>6</p>	<p>Inches</p> <p>0.4</p> <p>1.2</p> <p>2.4</p> <p>5.6</p> <p>6.8</p> <p>7.6</p>	<p>Inches</p>
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CALCULATIONS

Outlet

	<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>		
1. Vm (std)	42.26	43.00	43.61	=	$VM * 17.64 * \frac{PBAR + 13.6}{Tm} * Y$

		<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>
Vm (std) = Volume of gas collected, corrected to standard conditions, cuft.	=	42.26	43.00	43.61
Vm = Volume of gas sampled at meter box, cuft.	=	43.19	44.22	44.84
17.64 = Standard temperature, 528 Rankine / std pressure, 29.92.	=	17.64	17.64	17.64
Tm = Average dry gas meter temperature, + 460 Rankine.	=	530.03846	533.30769	533.19231
Pbar = Barometric pressure, inches of mercury (Hg)	=	29.32	29.32	29.32
^H = Average pressure differential across orifice.	=	1.8	1.8	1.8
13.6 = Specific gravity of mercury.	=	13.6	13.6	13.6
Y = Calibration factor of meter box.	=	0.9982	0.9982	0.9982

	<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>		
2. Vw (std)	8.98	9.69	10.00	=	$Vlc * \frac{P H20}{Mh20} * \frac{R Tstd}{Pstd} = K2 * Vlc$

		<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>
Vlc = Volume of water and silica collected.	=	190.5	205.7	212.2
P H20 = Density of water, 0.002201 lb/ml.	=	0.002201	0.002201	0.002201
M H20 = Molecular weight of water, 18.01 lb/lb-mole.	=	18.01	18.01	18.01
R = Ideal gas constant, 21.85 in. hg - ft ³ /R-lb-mole.	=	21.85	21.85	21.85
Tstd = Standard absolute temperature, 528 R.	=	528	528	528
Pstd = Standard absolute pressure, 29.92 in. Hg.	=	29.92	29.92	29.92
K2 = 0.0471 ft ³ / ml.	=	0.0471	0.0471	0.0471

		<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>					
3.	Bws	0.17521	0.18396	0.18651	=	$\frac{Vw(std)}{Vm(std) + Vw(std)}$			
	Bws	= Water vapor in the gas stream, proportion.			=	<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>	
						0.17521	0.18396	0.18651	
	Vw(std)	= Volume of water vapor in the gas sample, scf.			=	8.98	9.69	10.00	
	Vm(std)	= Volume of gas sampled at meter box, scf.			=	42.26	43.00	43.61	

		<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>					
4.	Md	30.642039	30.644368	30.642229	=	$0.44 (\%CO_2) + 0.32 (\%O_2) + 0.28 (\%N_2) + \%CO$			
	Md	= Dry molecular weight, lb / lb-mole.			=	<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>	
						30.64	30.64	30.64	
	0.44	= Molecular weight of CO2 divided by 100.			=	0.44	0.44	0.44	
	0.32	= Molecular weight of O2 divided by 100.			=	0.32	0.32	0.32	
	0.28	= Molecular weight of N2 or CO divided by 100.			=	0.28	0.28	0.28	
	Co2, O2, N2, and CO are in percent by volume, dry basis.								

		<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>					
5.	Ms	28.43	28.32	28.28	=	$Md * (1-Bws) + M H_2O * (Bws)$			
	Ms	= Molecular weight of gas , wet basis, lb /lb-mole.			=	<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>	
						28.43	28.32	28.28	
	M H2O	= Molecular weight of water, 18 lb / lb-mole.			=	18	18	18	

CALCULATIONS

<u>VOC</u>	<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>	=	PPM * 5.9 / (20.9 - O2)	
1 PPM @ 15% O2	41.38	41.43	40.76	=	PPM * 5.9 / (20.9 - O2)	
					<u>RUN #1</u> <u>RUN #2</u> <u>RUN #3</u>	
02	=	Oxygen	=	4.05	4.11	4.06
PPM	=	PPM	=	118.1633	117.91064	116.36273

CALCULATIONS

NOX

		<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>				
1	PPM Corr.	45.22	40.59	37.99	=	$C_{gas} = (C - C_o) \frac{C_{ma}}{C_m - C_o}$		

						<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>
Co	=	Average of initial and final system calibration bias check responses for the zero gas, ppm.			=	-0.315	-2.005	-3.24
C	=	Effluent gas concentration, dry basis, ppm.			=	45.11	38.97	35.49
Cm	=	Average of initial and final system calibration bias check responses for the upscale gas, ppm.			=	248.83	248.335	249.605
Cma	=	Actual concentration of the upscale calibration gas, ppm.			=	248	248	248

		<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>		
2	PPM @ 15% O2	15.83	14.26	13.31	=	$PPM * 5.9 / (20.9 - O_2)$

						<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>
O2	=	Oxygen			=	4.0509707	4.11	4.06
PPM	=	PPM			=	45.21624	40.591995	37.987858

CALCULATIONS

CO

		<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>							
1	PPM Corr.	875.533	624.99	542.09	=	$C_{gas} = (C - C_o) \frac{C_{ma}}{C_m - C_o}$					

						<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>
Co	=	Average of initial and final system calibration bias check responses for the zero gas, ppm			=	0.68	-0.54	-0.54
C	=	Effluent gas concentration, dry basis, ppm.			=	882.52	625.76	542.29
Cm	=	Average of initial and final system calibration bias check responses for the upscale gas, ppm			=	1264.72	1257.1	1256.2
Cma	=	Actual concentration of the upscale calibration gas, ppm.			=	1255	1255	1255

		<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>						
2	PPM @ 15% O2	309.03	219.88	189.95	=	PPM * 5.9 / (20.9 - O2)				

						<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>
O2	=	Oxygen			=	4.050971	4.11	4.06
PPM	=	PPM			=	875.53	624.99	542.09

CALCULATIONS

O2

		<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>		
1	PPM Corr.	4.05	4.11	4.06	=	$C_{gas} = \frac{C_{ma} (C - C_o)}{C_m - C_o}$

				<u>RUN #1</u>	<u>RUN #2</u>	<u>RUN #3</u>
Co	=	Average of initial and final system calibration bias check responses for the zero gas	=	0.11	-0.045	-0.195
C	=	Effluent gas concentration, dry basis,	=	4.13	4.06	3.90
Cm	=	Average of initial and final system calibration bias check responses for the upscale	=	9.845	9.755	9.71
Cma	=	Actual concentration of the upscale calibration gas, ppm.	=	9.81	9.81	9.81