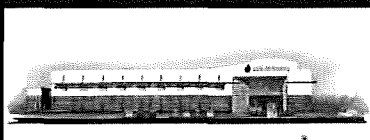# EMISSION COMPLIANCE TEST
FOR THE
GENERAL ELECTRIC, COMBUSTION TURBINE,
UNIT #CTG2
PREPARED FOR
INDECK NILES, LLC
AT THE
INDECK NILES ENERGY CENTER
NILES, MICHIGAN
JUNE 21-22, 2022

Permit No: 75-16B
Report Date: July 15, 2022

N6921_test_20220621

EMISSION COMPLIANCE TEST
FOR THE
GENERAL ELECTRIC, COMBUSTION TURBINE,
UNIT #CTG2
PREPARED FOR
INDECK NILES, LLC
AT THE
INDECK NILES ENERGY CENTER
NILES, MICHIGAN
JUNE 21-22, 2022

Prepared and Reviewed by:

_____
Darin Grimes
Sr. Testing Solutions Specialist

_____
Thomas K. Graham, PE, QSTI
Director of AHU

I, _____
Cole McBride, QSTI
Sr. Project Manager
certify that this testing was conducted and
this report was created in conformance
with the requirements of ASTM D7036

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CERTIFICATION OF INFORMATION

I certify under penalty of law that I believe the information provided in this document is true, accurate and complete. I am aware that there are significant civil and criminal penalties, including the possibility of fine or imprisonment or both, for submitting false, inaccurate or incomplete information.

_____
Cole McBride, QSTI
Sr. Project Manager
Air Hygiene International, Inc.

_____July 4, 2022_____
Date

FACILITY CERTIFICATION

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this document and all attached documents and, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate and complete. I am aware that there are significant civil and criminal penalties, including the possibility of fine or imprisonment or both, for submitting false, inaccurate or incomplete information.

I am the responsible official with direct knowledge and overall responsibility for the information contained in this report.

_____
Name

_____
Title

_____
Signature

_____
Date

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APPENDICES

Emissions Compliance Test
General Electric, Combustion Turbine, Unit #CTG2
Indeck Niles, LLC
Indeck Niles Energy Center
Niles, Michigan
June 21-22, 2022

1.0 INTRODUCTION

Air Hygiene International, Inc. (Air Hygiene) has completed the Emissions Compliance Test for carbon monoxide (CO), total hydrocarbons/volatile organic compounds (THC/VOC), sulfur dioxide (SO_2) from sulfur (S) in fuel, particulate matter (PM), sulfuric acid mist (SAM as H_2SO_4), and formaldehyde (HCHO) from the exhaust of the General Electric, Combustion Turbine, Unit #CTG2 for Indeck Niles, LLC at the Indeck Niles Energy Center in Niles, Michigan. This report details the background, results, process description, and the sampling/analysis methodology of the stack sampling survey conducted on June 21-22, 2022.

1.1 TEST PURPOSE AND OBJECTIVES

The purpose of the test was to conduct an initial compliance emission test to document levels of selected pollutants at base (maximum) load with duct burners in operation [BaseDB]. The information will be used to confirm compliance with the operating permit issued by the Michigan Department of Environment, Great Lakes, and Energy (EGLE). The specific objective was to determine the emission concentration of CO, THC/VOC, SO_2 from fuel S, PM, SAM, and HCHO from the exhaust of Indeck Niles, LLC's General Electric, Combustion Turbine, Unit #CTG2.

1.2 SUMMARY OF TEST PROGRAM

The following list details pertinent information related to this specific project:

1.2.1 Participating Organizations
- Michigan Department of Environment, Great Lakes, and Energy (EGLE)
- Indeck Niles, LLC
- Kiewit Corporation
- Air Hygiene
1.2.2 Industry
- Electric Utility / Electric Services
1.2.3 Air Permit Requirements
- Permit Number: 75-16B
1.2.4 Plant Location
- Indeck Niles Energy Center in Niles, Michigan
  - GPS Coordinates [Latitude 41.85831, Longitude -86.22417]
  - Physical Address: 2200 Progressive Dr., Niles, Michigan 49120
  - Federal Registry System / Facility Registry Service (FRS) No. – 110017413985
  - Source Classification Code (SCC) – 20100201
1.2.5 Equipment Tested
- General Electric, Combustion Turbine, Unit #CTG2

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1.2.6 Emission Points
- Exhaust from the General Electric, Combustion Turbine, Unit #CTG2
- For CO, THC/VOCs, and HCHO, one sample point in the stack from the General Electric, Combustion Turbine, Unit #CTG2, determined after conducting a stratification test
- For all PM testing, 24 sampling points in the stack from the General Electric, Combustion Turbine, Unit #CTG2
- For all SAM testing, one sample point in the stack from the General Electric, Combustion Turbine, Unit #CTG2

1.2.7 Emission Parameters Measured
- CO
- THC/VOC
- SO_2 from fuel S
- PM (filterable PM [Method 5] and total $PM_{10}/PM_{2.5}$ [Methods 5 and 202])
- SAM as H_2SO_4
- HCHO
- Flow
- H_2O
- CO_2
- O_2

1.2.8 Dates of Emission Test
- June 21-22, 2022

1.2.9 Federal Certifications
- Stack Testing Accreditation Council AETB Certificate No. 3796.02
- International Standard ISO/IEC 17025:2005 Certificate No. 3796.01

1.3 KEY PERSONNEL

Indeck Niles, LLC:	Tom Krysiak (tkrysiak@indeckenergy.com)	716-225-6478
Kiewit Corporation:	Derek Goettemoeller (Derek.Goettemoeller@Kiewit.com)	913-905-9068
Air Hygiene:	Cole McBride (cmcbride@airhygiene.com)	918-307-8865
Air Hygiene:	Swanson Bierman	918-307-8865
Air Hygiene:	Colby Gniech	918-307-8865
Air Hygiene:	Harold Jones	918-307-8865
Air Hygiene:	Jason Hass	918-307-8865
Air Hygiene:	Trevor Thompson	918-307-8865
Air Hygiene:	Sean Barnes	918-307-8865

2.0 SUMMARY OF TEST RESULTS

Results from the sampling conducted on Indeck Niles, LLC's General Electric, Combustion Turbine, Unit #CTG2 located at the Indeck Niles Energy Center on June 21-22, 2022 are summarized in the following table and relate only to the items tested.

The results of all measured pollutant emissions were below the required limits. All testing was performed without any real or apparent errors. All testing was conducted according to the approved testing protocol.

kie-22-niles.mi-start#1-CTG2-COMP-rpt

RECEIVED

AUG 0 1 2022

AIR QUALITY DIVISION

TABLE 2.1
SUMMARY OF GENERAL ELECTRIC, COMBUSTION TURBINE,
UNIT #CTG2 RESULTS

Parameter	BaseDB Load Emissions	Permit Limits
Turbine Fuel Flow (SCFH)	3,142,742	--
Duct Burner Fuel Flow (SCFH)	57,289	--
Total Fuel Flow (SCFH)	3,200,031	--
Power Output (megawatts)	366.6	--
CO (ppmvd)	0.08	--
CO (ppm@15%O_2)	0.06	4
CO (lb/hr)	0.42	24.7
CO (ton/year) at 8760 hr/year	1.84	--
VOC (as CH_4) (ppmvd)	0.00	--
VOC (as CH_4) (ppm@15%O_2)	0.00	4
VOC (as CH_4) (lb/hr)	0.00	--
VOC (as CH_4) (ton/year) at 8760 hr/year	0.00	--
HCHO (ppbvd)	57.24	--
HCHO (ppb@15%O_2)	38.38	--
HCHO (lb/hr)	0.31	--
HCHO (ton/year) at 8760 hr/year	1.35	9.3
Filterable PM (mg)	1.77	--
Filterable PM (gr/dscf)	1.54E-04	--
Filterable PM (lb/hr)	1.43	9.9
Filterable PM (ton/year) at 8760 hr/year	6.25	--
Total PM_{10}/$PM_{2.5}$ (mg)	4.15	--
Total PM_{10}/$PM_{2.5}$ (gr/dscf)	3.63E-04	--
Total PM_{10}/$PM_{2.5}$ (lb/hr)	3.35	19.8
Total PM_{10}/$PM_{2.5}$ (ton/year) at 8760 hr/year	14.69	--
Fuel Sulfur (grains / 100 scf)	0.0031	--
SO_2 from fuel sulfur (lb/hr)	0.029	11.7
SO_2 from fuel sulfur (lb/MMBtu)	8.54E-06	0.060
SAM (as H_2SO_4) (mg)	0.0095	--
SAM (as H_2SO_4) (gr/dscf)	3.89E-06	--
SAM (as H_2SO_4) (lb/hr)	0.04	4.6
SAM (as H_2SO_4) (ton/year) at 8760 hr/year	0.16	--

3.0 SOURCE OPERATION

3.1 PROCESS DESCRIPTION

Indeck Niles, LLC owns and operates the Indeck Niles Energy Center located at 2200 Progressive Dr., in Niles, Michigan. The facility includes two combined-cycle natural gas fired combustion turbine generators (CTGs). The two CTGS are rated at 3,651 million British thermal unit per hour (MMBtu/hr) and are coupled with heat

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recovery steam generators (HRSG) in a two-on-one configuration with a steam turbine generator. Each HRSG is equipped with a natural gas-fired duct burner rated at 71 MMBtu/hr to provide heat for additional steam production. The HRSGs are not capable of operating independently from each CTG. Each CTG/HRSG is equipped with dry low NOx burners (DLNB), selective catalytic reduction (SCR), and an oxidation catalyst.

3.2   SAMPLING LOCATION

The stacks are vertical, circular, and measure 21.7 feet (ft) (260 inches) in diameter at the test ports which are approximately 159 ft above grade level with an exit elevation of approximately 170 ft above grade level. The test ports are located approximately 55.2 ft (662 inches) [2.5 dia] downstream and approximately 11 ft (132 inches) [0.5 dia] upstream from the nearest disturbances. Air Hygiene has field verified the measurable dimensions. Non-field verified dimensions are provided by Indeck Niles, LLC. All exhaust samples for gaseous emissions were continuously drawn from the exhaust system at the sample ports from a single point determined after conducting a stratification test for oxides of nitrogen (NOx) and O_2. During the stratification test three points were traversed from each of the four ports. The probe was allowed to remain at a point for at least two times the system response time. For PM testing, an initial velocity traverse was performed across the stack from 24 total points to confirm the absence of cyclonic flow. All PM sampling occurred from the same 24 points by leaving the probe at each for an equal amount of time. For SAM testing, all sampling occurred from a single point in the stack.

4.0   SAMPLING AND ANALYTICAL PROCEDURES

4.1   TEST METHODS

The emission test on the General Electric, Combustion Turbine, Unit #CTG2 at the Indeck Niles Energy Center was performed following United States Environmental Protection Agency (EPA) methods described by the Code of Federal Regulations (CFR). Table 4.1 outlines the specific methods performed on June 21-22, 2022.

TABLE 4.1
SUMMARY OF SAMPLING METHODS

Pollutant or Parameter	Sampling Method	Analysis Method
Sample Point Location	EPA Method 1	Equal Area Method
Stack Flow Rate	EPA Method 2	S-Type Pitot Tube
Oxygen	EPA Method 3A	Paramagnetic Cell
Carbon Dioxide	EPA Method 3A	Nondispersive Infrared Analyzer
Stack Moisture Content	EPA Method 4	Gravimetric Analysis
Particulate Matter	EPA Method 5	Front Half Filterables
Carbon Monoxide	EPA Method 10	Nondispersive Infrared Analyzer
Stack Flow Rate	EPA Method 19	Dry Oxygen F Factor
Total Hydrocarbons	EPA Method 25A	Flame Ionization Detector

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Pollutant or Parameter	Sampling Method	Analysis Method
Particulate Matter	EPA Method 202	Back Half Condensables
Formaldehyde	EPA Method 320	Fourier Transform Infrared with StarBoost Filter
Sulfuric Acid Mist	EPA CTM-013	Ion Chromatography
Fuel Content and Sulfur Analysis	ASTM D-1945 and D3246	Fuel Gas Sample and Laboratory Analysis

4.2   INSTRUMENT CONFIGURATION AND OPERATIONS FOR GAS ANALYSIS

The sampling and analysis procedures used during these tests conform with the methods outlined in the Code of Federal Regulations (CFR), Title 40, Part 60, Appendix A, Methods 1, 2, 3A, 4, 5, 10, 19, 25A; 40 CFR 51, Appendix M, Method 202; 40 CFR 63, Appendix A, Method 320; and Conditional Test Method (CTM)-013.

Figure 4.1 depicts the sample system used for the real-time gas analyzer tests. The gas sample was continuously pulled through the probe and transported, via heat-traced Teflon® tubing, to a heated head pump and into the FTIR then to a stainless-steel minimum-contact condenser designed to dry the sample. Transportation of the sample, through Teflon® tubing, continued into the sample manifold within the mobile laboratory via a stainless steel/Teflon® diaphragm pump. From the manifold, the sample was partitioned to the real-time analyzers through rotameters that controlled the flow rate of the sample. Exhaust samples were routed to the wet based analyzer prior to gas conditioning.

Figure 4.1 shows that the sample system was also equipped with a separate path through which a calibration gas could be delivered to the probe and back through the entire sampling system. This allowed for convenient performance of system bias checks as required by the testing methods.

All instruments were housed in a climate controlled, trailer-mounted mobile laboratory. Gaseous calibration standards were provided in aluminum cylinders with the concentrations certified by the vendor. EPA Protocol No. 1 was used to determine the cylinder concentrations where applicable (i.e., NOx calibration gases).

Table 4.2 provides a description of the analyzers used for the instrument portion of the tests. All data from the continuous monitoring instruments were recorded on a Logic Beach Portable Data Logging System which retrieves calibrated electronic data from each instrument every one second and reports an average of the collected data every 30 seconds. For target compounds measured with the Fourier transform infrared (FTIR) spectrometer, interferograms consisting of 30 co-added scans were recorded continuously during the test periods, and provided approximately 30-second average concentrations. Spectral data was analyzed by the MKS MG2000 software.

Figure 4.2 represents the sample system used for the PM tests. A heated stainless-steel probe with a glass liner and nozzle was inserted into the sample ports of the stack to extract gas measurements from the emission stream through a filter and glass impinger train. Flow rates are monitored with oil filled manometers and total sample volumes are measured with a dry gas meter. Glassware that is used to collect and analyze Method 202 condensable particulate samples is cleaned prior to the test with soap and water, and rinsed using tap water, deionized water, acetone, and finally, hexane. After cleaning, Air Hygiene incorporates a glassware bake at 300°C for six hours rather than the alternative of collecting a field train proof blank.

Figure 4.3 represents the sample system used for the SAM tests. A heated stainless-steel probe with a glass liner was inserted into the sample ports of the stack to extract gas measurements from the emission stream through a

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filter and glass impinger train. Flow rates are monitored with oil filled manometers and total sample volumes are measured with a dry gas meter.

The stack gas analysis for O_2 and CO_2 concentrations was performed in accordance with procedures set forth in EPA Method 3A. The O_2 analyzer uses a paramagnetic cell detector and the CO_2 analyzer uses a continuous nondispersive infrared analyzer.
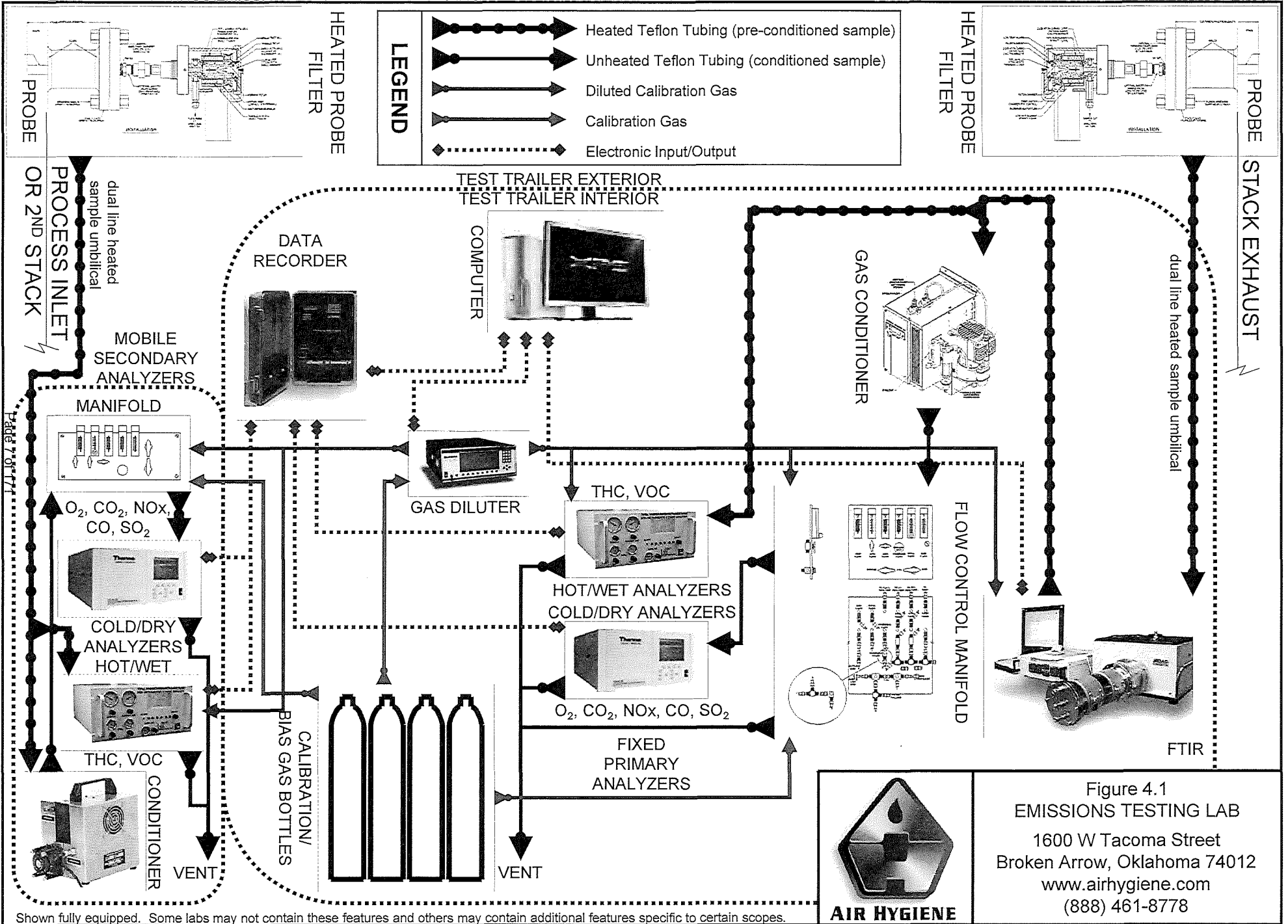
CO emission concentrations were quantified in accordance with procedures set forth in EPA Method 10. A continuous nondispersive infrared (NDIR) analyzer was used for this purpose.

THC emission concentrations were quantified in accordance with procedures set forth in EPA Method 25A. A continuous flame ionization (FID) analyzer was used for this purpose. VOC emission concentrations were assumed as THCs.

A MKS Instruments - MultiGas™ Fourier Transform Infrared (FTIR) spectrometer, equipped with StarBoost technology filter, was used for HCHO analysis per EPA Method 320. The FTIR spectrometer spectral resolution was 0.5 cm^{-1}. The system employed a silicon carbide infrared source at 1200°C, a helium neon reference laser, beam splitters, potassium bromide (KBr) cell window, front-surface optical transfer mirrors, and multi-pass absorption cells. MCT detectors were used and cooled with liquid nitrogen in order to maintain a constant temperature of 77 Kelvin. The approximately 5.11-meter multi-pass path cells incorporated aspheric, aberration-correcting mirrors to increase the optical throughput and the detection sensitivity. Transducers and thermocouples were connected directly to the insulated sample cells that provide the pressure and temperatures of the sample streams. During testing, the temperature of the absorption cells was set at 191°C. Elevated temperature prevented gas condensation within the cell and minimized compound adhesion to the cell walls and mirrors. The volume of the absorption cell was 0.5 liters, so at a sample gas flow rate of 4.0 liters per minute, the sample gas in the cell is refreshed approximately four times each minute. Interferograms consisting of 30 co-added scans were recorded continuously during the test periods, and provided approximately 30-second average concentrations.

TABLE 4.2
ANALYTICAL INSTRUMENTATION

Parameter	Manufacturer and Model	Range	Sensitivity	Detection Principle
CO	THERMO 48 series	User may select up to 10,000 ppm	0.1 ppm	Infrared absorption, gas filter correlation detector, microprocessor-based linearization.
CO_2	SERVOMEX 1440	0-20%	0.1%	Nondispersive infrared
HCHO	MKS 2030	User may select from multiple ranges	0.1 ppm	Fourier Transform Infrared – FTIR with StarBoost filter
VOC	VIG 210	User may select up to 10,000 ppm	0.1 ppm	Flame Ionization Detector
O_2	SERVOMEX 1440	0-25%	0.1%	Paramagnetic cell, inherently linear.

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HEATED PROBE FILTER

LEGEND

- Heated Teflon Tubing (pre-conditioned sample)
- Unheated Teflon Tubing (conditioned sample)
- Diluted Calibration Gas
- Calibration Gas
- Electronic Input/Output

HEATED PROBE FILTER

PROBE

PROCESS INLET OR 2ND STACK

dual line heated sample umbilical

STACK EXHAUST

PROBE

dual line heated sample umbilical

TEST TRAILER EXTERIOR
TEST TRAILER INTERIOR

DATA RECORDER

COMPUTER

GAS CONDITIONER

MOBILE SECONDARY ANALYZERS

MANIFOLD

O_2, CO_2, NOx, CO, SO_2

GAS DILUTER

THC, VOC

HOT/WET ANALYZERS
COLD/DRY ANALYZERS

FLOW CONTROL MANIFOLD

COLD/DRY ANALYZERS HOT/WET

O_2, CO_2, NOx, CO, SO_2

FIXED PRIMARY ANALYZERS

FTIR

THC, VOC

CONDITIONER

VENT

CALIBRATION/ BIAS GAS BOTTLES

VENT

Figure 4.1
EMISSIONS TESTING LAB

1600 W Tacoma Street
Broken Arrow, Oklahoma 74012
www.airhygiene.com
(888) 461-8778

AIR HYGIENE

Shown fully equipped. Some labs may not contain these features and others may contain additional features specific to certain scopes.

Temperature Sensor

Probe

Type S Pitot Tube

View of Probe End
(from the bottom)

Temperature
Sensor
(here and
multiple
locations)

CPM
Filter
Holder
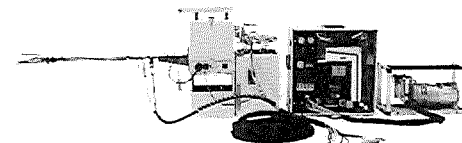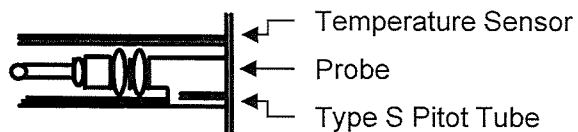
Wet Chemistry Assembly
(photo)

Temperature
Sensor

Stack
Wall

Liner
(glass)

Vertical
Condenser
With
Dropout

Nozzle

Probe
Sheath
(heated)

Type S Pitot
Tube

Glass
Filter
Holder

Vacuum
Line

Oil-Filler
Manometer

Heated Area

Ice
Water
Bath

Impingers

Hot Box

Recirc.
pump

Split Cold Box

Vacuum
Gauge

Orifice

By-pass
Valve
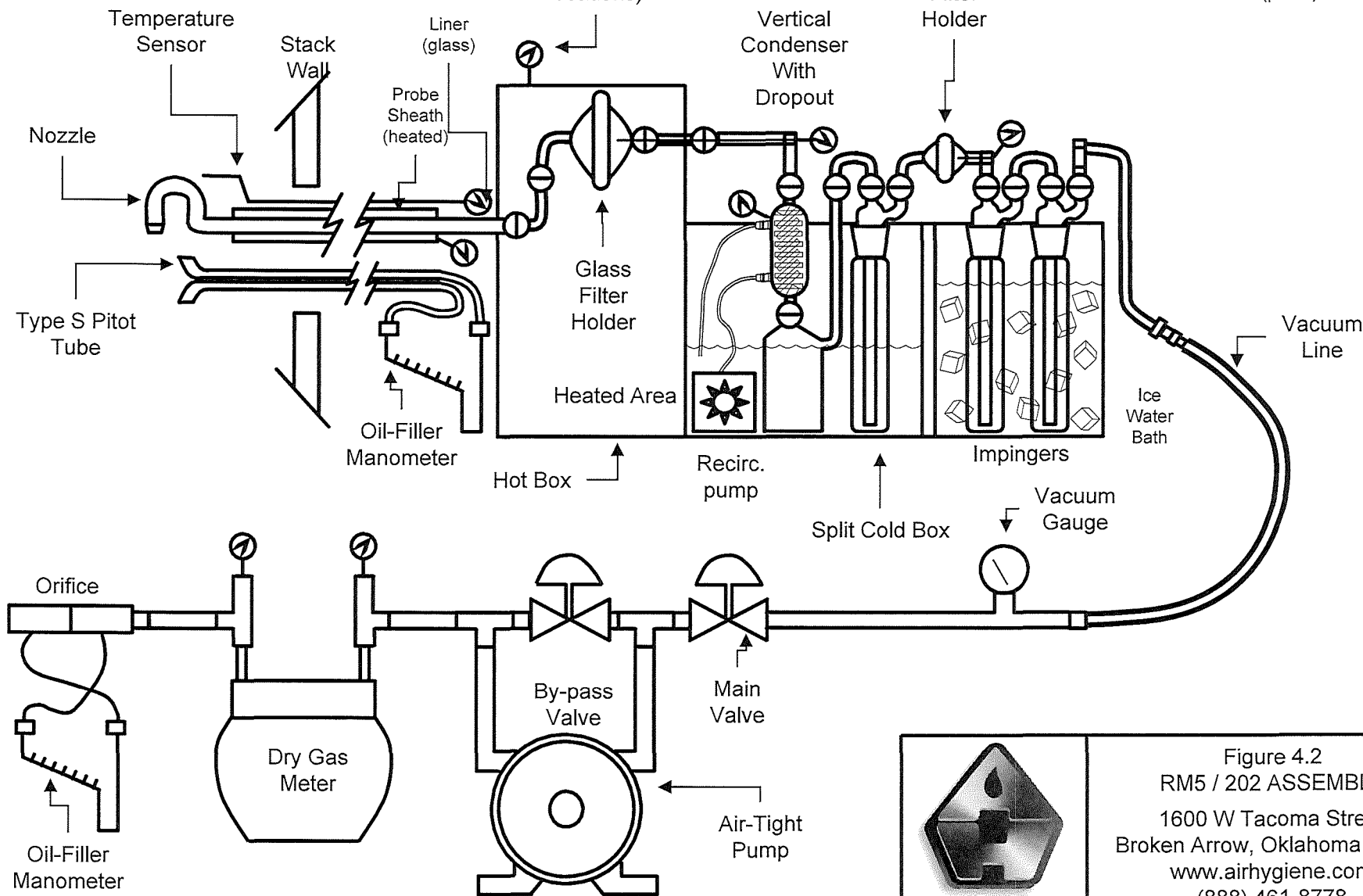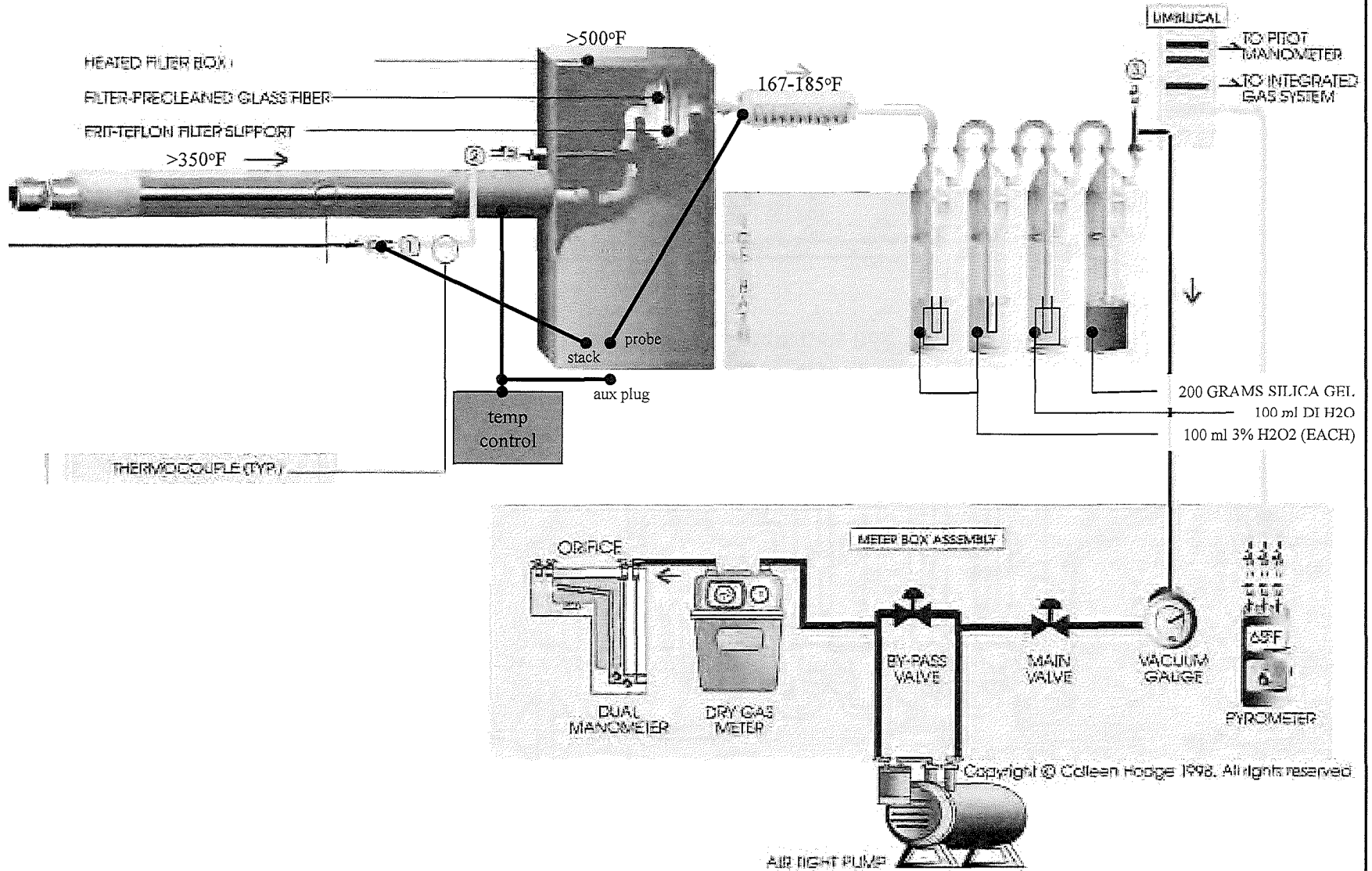
Main
Valve

Dry Gas
Meter

Oil-Filler
Manometer

Air-Tight
Pump

AIR HYGIENE

Figure 4.2
RM5 / 202 ASSEMBLY

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>500°F

HEATED FILTER BOX

FILTER-PRECLEANED GLASS FIBER

FRIT-TEFLON FILTER SUPPORT

>350°F

167-185°F

UMBILICAL

TO PITOT MANOMETER

TO INTEGRATED GAS SYSTEM

probe

stack

aux plug

temp control

THERMOCOUPLE (TYP.)

200 GRAMS SILICA GEL

100 ml DI H2O

100 ml 3% H2O2 (EACH)

ORIFICE

METER BOX ASSEMBLY

BY-PASS VALVE

MAIN VALVE

VACUUM GAUGE

Δ°F

PYROMETER

DUAL MANOMETER

DRY GAS METER

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AIR TIGHT PUMP

TEST NOTES:
10 LPM SAMPLE FLOW
Delta H @ 0.35 IS ABOUT 10 LPM ON STANDARD CONSOLE
15 MIN AMBIENT AIR PURGE

Figure 4.3
METHOD 8A ASSEMBLY

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AIR HYGIENE

APPENDIX A

TEST RESULTS AND CALCULATIONS

TABLE A.1: EMISSIONS TESTING SCHEDULE

Unit	Load	Component	Run	Date	Start	Stop	Time Sync	Duration
CTG2	BaseDB	Stratification Test	1	06/21/22	08:15	08:55	DAHS	00:40
CTG2	BaseDB	CO, VOC, HCHO	1-1	06/22/22	04:29	05:28	DAHS	01:00
CTG2	BaseDB	CO, VOC, HCHO	1-2	06/22/22	05:44	06:43	DAHS	01:00
CTG2	BaseDB	CO, VOC, HCHO	1-3	06/22/22	08:01	09:00	DAHS	01:00
CTG2	BaseDB	Cyc. Flow Chk.	CTG2_PM-V1	06/21/22	08:15	08:38	DAHS	00:23
CTG2	BaseDB	PM	CTG2_PM-1	06/21/22	09:20	16:20	DAHS	07:00
CTG2	BaseDB	PM	CTG2_PM-2	06/21/22	16:45	02:13	DAHS	09:28
CTG2	BaseDB	PM	CTG2_PM-3	06/22/22	04:53	08:02	DAHS	03:09
CTG2	BaseDB	PM	CTG2_PM-4	06/22/22	08:16	11:31	DAHS	03:15
CTG2	BaseDB	SAM	CTG2_100_wdb_8A-1	06/21/22	09:54	15:46	DAHS	05:52
CTG2	BaseDB	SAM	CTG2_100_wdb_8A-2	06/21/22	16:50	00:47	DAHS	07:57
CTG2	BaseDB	SAM	CTG2_100_wdb_8A-3	06/22/22	01:18	04:42	DAHS	03:24

TEST RESULTS AND CALCULATIONS

CO, VOC, HCHO, and SO_2 from Fuel S
Emissions Data

GENERAL ELECTRIC, COMBUSTION TURBINE, UNIT #CTG2 BASEDB LOAD DATA SUMMARY

Parameter	Basedb Load, Run - 1-1	Basedb Load, Run - 1-2	Basedb Load, Run - 1-3	Average
Date (mm/dd/yy)	06/22/22	06/22/22	06/22/22	06/22/22
Start Time (hh:mm:ss)	4:29:23	5:44:23	8:01:12	4:29:23
End Time (hh:mm:ss)	5:28:53	6:43:53	9:00:42	9:00:42
Run Duration (min / run)	60	60	60	60
Bar. Pressure (in. Hg)	29.25	29.24	29.23	29.24
Amb. Temp. (°F)	71	70	75	72
Rel. Humidity (%)	80	80	66	75
Spec. Humidity (lb water / lb air)	0.013296	0.012847	0.012546	0.012896
Turbine Fuel Flow (SCFH)	3,131,653	3,137,067	3,159,507	3,142,742
Duct Burner Fuel Flow (SCFH)	57,467	57,600	56,800	57,289
Total Fuel Flow (SCFH)	3,189,120	3,194,667	3,216,307	3,200,031
Stack Flow (RM19) (SCFH)	68,448,941	68,650,228	69,657,705	68,918,958
Stack Moisture (% Method 320)	12.6	12.6	12.3	12.5
Power Output (megawatts)	364.8	365.8	369.2	366.6
CO (ppmvd)	0.05	0.07	0.13	0.08
CO (ppm@15%O_2)	0.03	0.05	0.09	0.06
CO (lb/hr)	0.24	0.36	0.66	0.42
CO (ton/year) at 8760 hr/year	1.06	1.56	2.91	1.84
VOC (as CH_4) (ppmvd)	0.001	0.000	0.000	0.000
VOC (as CH_4) (ppm@15%O_2)	0.001	0.000	0.000	0.000
VOC (as CH_4) (lb/hr)	0.00	0.00	0.00	0.00
VOC (as CH_4) (ton/year) at 8760 hr/year	0.01	0.00	0.00	0.00
HCHO (ppbvd)	23.70	30.36	117.65	57.24
HCHO (ppb@15%O_2)	15.79	20.25	79.11	38.38
HCHO (lb/hr)	0.13	0.16	0.64	0.31
HCHO (lb/MW*hr)	0.00	0.00	0.00	0.00
HCHO (ton/year) at 8760 hr/year	0.55	0.71	2.80	1.35
Fuel Sulfur (grains / 100 scf)	0.0031	--	--	0.0031
SO_2 from fuel sulfur (lb/hr)	0.0287	--	--	0.0287
SO_2 from fuel sulfur (lb/MMBtu)	8.54E-06	--	--	8.54E-06
CO_2 (%)	5.13	4.45	5.06	4.88
O_2 (%)	12.05	12.06	12.13	12.08

Calculations, Formulas, and Constants

The following information supports the spreadsheets for this testing project.

Given Data:

Ideal Gas Conversion Factor = 385.23 SCF/lb-mol at 68 deg F & 14.696 psia
Fuel Heating Value is based upon Air Hygiene's fuel gas calculation sheet. All calculations are based upon a correction to 68 deg F & 14.696 psia
High Heating Values (HHV) are used for the Fuel Heating Value, F-Factor, and Fuel Flow Data per EPA requirements.

ASTM D 3588

Molecular Weight of NOx (lb/lb-mole) = 46.01
Molecular Weight of CO (lb/lb-mole) = 28.00
Molecular Weight of SO_2 (lb/lb-mole) = 64.00
Molecular Weight of THC (propane) (lb/lb-mole) = 44.00
Molecular Weight of VOC (methane) (lb/lb-mole) = 16.00
Molecular Weight of NH_3 (lb/lb-mole) = 17.03
Molecular Weight of HCHO (lb/lb-mole) = 30.03
Molecular Weight of CO_2 (lb/lb-mole) = 44.01

40CFR60, App. A., RM 19, Table 19-1

Conversion Constant for NOx = 0.0000001194351
Conversion Constant for CO = 0.0000000726839
Conversion Constant for SO_2 = 0.0000001661345
Conversion Constant for THC = 0.0000001142175
Conversion Constant for VOC (methane) = 0.0000000415336
Conversion Constant for NH_3 = 0.0000000442074
Conversion Constant for HCHO = 0.0000000779534
Conversion Constant for CO_2 = 0.0000001142434

NOTE: units are $lb/ppm*ft^3$

Formulas:

1. Corrected Raw Average (C_{Gas}), 40CFR60, App. A, RM 7E, Eq. 7E-5 (08/15/06)

$$C_{Gas} = \left(C_{Avg} - C_o\right) \times \left(\frac{C_{MA}}{C_M - C_o}\right)$$

2. Correction to % O_2, 40CFR60, App. A, RM 20, Eq. 20-5 (11/26/02)

$$C_{adj} = C_{Gas(Target)} \times \left(\frac{20.9\% - AdjFactor}{20.9\% - C_{Gas(O2)}}\right)$$

3. Correction to % O_2 and ISO Conditions

$$C_{ISO} = C_{Adj} \times \sqrt{\frac{P_r}{P_o}} \times e^{(19 \times (H_o - 0.00633))} \times \left(\frac{288}{T_a}\right)^{1.53}$$

4. Method 19 stack exhaust flow (scfh) [ref. EPA EMC FAQ Method 19]

$$Q_s = \left(\frac{FFactor \times Q_f \times HHV}{1,000,000}\right) \times \left(\frac{20.9\%}{20.9\% - C_{Gas(O2)}}\right)$$

5. Emission Rate in lb/hr

$$E_{lb/hr} = \frac{C_{Gas}}{10^6} \times \frac{Q_s \times MW}{G}$$

6. Emission Rate in tons per year

$$E_{ton/yr} = \frac{E_{lb/hr} \times hr_{year}}{2000}$$

7. Emission Concentration in lb/MMBtu (O_2 based)

$$E_{lb/MMBtu} = \frac{C_{Gas} \times F_d Factor \times Conv_C \times 20.9\%}{20.9\% - C_{Gas(O2)}}$$

8. Emission Concentration in g/hp*hr

$$E_{g/hp \cdot hr} = \frac{E_{lb/hr} \times 453.6}{mw \times 1341.022} \; or \; \frac{E_{lb/hr} \times 453.6}{hp}$$

RM 7E, (08-15-06), 12.1 Nomenclature. The terms used in the equations are defined as follows:

ACE = Analyzer calibration error, percent of calibration span.

B_{WS} = Moisture content of sample gas as measured by Method 4 or other approved method, percent/100.

C_{Avg} = Average unadjusted gas concentration indicated by data recorder for the test run.

C_D = Pollutant concentration adjusted to dry conditions.

C_{Dir} = Measured concentration of a calibration gas (low, mid, or high) when introduced in <u>direct</u> calibration mode.

C_{Gas} = Average effluent gas concentration adjusted for bias.

C_M = Average of initial and final system calibration bias (or 2-point system calibration error) check <u>responses</u> for the upscale calibration gas.

C_{MA} = Actual concentration of the upscale calibration gas, ppmv.

C_O = Average of the initial and final system calibration bias (or 2-point system calibration error) check <u>responses</u> from the low-level (or zero) calibration gas.

C_S = Measured concentration of a calibration gas (low, mid, or high) when introduced in <u>system</u> calibration mode.

C_{SS} = Concentration of NOx measured in the spiked sample.

C_{Spike} = Concentration of NOx in the undiluted spike gas.

C_{Calc} = Calculated concentration of NOx in the spike gas diluted in the sample.

C_V = Manufacturer certified concentration of a calibration gas (low, mid, or high).

C_W = Pollutant concentration measured under moist sample conditions, wet basis.

CS = Calibration span.

D = Drift assessment, percent of calibration span.

E_p = The predicted response for the low-level and mid-level gases based on a linear response line between the zero and high-level response.

Eff_{NO2} = NO$_2$ to NO converter efficiency, percent.

H = High calibration gas, designator.

L = Low calibration gas, designator.

M = Mid calibration gas, designator.

$NOFinal$ = The average NO concentration observed with the analyzer in the NO mode during the converter efficiency test in Section 16.2.2.

$NOxCorr$ = The NOx concentration corrected for the converter efficiency.

$NOxFinal$ = The final NOx concentration observed during the converter efficiency test in Section 16.2.2.

$NOxPeak$ = The highest NOx concentration observed during the converter efficiency test in Section 16.2.2.

Q_{Spike} = Flow rate of spike gas introduced in system calibration mode, L/min.

Q_{Total} = Total sample flow rate during the spike test, L/min.

R = Spike recovery, percent.

SB = System bias, percent of calibration span.

SB_i = Pre-run system bias, percent of calibration span.

SB_f = Post-run system bias, percent of calibration span.

SB / D_{Alt} = Alternative absolute difference criteria to pass bias and/or drift checks.

SCE = System calibration error, percent of calibration span.

SCE_i = Pre-run system calibration error, percent of calibration span.

SCE_{final} = Post-run system calibration error, percent of calibration span.

Z = Zero calibration gas, designator.

40CFR60.355(b)(1), (09-20-06), Nomenclature. The terms used in the equations are defined as follows:

P_r = reference combustor inlet absolute pressure at 101.3 kilopascals ambient pressure, mm Hg

P_o = observed combustor inlet absolute pressure at test, mm Hg

H_o = observed humidity of ambient air, g H$_2$O/g air

e = transcendental constant, 2.718

T_a = ambient temperature, K

Small Engine and FTIR Nomenclature. The terms used in the equations are defined as follows:

bhp = brake horsepower

hp = horsepower

Q_{sys} = system flow (lpm)

Q_m = matrix spike flow (lpm)

RM 19, (07-29-06), 12.1 Nomenclature. The terms used in the equations are defined as follows:

AdjFactor = Percent oxygen or carbon dioxide adjustment applied to a target pollutant

B_{wa} = Moisture fraction of ambient air, percent.

Btu = British thermal unit

$\%_C$ = Concentration of carbon from an ultimate analysis of fuel, weight percent.

$\%_{CO2d}, \%_{CO2w}$ = Concentration of carbon dioxide on a dry and wet basis, respectively, percent.

CIP / CDP = Combustor inlet pressure / compressor discharge pressure (mm Hg); note, some manufactures reference as PCD.

E = Pollutant emission rate, ng/J (lb/million Btu).

E_a = Average pollutant rate for the specified performance test period, ng/J (lb/million Btu).

E_{ao}, E_{ai} = Average pollutant rate of the control device, outlet and inlet, respectively, for the performance test period, ng/J (lb/million Btu).

E_{bi} = Pollutant rate from the steam generating unit, ng/J (lb/million Btu).

E_{bo} = Pollutant emission rate from the steam generating unit, ng/J (lb/million Btu).

E_{ci} = Pollutant rate in combined effluent, ng/J (lb/million Btu).

E_{co} = Pollutant emission rate in combined effluent, ng/J (lb/million Btu).

E_d = Average pollutant rate for each sampling period (e.g.,24-hr Method 6B sample or 24-hr fuel sample) or for each fuel lot (e.g., amount of fuel bunkered), ng/J (lb/million B

E_{di} = Average inlet SO_2 rate for each sampling period d, ng/J (lb/million Btu).

E_g = Pollutant rate from gas turbine, ng/J (lb/million Btu).

E_{ga} = Daily geometric average pollutant rate, ng/J (lbs/million Btu) or ppm corrected to 7 percent O_2.

E_{jo}, E_{ji} = Matched pair hourly arithmetic average pollutant rate, outlet and inlet, respectively, ng/J (lb/million Btu) or ppm corrected to 7 percent O_2.

E_h = Hourly average pollutant, ng/J (lb/million Btu).

E_{hj} = Hourly arithmetic average pollutant rate for hour "j," ng/J (lb/million Btu) or ppm corrected to 7 percent O_2.

EXP = Natural logarithmic base (2.718) raised to the value enclosed by brackets.

Fc = Ratio of the volume of carbon dioxide produced to the gross calorific value of the fuel from Method 19

F_d, F_w, F_c = Volumes of combustion components per unit of heat content, scm/J (scf/million Btu).

ft^3 = cubic feet

G = ideal gas conversion factor
   (385.23 SCF/lb-mol at 68 deg F & 14.696 psia)

GCM = gross Btu per SCF (constant, compound based)

GCV = Gross calorific value of the fuel consistent with the ultimate analysis, kJ/kg (Btu/lb).

GCV_p, GCV_r = Gross calorific value for the product and raw fuel lots, respectively, dry basis, kJ/kg (Btu/lb).

$\%_H$ = Concentration of hydrogen from an ultimate analysis of fuel, weight percent.

H_b = Heat input rate to the steam generating unit from fuels fired in the steam generating unit, J/hr (million Btu/hr).

H_g = Heat input rate to gas turbine from all fuels fired in the gas turbine, J/hr (million Btu/hr).

$\%_{H2O}$ = Concentration of water from an ultimate analysis of fuel, weight percent.

H_r = Total numbers of hours in the performance test period (e.g., 720 hours for 30-day performance test period).

K = volume of combustion component per pound of component (constant)

K = Conversion factor, 10^{-5} (kJ/J)/(%) $[10^6$ Btu/million Btu].

$K_c = (9.57 \text{ scm/kg})/\% [(1.53 \text{ scf/lb})/\%]$.

$K_{cc} = (2.0 \text{ scm/kg})/\% [(0.321 \text{ scf/lb})/\%]$.

$K_{hd} = (22.7 \text{ scm/kg})/\% [(3.64 \text{ scf/lb})/\%]$.

$K_{hw} = (34.74 \text{ scm/kg})/\% [(5.57 \text{ scf/lb})/\%]$.

$K_n = (0.86 \text{ scm/kg})/\% [(0.14 \text{ scf/lb})/\%]$.

$K_o = (2.85 \text{ scm/kg})/\% [(0.46 \text{ scf/lb})/\%]$.

$K_s = (3.54 \text{ scm/kg})/\% [(0.57 \text{ scf/lb})/\%]$.

$K_{sulfur} = 2 \times 10^4$ Btu/wt%-MMBtu

$K_w = (1.30 \text{ scm/kg})/\% [(0.21 \text{ scf/lb})/\%]$.

lb = pound

ln = Natural log of indicated value.

L_p, L_r = Weight of the product and raw fuel lots, respectively, metric ton (ton).

$\%_N$ = Concentration of nitrogen from an ultimate analysis of fuel, weight percent.

$M_\%$ = mole percent

mol = mole

MW = molecular weight (lb/lb-mol)

MW_{AIR} = molecular weight of air (28.9625 lb/lb-mole)[1]

NCM = net Btu per SCF (constant based on compound)

$\%_O$ = Concentration of oxygen from an ultimate analysis of fuel, weight percent.

$\%_{O2d}, \%_{O2w}$ = Concentration of oxygen on a dry and wet basis, respectively, percent.

P_B = barometric pressure, in Hg

P_s = Potential SO2 emissions, percent.

$\%_S$ = Sulfur content of as-fired fuel lot, dry basis, weight percent.

S_e = Standard deviation of the hourly average pollutant rates for each performance test period, ng/J (lb/million Btu).

$\%_{sf}$ = Concentration of sulfur from an ultimate analysis of fuel, weight percent.

S(wt%) = weight percent of sulfur, per lab analysis by appropriate ASTM standard

S_i = Standard deviation of the hourly average inlet pollutant rates for each performance test period, ng/J (lb/million Btu).

S_o = Standard deviation of the hourly average emission rates for each performance test period, ng/J (lb/million Btu).

$\%S_p, \%S_r$ = Sulfur content of the product and raw fuel lots respectively, dry basis, weight percent.

SCF = standard cubic feet

SH = specific humidity, pounds of water per pound of air

$t_{0.95}$ = Values shown in Table 19-3 for the indicated number of data points n.

T_{amb} = ambient temperature, °F

W/D Factor =   1.0236   = conv. at 14.696 psia and
   68 deg F (ref. Civil Eng. Ref. Manual, 7th Ed.)

X_{CO2}=CO_2 Correction factor, percent.

X_k = Fraction of total heat input from each type of fuel k.

EXAMPLE CALCULATIONS (FFACTOR)

RM 19, (02-27-14),
2.0 Summary of Method,
2.1 Emission Rates. Oxygen (O_2) or carbon dioxide (CO_2) concentrations and appropriate F factors (ratios of combustion gas volumes to heat inputs) are used to calculate pollutant emission rates from pollutant concentrations.

Mark's Std Hdbk, 10th ed.,pg 4-26
High Heat Value Dry (HHV_{dry}), calc for Methane (single component for the fuel gas)

$$HHV_{dry}(Btu/SCF) = \left[\left(\frac{M_{\%}}{100}\right) \times GCM\right]$$

$$HHV_{dry} = \frac{91.60\%}{100.00} \times \frac{994.85 \text{ Btu}}{SCF} = \frac{911.30 \text{ Btu}}{SCF}$$

Mark's Std Hdbk, 10th ed., pg 4-26
Low Heat Value Dry (LHV_{dry}), calc for Methane (single component for the fuel gas)

$$LHV_{dry}(Btu/SCF) = \left[\left(\frac{M_{\%}}{100}\right) \times NCM\right]$$

$$LHV_{dry} = \frac{91.60\%}{100.00} \times \frac{895.75 \text{ Btu}}{SCF} = \frac{820.53 \text{ Btu}}{SCF}$$

RM 19, (02-27-14),
12.2 Emission Rates of PM, SO_2, and NOx. Select from the following sections the applicable procedure to compute the PM, SO_2, or NOx emission rate (E) in lb/MMBtu. The pollutant concentration must be in lb/scf and the F factor must be in scf/MMBtu. If the pollutant concentration (C) is not in the appropriate units, use Table 19–1 in Section 17.0 to make the proper conversion. An F factor is the ratio of the gas volume of the products of combustion to the heat content of the fuel. The dry F factor (F_d) includes all components of combustion less water, the wet F factor (F_w) includes all components of combustion, and the carbon F factor (F_c) includes only carbon dioxide.

Civil Eng. Ref. Man.,7th Ed.,pg 14-9/GPA Ref. Bulletin 181-86, App. C
High Heat Value Wet (HHV_{wet}), calc for entire sample (all components of the fuel gas)

$$HHV_{wet}(Btu/SCF) = \frac{HHV_{dry}}{W/D.factor}$$

$$HHV_{wet} = \frac{1,051.50 \text{ Btu/SCF}}{1.0236} = 1,027.25 \text{ Btu/SCF}$$

Civil Eng. Ref. Man.,7th Ed.,pg 14-9/GPA Ref. Bulletin 181-86, App. C
Low Heat Value Wet (LHV_{wet}), calc for entire sample (all components of the fuel gas)

$$LHV_{wet}(Btu/SCF) = \frac{LHV_{dry}}{W/D.factor}$$

$$LHV_{wet} = \frac{948.83 \text{ Btu/SCF}}{1.0236} = 926.95 \text{ Btu/SCF}$$

Lbs Component per Lb-Mol of Gas (CM), calc for Methane (single component for the fuel gas)

$$CM(lb/lb-mol) = \left[\left(\frac{M_{\%}}{100}\right) \times MW\right]$$

$$CM = \frac{91.60\%}{100.00} \times \frac{16.04 \text{ lb}}{lb-mol} = 14.70 \text{ lb/lb-mol}$$

ASTM D 3588
Fuel Molecular Weight (MW_{Fuel})

$$MW_{Fuel}(lb/lb \cdot mol) = \left[\sum(CM)\right]$$

$MW_{Fuel} = 14.70$ lb/lb-mol
$+\ 2.24$ lb/lb-mol
$+$ etc. $=\ 17.306$ lb/lb-mol

Btu per Lb of Gas Gross (**GCV**)

$$GCV(Btu/lb) = \left[\frac{HHV_{dry} \times G}{MW_{Fuel}}\right]$$

$$GCV = \frac{1,051.50 \text{ Btu/SCF} \times 385.23 \text{ ft}^3/lbmol}{17.306 \text{ lb/lb-mol}} = 23,406.11 \text{ Btu/lb}$$

ASTM D 3588 (SG)
Specific Gravity

$$SG = \left[\frac{MW_{Fuel}}{MW_{AIR}}\right]$$

$$SG = \frac{17.31 \text{ lb/lb-mol}}{28.96 \text{ lb/lb-mol}} = 0.5975$$

Btu per Lb of Gas Net (**NCV**)

$$NCV(Btu/lb) = \left[\frac{LHV_{dry} \times G}{MW_{Fuel}}\right]$$

$$NCV = \frac{948.83 \text{ Btu/SCF} \times 385.23 \text{ ft}^3/lbmol}{17.306 \text{ lb/lb-mol}} = 21,120.70 \text{ Btu/lb}$$

Weight Percent of Component ($C_\%$), methane

$$C_\%(\%) = \left[\left(\frac{CM}{MW_{Fuel}}\right) \times 100\right]$$

$$C_\% = \frac{14.70 \text{ lb/lb-mol}}{17.31 \text{ lb/lb-mol}} \times 100 = 84.92\%$$

Weight Percent of Volatile Organic Compounds ($VOC_\%$)

$$VOC_\%(\%) = \left[\sum_{C_3H_8}^{C_8H_{18}} Wt_\%\right]$$

$VOC_\% = 0.79\% + 0.12\% + 0.09\% + $ etc. $= 1.07\%$

RM 19, (02-27-14), 12.3.2 Determined **F Factors**. If the fuel burned is not listed in Table 19–2 or if the owner or operator chooses to determine an F factor rather than use the values in Table 19–2, use the procedure below: 12.3.2.1 Equations. Use the eq

RM 19, (02-27-14),
12.1 Nomenclature
K (scf/lb)/%

H	3.64
C	1.53
S	0.57
N_2	0.14
O_2	0.46

$$F_d = \frac{K(K_{hd}\%H + K_c\%C + K_s\%S + K_n\%N - K_o\%O)}{GCV}$$

Eq. 19-13

$$F_d = \frac{10^6 Btu}{MMBtu} \times \left[\frac{3.64 \text{ SCF}}{lb \cdot \%} \times 24.14\% + \frac{1.53 \text{ SCF}}{lb \cdot \%} \times 74.92\% + \frac{0.57 \text{ SCF}}{lb \cdot \%} \times 0.00\% + \frac{0.14 \text{ SCF}}{lb \cdot \%} \times 0.57\% - \frac{0.46 \text{ SCF}}{lb \cdot \%} \times 0.37\%\right] \times \frac{lb}{23,406.11 \text{ Btu}} = \frac{8,647.63 \text{ SCF}}{MMBtu}$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (INFORMATION)

Specific Humidity (RH$_{sp}$)   Note: RHsp (gr/lb) calculated using temperature, relative humidity, and barometric pressure with psychrometric chart, psychrometric calculator, or built in psychrometric algorithm.

$$RH_{sp}(lb/lb) = \left[\left(\frac{gr}{lb} \right) \times \frac{lb}{7000gr} \right]$$

$$RH_{sp} = \frac{93.07 \text{ gr}}{lb} \times \frac{1 \text{ lb}}{7000 \text{ gr}} = 0.013296 \frac{lb \text{ } H_2O}{lb \text{ Air}}$$

EXAMPLE CALCULATIONS (CALIBRATION)

Analyzer Calibration Error
RM 7E, (02-27-14), 12.2 Analyzer Calibration Error. For non-dilution systems, use Equation 7E-1 to calculate the analyzer calibration error for the low-, mid-, and high-level calibration gases. (calc for CO analyzer mid gas, if applicable)

$$ACE = \left(\frac{C_{Dir} - C_V}{CS} \right) \times 100 \qquad \text{Eq. 7E-1}$$

$$ACE = \frac{5.26 \text{ ppm} - 5.22 \text{ ppm}}{8.90 \text{ ppm}} \times 100 = 0.45 \text{ \%}$$

Calibration Error and Estimated Point, RM 25A, THC/VOC Analyzer
RM 25A, (02-27-14), 8.4 Calibration Error Test. Immediately prior to the test series (within 2 hours of the start of the test), introduce zero gas and high-level calibration gas at the calibration valve assembly. Adjust the analyzer output to the appropriate levels, if necessary. Calculate the predicted response for the low-level and mid-level gases based on a linear response line between the zero and high-level response. Then introduce low-level and mid-level calibration gases successively to the measurement system. ... These differences must be less than 5 percent of the respective calibration gas value. (calc for THC/VOC analyzer mid gas, if applicable)

$$E_P = \frac{C_{Dir(H)} - C_{Dir(Z)}}{C_{V(H)} - C_{V(Z)}} \times C_{Dir(M)} + C_{Dir(Z)} \qquad \begin{array}{l} \text{Eq. of a line} \\ y=mx+b \end{array}$$

$$E_P = \frac{8.84 \text{ ppm} - 0.01 \text{ ppm}}{8.71 \text{ ppm} - 0.00 \text{ ppm}} \times 5.19 \text{ ppm} + 0.01 = 5.27 \text{ ppm}$$

$$ACE = \left(\frac{C_{Dir} - C_V}{CS} \right) \times 100 \qquad \text{Eq. 7E-1}$$

$$ACE_{voc} = \frac{5.13 \text{ ppm} - 5.27 \text{ ppm}}{5.19 \text{ ppm}} \times 100 = -2.73 \text{ \%}$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (BIAS, DRIFT, AND CORRECTED RAW AVERAGE)

System Bias
RM 7E, (02-27-14), 12.3 System Bias. For non-dilution systems, use Equation 7E-2 to calculate the system bias separately for the low-level and upscale calibration gases. (calc for CO analyzer upscale gas, Run 1 initial bias, if applicable)

$$SB = \left(\frac{C_S - C_{Dir}}{CS} \right) \times 100 \qquad \text{Eq. 7E-2}$$

$$SB = \frac{5.32 \text{ ppm} - 5.26 \text{ ppm}}{8.90 \text{ ppm}} \times 100 = 0.67 \text{ \%}$$

Drift Assessment
RM 7E, (02-27-14), 12.5 Drift Assessment. Use Equation 7E-4 to separately calculate the low-level and upscale drift over each test run. (calc for CO analyzer upscale drift, Run 1, if applicable)

$$D = |SB_{final} - SB_i| \qquad \text{Eq. 7E-4}$$

$$D = | \text{ } 0.90 \text{ \% } - 0.67 \text{ \% } | = 0.22 \text{ \%}$$

Alternative Drift and Bias
RM 7E, (02-27-14), 13.2 / 13.3 System Bias and Drift. Alternatively, the results are acceptable if |Cs − Cdir| is ≤ 0.5 ppmv or if |Cs − Cv| is ≤ 0.5 ppmv (as applicable). (calc for CO analyzer initial upscale, Run 1, if applicable)

$$SB/D_{Alt} = |C_S - C_{Dir}| \qquad \text{Eq. Section 13.2 and 13.3}$$

$$SB/D_{Alt} = | \text{ } 5.32 \text{ ppm} - 5.26 \text{ ppm } | = 0.06 \text{ ppm}$$

Bias Adjusted Average
RM 7E, (02-27-14), 12.6 Effluent Gas Concentration. For each test run, calculate Cavg, the arithmetic average of all valid CO concentration values (e.g., 1-minute averages). Then adjust the value of Cavg for bias, using Equation 7E-5b. (calc for CO analyzer, Run 1, if applicable)

$$C_{Gas} = (C_{Avg} - C_O) \times \left(\frac{C_M}{C_M - C_O} \right) \qquad \text{Eq. 7E-5b}$$

$$C_{Gas} = \left(0.07 \text{ ppm} - 0.03 \text{ ppm} \right) \left(\frac{5.22 \text{ ppm}}{5.33 \text{ ppm} - 0.03 \text{ ppm}} \right)$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (RUNS)

Stack Exhaust Flow (Q_S) - RM19

$$Q_s = \left(\frac{FFactor \times Q_f \times HHV}{1,000,000} \right) \times \left(\frac{20.9\%}{20.9\% - C_{Gas(O2)}} \right)$$

Note: Equation presented in EPA Emission Measurement Center (EMC), Frequently Asked Questions (FAQ) for Method 19

$$Q_S = \frac{8,647.63 \text{ SCF}}{\text{MMBtu}} \times \frac{3,189,120.00 \text{ SCF}}{\text{hr}} \times \frac{1,051.50 \text{ Btu}}{\text{SCF}}$$

$$\times \frac{\text{MMBtu}}{10^6 \text{ Btu}} \times \left[\frac{20.90\%}{20.9\% - 12.0\%} \right] = 68,448,941.15 \text{ SCFH}$$

Moisture Correction

RM 7E, (02-27-14), 12.10 Moisture Correction. Use Equation 7E-10 if your measurements need to be corrected to a dry basis. (calc for CO analyzer, Run 1, if applicable) Note: Calculations may not match as Run 1 results are typically also bias adjusted

$$C_w = C_D \times (1 - B_{ws})$$

$$C_D = \frac{C_w}{1 - B_{ws}}$$ Eq. 7E-10 $$C_D = \frac{0.04 \text{ ppmvw}}{1 - 0.13} = 0.05 \text{ ppmvc}$$ or inversely, $$C_W = 0.05 \text{ ppmvd} \times \left(1 - 0.13\right) = 0.04 \text{ ppmvw}$$

Diluent-Corrected Pollutant Concentration, O_2 Based

RM 20, (11-26-02), 7.3.1 Correction of Pollutant Concentration Using O_2 Concentration. Calculate the O_2 corrected pollutant concentration, as follows: (calc for CO gas, Run 1, if applicable) [now contained in applicable Subpart]

$$C_{adj} = C_{Gas(Target)} \times \left(\frac{20.9\% - AdjFactor}{20.9\% - C_{Gas(O2)}} \right)$$ Eq. 20-4 $$C_{adj} = 0.05 \text{ ppm} \times \left(\frac{20.9\% - 15.00\%}{20.9\% - 12.05\%} \right) = 0.03 \text{ ppm@15\%}O_2$$

Emissions Rate (lb/hr)

Calculation for pound per hour emission rate. Calculate, as follows: (calc for CO gas Run 1, if applicable)

$$E_{lb/hr} = \frac{C_{Gas}}{10^6} \times \frac{Q_s \times MW}{G}$$

$$E_{lb/hr} = \frac{0.05 \text{ ppmvd}}{10^6 \text{ ppm/part}} \times \frac{68,448,941 \text{ DSCFH} \times 28.00 \text{ lb/lb-mol}}{385.23 \text{ SCF/lb-mol}} = \frac{0.24 \text{ lb}}{\text{hr}}$$

Emissions Rate (ton/year)

Calculation for tons per year emission rate based on 8760 hours per year. Calculate, as follows: (calc for CO gas Run 1, if applicable)

$$E_{ton/yr} = \frac{E_{lb/hr} \times hr_{year}}{2000}$$

$$E_{ton/yr} = \frac{0.24 \text{ lb}}{\text{hr}} \times \frac{8,760 \text{ hr}}{\text{year}} \times \frac{\text{ton}}{2000 \text{ lb}} = \frac{1.06 \text{ ton}}{\text{year}}$$

Sulfur Dioxide Rate (lb/MMBtu), 40CFR75, App. D, Eq. D-1h

$$SO_2(lb/MMBtu) = \left[\frac{2.0}{7000} \right] \times [10^6] \times \left[\frac{S_{total}}{GCV} \right]$$

$$SO_2 = \frac{2 \text{ lb } SO_2}{\text{lb S}} \times \frac{\text{lb/100scf}}{7000 \text{ gr/100scf}} \times \frac{1000000 \text{ Btu}}{\text{MMBtu}} \times \frac{0.00314 \text{ S gr/100scf}}{105150 \text{ GCV Btu/100scf}} = \frac{8.54E\text{-}06 \text{ lb}}{\text{MMBtu}}$$

Calculate grains of sulfur per 100 standard cubic feet of fuel gas (gr S / 100 scf) from parts per million by weight (ppmw)

$$S \left(gr\,S/100\,scf \right) = ppmw \times fuel_{MW} \times \frac{1}{G} \times \frac{1}{10^6} \times \frac{7000\,gr}{lb} \times \frac{100\,scf}{100\,scf}$$

$$S = \frac{0.10 \text{ lb sulfur}}{\text{million lb fuel}} \times \frac{17.31 \text{ lb fuel}}{\text{lb-mol fuel}} \times \frac{\text{lb-mol fuel}}{385.23 \text{ scf fuel}} \times \frac{\text{million lb S}}{1,000,000 \text{ lb S}} \times \frac{7,000 \text{ gr S}}{\text{lb S}} \times \frac{100 \text{ scf fuel}}{100 \text{ scf fuel}}$$

$$S = \frac{0.0031 \text{ gr}}{100 \text{ scf}}$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

Method 320 Equation 3, Dilution Factor (DF)

(example calculation for Trial #1, where applicable)

$$DF = \frac{SF_{6\,(spk)}}{SF_{6\,(dir)}} = \frac{\left(SF_{6\,(spk+native)} - SF_{6\,(native)}\right)}{SF_{6\,(dir)}} \; OR \; \frac{\left(CO_{2(native)} - CO_{2(spk+native)}\right)}{CO_{2(native)}}$$

$$DF\,(CO_2) = \frac{5.3470 \quad - \quad 4.7890 \quad ppbvw}{5.35 \quad ppbvw} =$$

$$0.1043$$

Test Method 320, Section 9.0 Quality Control

Where,

$SF_{6(dir)}$ = SF_6 (or tracer gas) concentration measured directly in undiluted spike gas

$SF_{6(spk)}$ = Diluted SF_6 (or tracer gas) concentration measured in a spiked sample

$SF_{6(spk)}$ = $SF_{6(spk+native)}$ - $SF_{6(native)}$

$SF_{6(spk+native)}$ = Diluted SF_6 (or tracer gas) concentration measured in a spiked sample in stack gas

$SF_{6(native)}$ = SF_6 (or tracer gas) concentration measured in a native stack gas sample

Unspike = Native concentration of analytes in unspiked samples

$Spike_{dir}$ = Concentration of the analyte in the spike standard measured by filling the FTIR cell directly

Dilution Factor Ratio

(example calculation for Trial #1, where applicable)

$$DF\,Ratio = \frac{SF_{6\,(dir)}}{SF_{6\,(spk)}} = \frac{SF_{6\,(dir)}}{\left(SF_{6\,(spk+native)} - SF_{6\,(native)}\right)} \; OR \; \frac{CO_{2(native)}}{CO_{2(native)} - CO_{2(spk+native)}} \geq 10$$

$$\frac{DF}{Ratio} = \frac{5.35 \quad ppbvw}{5.3470 \quad - \quad 4.7890 \quad ppbvw} =$$

$$\frac{Spike}{Ratio} = 9.6 \quad :1$$

Method 320 Equation 4 [Method 321 Equation 2], Excepted Concentration of the Spiked Samples

Ideal Spike Yield *(example calculation for Trial #1 (HCHO), where applicable)*

$$CS = DF \times Spike_{dir} + Unspike\,(1 - DF)$$

$$CS = 0.1043 \quad X \quad 56205.0230 \; ppbvw \quad + \quad -221.7947 \; ppbvw \quad X \left[1 - 0.1043\right] = 5{,}666.3243 \; ppbvw$$

Method 320 Spiked vs Expected

$$Spiked\,vs\,Expected = \frac{Actual\,Spike\,Yield}{Ideal\,Spike\,Yield} \times 100$$

(example calculation for Trial #1 (HCHO), where applicable)

$$\% \, Recovery = \frac{4{,}262.8087 \;\; ppbvw}{5{,}666.3243 \;\; ppbvw} \times 100 = 75.231 \; \%$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

Method 320 Equation 3, Dilution Factor (DF)

(example calculation for Trial #2, where applicable)

$$DF = \frac{SF_{6(spk)}}{SF_{6(dir)}} = \frac{(SF_{6(spk+native)} - SF_{6(native)})}{SF_{6(dir)}} \; OR \; \frac{(CO_{2(native)} - CO_{2(spk+native)})}{CO_{2(native)}}$$

DF (CO_2) = $\dfrac{5.2869 \quad - \quad 4.7885 \quad ppbvw}{5.29 \quad ppbvw}$ =

0.0943

Test Method 320, Section 9.0 Quality Control

Where,

$SF_{6(dir)}$ = SF_6 (or tracer gas) concentration measured directly in undiluted spike gas

$SF_{6(spk)}$ = Diluted SF_6 (or tracer gas) concentration measured in a spiked sample

$SF_{6(spk)}$ = $SF_{6(spk+native)}$ - $SF_{6(native)}$

$SF_{6(spk+native)}$ = Diluted SF_6 (or tracer gas) concentration measured in a spiked sample in stack gas

$SF_{6(native)}$ = SF_6 (or tracer gas) concentration measured in a native stack gas sample

Unspike = Native concentration of analytes in unspiked samples

Spike$_{dir}$ = Concentration of the analyte in the spike standard measured by filling the FTIR cell directly

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Dilution Factor Ratio

(example calculation for Trial #2, where applicable)

$$DF \; Ratio = \frac{SF_{6(dir)}}{SF_{6(spk)}} = \frac{SF_{6(dir)}}{(SF_{6(spk+native)} - SF_{6(native)})} \; OR \; \frac{CO_{2(native)}}{CO_{2(native)} - CO_{2(spk+native)}} \geq 10$$

DF Ratio = $\dfrac{5.29 \quad ppbvw}{5.2869 \quad - \quad 4.7885 \quad ppbvw}$ =

Spike Ratio = 10.6 : 1 ≥ 10

Method 320 Equation 4 [Method 321 Equation 2], Excepted Concentration of the Spiked Samples

Ideal Spike Yield
(example calculation for Trial #2 (HCHO), where applicable)

$$CS = DF \times Spike_{dir} + Unspike\,(1 - DF)$$

CS = 0.0943 X 56205.0230 ppbvw + -92.6490 ppbvw X (1 - 0.0943) = 5,214.4066 ppbvw

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Method 320 Spiked vs Expected

(example calculation for Trial #2 (HCHO), where applicable)

$$Spiked \; vs \; Expected = \frac{Actual \; Spike \; Yield}{Ideal \; Spike \; Yield} \times 100$$

% Recovery = $\dfrac{4,307.1046 \quad ppbvw}{5,214.4066 \quad ppbvw}$ x 100 = 82.600 %

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

Method 320 Equation 3, Dilution Factor (DF)

(example calculation for Trial #3, where applicable)

$$DF = \frac{SF_{6\,(spk)}}{SF_{6\,(dir)}} = \frac{\left(SF_{6\,(spk+native)} - SF_{6\,(native)}\right)}{SF_{6\,(dir)}} \; OR \; \frac{\left(CO_{2\,(native)} - CO_{2\,(spk+native)}\right)}{CO_{2\,(native)}}$$

DF (CO_2) = $\dfrac{5.3075 \;-\; 4.7688 \quad ppbvw}{5.31 \quad ppbvw}$ =

0.1015

Test Method 320, Section 9.0 Quality Control

Where,

$SF_{6\,(dir)}$ = SF_6 (or tracer gas) concentration measured directly in undiluted spike gas

$SF_{6\,(spk)}$ = Diluted SF_6 (or tracer gas) concentration measured in a spiked sample

$SF_{6\,(spk)}$ = $SF_{6\,(spk+native)}$ - $SF_{6\,(native)}$

$SF_{6\,(spk+native)}$ = Diluted SF_6 (or tracer gas) concentration measured in a spiked sample in stack gas

$SF_{6\,(native)}$ = SF_6 (or tracer gas) concentration measured in a native stack gas sample

Unspike = Native concentration of analytes in unspiked samples

Spike$_{dir}$ = Concentration of the analyte in the spike standard measured by filling the FTIR cell directly

Dilution Factor Ratio

(example calculation for Trial #3, where applicable)

$$DF\;Ratio = \frac{SF_{6\,(dir)}}{SF_{6\,(spk)}} = \frac{SF_{6\,(dir)}}{\left(SF_{6\,(spk+native)} - SF_{6\,(native)}\right)} \; OR \; \frac{CO_{2\,(native)}}{CO_{2\,(native)} - CO_{2\,(spk+native)}} \geq 10$$

DF Ratio   = $\dfrac{5.31 \quad ppbvw}{5.3075 \;-\; 4.7688 \quad ppbvw}$ =

Spike Ratio   =   9.9   : 1

Method 320 Equation 4 [Method 321 Equation 2], Excepted Concentration of the Spiked Samples

Ideal Spike Yield   *(example calculation for Trial #3 (HCHO), where applicable)*

$$CS = DF \times Spike_{dir} + Unspike\,(1 - DF)$$

CS =   0.1015   X   56205.0230 ppbvw   +   -99.8093   ppbvw   X $\left[1 - 0.1015 \right]$ =   5,614.7605 ppbvw

Method 320 Spiked vs Expected

$$Spiked\;vs\;Expected = \frac{Actual\;Spike\;Yield}{Ideal\;Spike\;Yield} \times 100$$

(example calculation for Trial #3 (HCHO), where applicable)

% Recovery   = $\dfrac{4,311.3874 \quad ppbvw}{5,614.7605 \quad ppbvw}$ x 100 =   76.787 %

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

TEST RESULTS AND CALCULATIONS

PM
Emissions Data

METHOD 5 (FRONT) AND 202 (BACK) - RESULTS

Plant Name	Indeck Niles Energy Center
Sampling Location	CTG2
Project #	kie-22-niles.mi-start#1

Historical Data	CTG2_PM-1	CTG2_PM-2	CTG2_PM-3	CTG2_PM-4	Average	Units
Run Start Time	09:20	16:45	04:53	08:16		hh:mm
Run Stop Time	16:20	02:13	08:02	11:31		hh:mm
Test Date	06/21/22	06/21/22	06/22/22	06/22/22		mm/dd/yy
Load	BaseDB	BaseDB	BaseDB	BaseDB		% or w/DB
Meter Calibration Factor	0.975	0.975	0.975	0.975		
Pitot Tube Coefficient	0.8330	0.8330	0.8330	0.8330		
Average Nozzle Diameter	0.250	0.250	0.250	0.250		in
Stack Test Data	CTG2_PM-1	CTG2_PM-2	CTG2_PM-3	CTG2_PM-4	Average	Units
Initial Meter Volume	72.260	250.910	452.970	648.570		ft³
Final Meter Volume	249.210	441.510	649.000	836.030		ft³
Total Meter Volume	176.950	190.600	196.030	187.460	187.760	ft³
Total Sampling Time	180.00	180.00	180.00	180.00	180.00	min
Average Meter Temperature	75.25	71.08	72.96	70.96	72.56	°F
Average Stack Temperature	194.08	181.67	190.50	193.17	189.85	°F
Barometric Pressure	29.30	29.18	29.22	29.23	29.23	in Hg
Stack Static Pressure	-0.78	-0.78	-0.78	-0.78	-0.78	in H₂O
Absolute Stack Pressure	29.24	29.12	29.16	29.17	29.18	in Hg
Average Orifice Pressure Drop	3.19	3.46	3.59	3.45	3.42	in H₂O
Absolute Meter Pressure	29.43	29.31	29.35	29.36	29.37	in Hg
Avg Square Root Pitot Pressure	1.05	1.10	1.13	1.09	1.09	√(in H₂O)
Moisture Content Data	CTG2_PM-1	CTG2_PM-2	CTG2_PM-3	CTG2_PM-4	Average	Units
Impinger Water Weight Gain	397.60	391.10	405.30	367.80	390.45	g
Silica Gel Weight Gain	50.90	47.70	52.90	47.20	49.68	g
Total Water Volume Collected	449.31	439.59	459.03	415.75	440.92	ml
Standard Water Vapor Volume	21.15	20.69	21.60	19.57	20.75	scf
Standard Meter Volume	168.0	181.8	186.6	179.1	178.9	dscf
Standard Metric Meter Volume	4.8	5.1	5.3	5.1	5.1	dscm
Calculated Stack Moisture	11.18	10.22	10.38	9.85	10.41	%
Saturated Stack Moisture	70.81	54.37	65.79	69.62	65.15	%
Reported Stack Moisture Content	11.18	10.22	10.38	9.85	10.41	%
Gas Analysis Data	CTG2_PM-1	CTG2_PM-2	CTG2_PM-3	CTG2_PM-4	Average	Units
Carbon Dioxide Content	5.4	5.4	5.4	5.1	5.3	%
Oxygen Content	11.8	11.8	11.8	12.0	11.9	%
Carbon Monoxide Content	0.0	0.0	0.0	0.0	0.0	ppm
Nitrogen Content	82.8	82.8	82.8	82.9	82.8	%
Stack Dry Molecular Weight	29.34	29.34	29.34	29.30	29.33	lb/lb-mole
Stack Wet Molecular Weight	28.07	28.18	28.16	28.18	28.15	lb/lb-mole
Calculated Fuel Factor	1.685	1.685	1.685	1.745	1.700	
Fuel F-Factor	8647.63	8647.63	8647.63	8647.63	8647.63	dscf/MMBtu
Percent Excess Air	117.3	117.3	117.3	121.4	118.3	%

METHOD 5 (FRONT) AND 202 (BACK) - RESULTS

Plant Name	Indeck Niles Energy Center
Sampling Location	CTG2
Project #	kie-22-niles.mi-start#1

Volumetric Flow Rate Data	CTG2_PM-1	CTG2_PM-2	CTG2_PM-3	CTG2_PM-4	Average	Units
Average Stack Gas Velocity	66.99	69.36	71.32	69.50	69.29	ft/sec
Stack Cross-Sectional Area	368.70	368.70	368.70	368.70	368.70	ft^2
Actual Stack Flow Rate	1,482,034	1,534,283	1,577,785	1,537,419	1,532,880	acfm
Wet Standard Stack Flow Rate	70,156	73,731	74,895	72,706	72,872	wkscfh
Dry Standard Stack Flow Rate	62,312,410	66,195,904	67,123,014	65,544,860	65,294,047	dscfh
Percent of Isokinetic Rate	97.3	99.0	100.2	99.4	99.0	%
Gravimetric Analysis	CTG2_PM-1	CTG2_PM-2	CTG2_PM-3	CTG2_PM-4	Average	Units
NH_4OH Correction	0.0000	0.0000	0.0000	0.0000	0.0000	ml
NH_4OH Correction	0.0000	0.0000	0.0000	0.0000	0.0000	mg
Emission Rate Data	CTG2_PM-1	CTG2_PM-2	CTG2_PM-3	CTG2_PM-4	Average	Units
Total $PM_{10}/PM_{2.5}$ Mass	5.92	4.35	2.24	4.09	4.15	mg
Total $PM_{10}/PM_{2.5}$ Concentration	3.52E-05	2.39E-05	1.20E-05	2.28E-05	2.35E-05	g/dscf
	5.44E-04	3.70E-04	1.85E-04	3.52E-04	3.63E-04	gr/dscf
Total $PM_{10}/PM_{2.5}$ Emission Rate	2.20	1.59	0.81	1.50	1.52	kg/hr
	4.84	3.49	1.78	3.30	3.35	lb/hr
	21.21	15.31	7.79	14.46	14.69	tpy
	0.0015	0.0010	0.0005	0.0010	0.0010	lb/MMBtu
Filterable PM Mass	2.52	1.55	1.55	1.44	1.77	mg
Filterable PM Concentration	1.50E-05	8.54E-06	8.33E-06	8.04E-06	9.98E-06	g/dscf
	2.32E-04	1.32E-04	1.29E-04	1.24E-04	1.54E-04	gr/dscf
Filterable PM Emission Rate	0.94	0.57	0.56	0.53	0.65	kg/hr
	2.06	1.25	1.23	1.16	1.43	lb/hr
	9.03	5.46	5.40	5.09	6.25	tpy
	0.0007	0.0004	0.0004	0.0004	0.0004	lb/MMBtu
Condensable PM Mass	3.40	2.80	0.69	2.65	2.38	mg
Condensable PM Concentration	2.02E-05	1.54E-05	3.69E-06	1.48E-05	1.35E-05	g/dscf
	3.12E-04	2.38E-04	5.69E-05	2.28E-04	2.09E-04	gr/dscf
Condensable PM Emission Rate	1.26	1.02	0.25	0.97	0.87	kg/hr
	2.78	2.25	0.55	2.14	1.93	lb/hr
	12.18	9.85	2.39	9.36	8.44	tpy
	0.0009	0.0007	0.0002	0.0007	0.0006	lb/MMBtu

- %CO = carbon monoxide concentration (%)
- $\%CO_2$ = carbon dioxide concentration (%)
- $\%N_2$ = nitrogen concentration (%)
- $\%O_2$ = oxygen concentration (%)
- $\%O_{2,wet}$ = Oxygen content of gas stream, % by volume of wet gas. (Note: The oxygen percentage used in Method 201A, Equation 3 is on a wet gas basis. That means that since oxygen is typically measured on a dry gas basis, the measured percent O2 must be multiplied by the quantity $(1 - B_{ws})$ to convert to the actual volume fraction. Therefore, $\%O_{2,wet} = (1 - B_{ws}) * \%O_{2,dry}$)

- $(\%EA)_{avg}$ = average excess air (%)
- $(F_o)_{avg}$ = average calculated fuel factor
- $[(\Delta p)^{0.5}]_{avg}$ = Average of square roots of the velocity pressures measured during the preliminary traverse, inches W.C.
- μ = Gas viscosity, micropoise
- 12.0 = Constant calculated as 60 percent of 20.5 square inch cross-sectional area of combined cyclone head, square inches
- 17.03 = mg/milliequivalents for ammonium ion
- 22.4 = liters of ideal gas per lb-mol of substance at $0^{\circ}C$ and 1 atm (ref. Civil Engineering Reference Manual, 7th ed. - Michael R. Lindeburg)
- 24.04 = liters of ideal gas per lb-mol of substance at $20^{\circ}C$ and 1 atm (ref. Civil Engineering Reference Manual, 7th ed. - Michael R. Lindeburg)
- 5.02×10^4 = constant derived from the molecular weight and correcting standard temperature and pressure (ref. Bay Area Air Quality Management District, Source Test Procedure ST-1B, Ammonia Integrated Sampling, Adopted January 20, 1982, Regulation 7-303)
- A = distance upstream (in.)
- A_D = stack diameters upstream (dia.)
- An = Area of nozzle, square feet
- A_s = area of stack (ft^2)
- B = distance downstream (in.)
- B_D = stack diameters downstream (dia.)
- b_f = Average blockage factor calculated in Equation 26, dimensionless
- B_{wm} = meter moisture content (%)
- B_{ws} = stack moisture content (%)
- C = Cunningham correction factor for particle diameter, Dp, and calculated using the actual stack gas temperature, dimensionless
- C_1 = -150.3162 (micropoise)
- C_2 = 18.0614 (micropoise/$K^{0.5}$) = 13.4622 (micropoise/$R^{0.5}$)
- C_3 = 1.19183×10^6 (micropoise/K^2) = 3.86153×10^6 (micropoise/R^2)
- C_4 = 0.591123 (micropoise)
- C_5 = 91.9723 (micropoise)
- C_6 = 4.91705×10^{-5} (micropoise/K^2) = 1.51761×10^{-5} (micropoise/R^2)
- C_a = Acetone blank concentration, mg/mg
- C_b = Concentration of NH3 ion in the back half of train (breakthrough)
- C_f = Concentration of NH3 ion in the front half of train (main catch)
- C_{fPM10} = Conc. of filterable PM_{10}, gr/dscf
- $C_{fPM2.5}$ = Conc. of filterable $PM_{2.5}$, gr/dscf
- C_k = K Factor Constant, 849.8

Nomenclature

- C_n = nozzle diameter constant, 0.03575
- C_p' = Coefficient for the pitot used in the preliminary traverse, dimensionless
- C_p = Pitot coefficient for the combined cyclone pitot, dimensionless
- C_{cpm} = Concentration of the condensable PM in the stack gas, dry basis, corrected to standard conditions, milligrams/dry standard cubic foot.
- C_r = Re-estimated Cunningham correction factor for particle diameter equivalent to the actual cut size diameter and calculated using the actual stack gas temperature, dimensionless
- D_{50} = Particle cut diameter, micrometers
- $D_{50(N+1)}$ = D_{50} value for cyclone IV calculated during the N+1 iterative step, micrometers
- D_{50-1} = Re-calculated particle cut diameters based on re-estimated C_r, micrometers
- D_{50LL} = Cut diameter for cyclone I corresponding to the 2.25 micrometer cut diameter for cyclone IV, micrometer
- D_{50N} = D_{50} value for cyclone IV calculated during the Nth iterative step, micrometers
- D_{50T} = Cyclone I cut diameter corresponding to the middle of the overlap zone shown in Method 201A, Figure 10 of Section 17, micrometers
- D_e = equivalent stack diameter (in.)
- $\Delta H@$ = ΔH @ 0.75 scfm (in. H2O)
- ΔH_{avg} = average orifice pressure (in. H_2O)
- D_n = Inner diameter of sampling nozzle mounted on Cyclone I, inches
- D_{na} = actual nozzle diameter (in.)
- D_p = Physical particle size, micrometers
- Δp = velocity head (in. H_2O)
- Δp_1 = velocity head at first current traverse point (in. H_2O)
- $\Delta p'_1$ = velocity head at first preliminary traverse point (in. H_2O)
- Δp_{avg} = average pitot tube differential pressure (in. H_2O)
- Δp_n = velocity head at subsequent current traverse point (in. H_2O)
- Δp_{RM2} = method 2 velocity head (in. H_2O)
- D_s = diameter of stack (in.)
- F_d = fuel f-factor (dscf/MMBtu)
- f_{O2} = stack gas fraction of O_2, by volume, dry basis
- I = Percent isokinetic sampling, dimensionless
- K_1 = standard volume correction, $17.65°R/in.$ Hg
- K_4 = isokinetic conversion constant, $0.0945 min \cdot in.Hg/sec \cdot °R$
- K_5 = water mass to std water vapor, $0.04715 ft^3/g$
- K_p = 85.49, $((ft/sec)/(pounds/mole -°R))$
- L = length of stack (in.)
- L_{fw} = distance to far wall of stack (in.)
- L_{nw} = distance to near wall of stack (in.) [reference]
- $m_{\#x}$ = weight measurements (g)
- M_1 = Milligrams of PM collected on the filter, less than or equal to 2.5 micrometers
- M_2 = Milligrams of PM recovered from Container #2 (acetone blank corrected), greater than 10 micrometers
- M_3 = Milligrams of PM recovered from Container #3 (acetone blank corrected), less than or equal to 10 and greater than 2.5 micrometers
- M_4 = Milligrams of PM recovered from Container #4 (acetone blank corrected), less than or equal to 2.5 micrometers

Nomenclature

- m_a = Mass of residue of acetone after evaporation, mg
- m_c = Mass of the NH4+ added to sample to form ammonium sulfate, mg
- m_{cpm} = Mass of the total condensable PM, mg
- M_d = Molecular weight of dry gas, pounds/pound mole
- m_{fb} = Mass of total CPM in field train recovery blank, mg
- m_{fx} = final weight, avg of last two measurements (g)
- mg = Milligram
- mg/L = Milligram per liter
- m_i = Mass of inorganic CPM, mg
- m_{ib} = Mass of inorganic CPM in field train recovery blank, mg
- M_n = total particulates (mg)
- m_o = Mass of organic CPM, mg
- m_{ob} = Mass of organic CPM in field train blank, mg
- m_r = Mass of dried sample from inorganic fraction, mg
- m_{tx} = tare weight (g)
- MW = molecular weight (lb/lb-mole)
- M_w = Molecular weight of wet gas, pounds/pound mole
- N = Normality of ammonium hydroxide titrant
- N_a = null angle (deg.)
- N_{re} = Reynolds number, dimensionless
- N_{tp} = Number of iterative steps or total traverse points
- $P_b = P_{bar}$ = barometric pressure (in. Hg)
- P_{bar} = barometric pressure (in. Hg)
- ppmCO = carbon monoxide concentration (ppm)
- ppmv = Parts per million by volume
- ppmw = Parts per million by weight
- P_s = absolute stack pressure (in. Hg)
- P_{static} = static pressure (in. H_2O)
- P_{std} = standard pressure, 29.92 in. Hg
- Θ = total sampling time (min)
- Q_{aw} = average stack wet flow rate (ascf/min)
- Q_I = Sampling rate for cyclone I to achieve specified D_{50}
- Q_m = estimated orifice flow rate, 0.750 acfm, else Vm/Q from previous run
- Q_s = Sampling rate for cyclone I to achieve specified D_{50}
- $Q_{s(std)}$ = total cyclone flow rate at standard conditions (dscf/min)
- Q_{sd} = dry standard stack flow rate (dscfm)
- Q_{sST} = Dry gas sampling rate through the sampling assembly, dscfm
- Q_{sw} = wet standard stack flow rate (ascfm)
- R_{max} = Nozzle/stack velocity ratio parameter, dimensionless
- R_{min} = Nozzle/stack velocity ratio parameter, dimensionless
- t_1 = Sampling time at point 1, min
- t_m = average gas meter temperature (°F)
- t_m = average meter temperature (°F)
- T_m = Meter box and orifice gas temperature, °R
- t_n = Sampling time at point n, min

Nomenclature

- t_r = Total projected run time, min
- T_s = Absolute stack gas temperature, $^\circ$R
- T_{std} = standard temperature, 68°F, 528°R
- T_u = absolute temperature offset, 460°R
- V_a = Volume of acetone blank, ml
- V_{aw} = Volume of acetone used in sample recovery wash, ml
- V_b = Volume of aliquot taken for IC analysis, ml
- V_c = Quantity of water captured in impingers and silica gel, ml
- V_f = final impinger volume (ml)
- V_i = initial impinger volume (ml)
- V_{ic} = Volume of impinger contents sample, ml
- V_m = Dry gas meter volume sampled, acf
- $V_{m(std)}$ = standard meter volume (dscf)
- v_{max} = Maximum gas velocity calculated from Equations 18 or 19, ft/sec
- v_{max} = maximum nozzle velocity (ft/sec)
- V_{mf} = final dry gas meter reading (dcf)
- V_{mi} = initial dry gas meter reading (dcf)
- v_{min} = Minimum gas velocity calculated from Method 201A, Equations 16 or 17, ft/sec
- V_{ms} = Dry gas meter volume sampled, corrected to standard conditions, dscf
- v_n = Sample gas velocity in the nozzle, ft/sec
- v_{org} = organics wash volume (ml)
- V_p = Volume of water added during train purge
- v_s = average stack gas velocity (ft/sec)
- v_{sl} = local velocity (ft/sec)
- V_t = total impinger volume (ml) = ;$(V_f\text{-}V_i)$
- V_t = Volume of NH4OH titrant, ml
- $V_{w(std)}$ = volume of water vapor in gas sample at standard conditions (scf)
- v_x = blank volume (ml)
- W = width of stack (in.)
- $W_{2,3,4}$ = Weight of PM recovered from Containers #2, #3, and #4, mg
- W_a = Weight of blank residue in acetone used to recover samples, mg
- W_f = final impinger weight (g)
- W_i = initial impinger weight (g)
- W_t = total impinger weight (g) = ;$(W_f\text{-}W_i)$
- w_x = blank weight of solids (g)
- Y = meter calibration factor (a.k.a gamma)
- Z = Ratio between estimated cyclone IV D_{50} values, dimensionless
- γ = Dry gas meter gamma value, dimensionless
- ΔH = Meter box orifice pressure drop, inches W.C.
- ΔH@ = Pressure drop across orifice at flow rate of 0.75 scfm at standard conditions, inches W.C. (Note: Specific to each orifice and meter box.)
- Δp_1 = Velocity pressure measured at point 1, inches W.C.
- Δp_{avg} = Average velocity pressure, inches W.C.
- Δp_m = Observed velocity pressure using S-type pitot tube in preliminary traverse, inches W.C.
- Δp_{max} = Maximum velocity pressure, inches W.C.

Nomenclature

- Δp_{min} = Minimum velocity pressure, inches W.C.
- Δp_n = Velocity pressure measured at point n during the test run, inches W.C.
- Δp_s = Velocity pressure calculated in Method 201a, Equation 25, inches W.C.
- Δp_{s1} = Velocity pressure adjusted for combined cyclone pitot tube, inches W.C.
- Δp_{s2} = Velocity pressure corrected for blockage, inches W.C.
- θ = Total run time, min
- ρ_a = Density of acetone, mg/ml (see label on bottle)
- Σ_n = total number of sampling points

EXAMPLE CALCULATIONS (Reference Method 1 - Circular Stack)

Diameter of Stack (in.)

$$D(in.) = L_{fw} - L_{inr}$$

D (in.) = 266.00 in. - 6.00 in. = 260.00 in.

Stack Diameters Downstream

$$B_D(dia.) = \frac{B}{D}$$

B_D (dia.) = $\dfrac{662.38 \text{ in.}}{260.00 \text{ in.}}$ = 2.55 diameters

Area of Stack (ft²)

$$A_s(ft^2) = \pi \times \left(\frac{D}{2 \times 12}\right)^2$$

A_s (ft²) = 3.14 x ($\dfrac{260.00 \text{ in.}}{2 \times 12 \text{in./ft}}$)² = 368.70 ft²

Stack Diameters Upstream

$$A_D(dia.) = \frac{A}{D}$$

A_D (dia.) = $\dfrac{132.00 \text{ in.}}{260.00 \text{ in.}}$ = 0.51 diameters

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (Reference Method 3a) [Values from Run 1 test]

Carbon Monoxide Concentration (%)

$$\%CO = \frac{ppmCO}{10,000}$$

%CO (%) = $\dfrac{0.00 \quad ppm}{10,000 \ ppm/\%}$ = 0.0000 %

Nitrogen Concentration (%)

$$\%N_2 = 100 - \%CO_2 - \%O_2 - \%CO$$

%N₂ (%) = 100 - 5.40 % - 11.80 % - 0.00 / 10,000 % = 82.8 %

Stack Dry Molecular Weight (lb/lb-mole)

$$M_d(lb/lb-mol) = \sum\left(\frac{MW_{comp}}{100} \times \%component\right)$$

M_d (lb/lb-mol) = ($\dfrac{44 \ lb/lb-mol}{100}$ x 5.40 %) +

($\dfrac{32 \ lb/lb-mol}{100}$ x 11.80 %) + ($\dfrac{28 \ lb/lb-mol}{100}$ x [$\dfrac{0.00}{10,000}$ + 82.80]) = $\dfrac{29.34 \ lb}{lb-mol}$

Stack Wet Molecular Weight (lb/lb-mole)

$$M_S(lb/lb-mol) = \left[M_d \times \left(1 - \frac{B_{WS}}{100}\right)\right] + \left[MW_{H_2O} \times \frac{B_{WS}}{100}\right]$$

M_S (lb/lb-mol) = { $\dfrac{29.34 \ lb}{lb-mol}$ x (1 - $\dfrac{11.18 \ \%}{100}$) } + { $\dfrac{18 \ lb}{lb-mol}$ x $\dfrac{11.18 \ \%}{100}$ } = $\dfrac{28.07 \ lb}{lb-mol}$

Average Calculated Fuel Factor (F₀)

$$F_{o(avg)} = \frac{\left[20.9 - (\%O_2)_{avg} - (0.5 \times (\%CO)_{avg})\right]}{(\%CO_2)_{avg} + (\%CO)_{avg}}$$

$F_{o(avg)}$ = $\dfrac{20.9\% - 11.80 \ \% - (0.5 \ x \ 0.000 \ \%)}{5.40 \ \% \ + \ 0.000 \ \%}$ = 1.685

Average Excess Air (%)

$$\%EA_{avg}(\%) = \frac{100 \times \left[(\%O_2)_{avg} - (0.5 \times (\%CO)_{avg})\right]}{(0.264 \times (N_2)_{avg}) - \left[(\%O_2)_{avg} - (0.5 \times (\%CO)_{avg})\right]}$$

$(\%EA)_{AVG}$ = $\dfrac{100 \ x \ \{ \ 11.80 \ \% \ - \ (0.5 \ x \ 0.000 \ \% \ ) \ \}}{(\ 0.264 \ x \ 82.80 \ \%) - \{ \ 11.80 \ \% \ - \ (0.5 \ x \ 0.000 \ \%) \}}$ = 117.31 %

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (Reference Method 2) [Values from Run 1 test]

Absolute Stack Pressure (in. Hg)

$$P_S (in.Hg) = P_b + \frac{P_{static}}{13.6}$$

P_s (in. Hg) = 29.30 in. Hg + $\dfrac{-0.78 \text{ in. H}_2\text{O}}{13.6 \text{ in. H}_2\text{O/in. Hg}}$ = 29.24 in. Hg

Average Stack Gas Velocity (ft/sec)

$$v_s (ft/\sec) = K_p \times C_p \times \left(\sqrt{\Delta p}\right)_{avg} \times \sqrt{\frac{(t_s)_{avg} + T_u}{P_s \times M_s}}$$

v_{sl} (ft/sec) =

$\left(\dfrac{85.49 \text{ ft}}{\sec} \dfrac{(\text{lb/lb-mol})(\text{in. Hg})}{(^\circ\text{R})(\text{in. H}_2\text{O})}\right)^{1/2} \times$ 0.83 $\times$ 1.05 in.$\text{H}_2\text{O}^{1/2}$ $\times \sqrt{\dfrac{194.08 + 460\ ^\circ\text{R}}{29.24 \text{ in. Hg} \times 28.07 \text{ lb/lb-mol}}}$ = $\dfrac{66.9 \text{ ft}}{\sec}$

Average Stack Dry Standard Flow Rate (dscfh)

$$Q_{sd}(dscfh) = \frac{60 \times 60 \times \left(1 - \frac{B_{ws}}{100}\right) \times v_s \times A_s \times T_{std} \times P_s}{(t_s + T_u) \times P_{std}}$$

Q_{sd} (dscf/hr) = $\dfrac{3600 \text{ sec}}{\text{hr}} \times (1 - \dfrac{11.18 \text{ \%}}{100}) \times \dfrac{66.99 \text{ ft}}{\sec} \times$ 368.70 ft^2 $\times$

$\dfrac{68.00 + 460\ ^\circ\text{R}}{194.08 + 460\ ^\circ\text{R}} \times \dfrac{29.24 \text{ in. Hg}}{29.92 \text{ in. Hg}} = \dfrac{62,312,409.78 \text{ dscf}}{\text{hr}}$

Average Stack Wet Flow Rate (acfm)

$$Q_{aw}(acfm) = 60 \times v_s \times A_s$$

Q_{aw} (acf/min) = $\dfrac{60 \text{ sec}}{\text{min}} \times \dfrac{66.99 \text{ ft}}{\sec} \times$ 368.70 ft^2 = $\dfrac{1,482,034.33 \text{ acf}}{\text{min}}$

Average Stack Wet Standard Flow Rate (ascfh)

$$Q_{sw}(ascfh) = \frac{60 \times Q_{aw} \times T_{std} \times P_s}{(t_s + T_u) \times P_{std}}$$

Q_{sw} (ascf/hr) = $\dfrac{60 \text{ min}}{\text{hr}} \times \dfrac{1,482,034.33 \text{ acf}}{\text{min}} \times$

$\dfrac{68.00 + 460\ ^\circ\text{R}}{194.08 + 460\ ^\circ\text{R}} \times \dfrac{29.24 \text{ in. Hg}}{29.92 \text{ in. Hg}} = \dfrac{70,156,101.51 \text{ ascf}}{\text{hr}}$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (Reference Method 4) [Values from Run 1 test]

Water Volume Weighed (scf)

$$V_{wsg\,(std)}(scf) = W_t \times K_s$$

$V_{wsg(std)} = $ 448.50 g x 0.04715 ft^3/g = 21.147 scf

Standard Meter Volume (dscf)

$$V_{m(std)}(dscf) = \frac{K_1 \times Y \times V_m \times \left(P_b + \frac{\Delta H_{avg}}{13.6}\right)}{(t_m)_{avg} + T_u}$$

$V_{m(std)} = \dfrac{\dfrac{17.65\ °R}{in.\ Hg} \times 0.98 \times 176.95\ dcf \times \left(29.30\ in.\ Hg + \dfrac{3.19\ in.\ H_2O}{13.6\ in.\ H_2O\ /\ in.\ Hg}\right)}{75.25\ °F + 460\ °R} = $ 168.00 dscf

Calculated Moisture Content (%)

$$B_{ws(calc)}(\%) = 100 \times \frac{V_{wsg\,(std)}}{V_{wsg\,(std)} + V_{m(std)}}$$

$B_{ws(calc)} = 100 \times \dfrac{21.15\ dscf}{21.15\ dscf + 168.00\ dscf} = $ 11.18 %

Saturated Moisture Content (%)

$$B_{ws(svp)}(\%) = 100 \times \frac{10^{\,6.691 - \frac{3144}{t_{s(avg)} + 390.86}}}{P_b + \frac{P_{static}}{13.6}} \le 100$$

$B_{ws(svp)} = 100 \times \dfrac{10^{\left(6.691 - \frac{3144}{194.08\ °F + 390.86}\right)}}{29.30\ in.\ Hg + \dfrac{-0.78\ in.\ H_2O}{13.6\ in.\ H_2O\ /\ in.\ Hg}} \le 100 = $ 70.81 %

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (Isokinetic Sampling) [Values from Run 1 test]

Desired Orifice (in. H₂O) (first point)

$$\Delta H_d (in.H_2O) = K \times \Delta p$$

ΔH_d (in. H₂O) =   2.83   x

0.83   in. H₂O =   2.35   in. H₂O

Absolute Meter Pressure (in. Hg)

$$P_m (in.Hg) = P_b + \frac{\Delta H @}{13.6}$$

P_m (in. Hg) = 29.30   in. Hg + $\dfrac{1.83 \quad \text{in. H}_2\text{O}}{13.6 \text{ in. H}_2\text{O/in. Hg}}$ =   29.43   in. Hg

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Recommended Nozzle Diameter (in.)

$$D_m (in.) = \sqrt{\frac{C_n \times Q_m \times P_m}{(t_m + T_u) \times C_p} \times \left(\frac{1 - \frac{B_{wm}}{100}}{1 - \frac{B_{ws}}{100}}\right) \times \sqrt{(t_s + T_u) \times \left[\frac{M_d \times \left(1 - \frac{B_{ws}}{100}\right) + \left(18 \times \frac{B_{ws}}{100}\right)}{P_s \times \Delta p_{avg}}\right]}}$$

D_{ni} (in.) = $\sqrt{\dfrac{\dfrac{0.03575 \text{ (lb-mole·°R·in. H}_2\text{O)}^{1/2}\text{·min·in.}^2}{\text{acf·in. Hg}^{3/4}\text{·lb}^{1/2}} \times 0.75 \text{ acf} \times 29.43 \text{ in. Hg} \times \left(\dfrac{1 - \dfrac{0.00 \quad \%}{100}}{1 - \dfrac{11.18 \quad \%}{100}}\right) \times}{\left[75.25 \quad °\text{F} + 460°\text{R}\right] \times 0.83}}$

$\sqrt{\quad (194.08 \quad °\text{F} + 460°\text{R}) \times \dfrac{\dfrac{29.34 \text{ lb}}{\text{lb-mole}} \times (1 - \dfrac{11.18 \quad \%}{100}) + (\dfrac{18 \text{ lb}}{\text{lb-mol}} \times \dfrac{11.18 \%}{100})}{29.24 \text{ in. Hg} \times 1.05 \text{ in. H}_2\text{O}}}$ =   0.208   in.

ΔP to ΔH Isokinetic Factor

$$K = C_k \times C_p^2 \times \Delta H @ \times D_{na}^4 \times \left[\frac{M_d \times \left(1 - \frac{B_{wm}}{100}\right) + \left(18 \times \frac{B_{wm}}{100}\right)}{M_d \times \left(1 - \frac{B_{ws}}{100}\right) + \left(18 \times \frac{B_{ws}}{100}\right)}\right] \times \left(\frac{1 - \frac{B_{ws}}{100}}{1 - \frac{B_{wm}}{100}}\right)^2 \times \left(\frac{t_m + T_u}{ts + T_u}\right) \times \frac{P_s}{P_m}$$

K = $\dfrac{849.8}{\text{in. H}_2\text{O·in.}^4}$ x 0.83 ² x 1.83 in. H₂O x 0.25 ⁴ x $\left(\dfrac{1 - \dfrac{11.18 \quad \%}{100}}{1 - \dfrac{0.00 \quad \%}{100}}\right)^2$ x $\dfrac{75.25 \quad °\text{F} + 460°\text{R}}{194.08 \quad °\text{F} + 460°\text{R}}$) x

($\dfrac{\dfrac{29.34 \text{ lb}}{\text{lb/mole}} \times (1 - \dfrac{0.00 \quad \%}{100}) + (\dfrac{18 \text{ lb}}{\text{lb-mol}} \times \dfrac{0.00 \quad \%}{100})}{\dfrac{29.34 \text{ lb}}{\text{lb/mole}} \times (1 - \dfrac{11.18 \quad \%}{100}) + (\dfrac{18 \text{ lb}}{\text{lb-mol}} \times \dfrac{11.18 \quad \%}{100})}$ x $\dfrac{29.24 \text{ in. Hg}}{29.43 \text{ in. Hg}}$ =   2.83

Percent Isokinetic (%)   (first point)

$$I (\%) = \frac{K_4 \times \left((t_s)_{avg} + T_u\right) \times V_{m(std)}}{\left(\Theta \times \left(v_{s(l)}\right)_{avg} \times P_s \times \pi \times \left(\frac{D_{na}}{2} \times \frac{1}{12}\right)^2\right) \times \left(1 - \frac{B_{ws}}{100}\right)}$$

I (%) = $\dfrac{\dfrac{0.0945 \text{ min·in. Hg}}{\text{sec·°R}} \times (191.00 \quad °\text{F} + 460 °\text{R}) \times 5.74 \text{ dscf}}{7.50 \text{ min} \times \dfrac{57.78 \text{ ft}}{\text{sec}} \times 29.24 \text{ in. Hg} \times 3.14 \times \left(\dfrac{0.25 \text{ in.}}{2} \times \dfrac{\text{ft.}}{12 \text{ in.}}\right)^2 \times \left(1 - \dfrac{11.18 \quad \%}{100}\right)}$ =   91.81   %

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (Isokinetic Sampling) [Values from Run 1 test]

Cumulative Percent Isokinetic (%)   (weighted average of all points)
Using Method 5, Eq 5-8 to determine intermediate isokinetics at each point, weighted averaging
of the cumulative isokinetics is necessary since all points are not equal, and determined by using
the dry standard meter volume collected at each point to weight the cumulative average. Intermediate isokinetics and dry
standard meter volumes are found at each point. At each point the cumulative sum is found of each value and the quotient of the
two used to determine the cumulative isokinetics for each residual point (n).

$$I(\%) = \sum_{1-n} \frac{\left[I(\%) \times V_{m(std)}\right]_{1-n}}{V_{m(std)_{1-n}}}$$

Pt	In (%)	x	Vm(std)n	=	I (%)n	Σ(I (%)n)	/	Σ(Vm(std)n)	=	I (%)
A-1	91.81	x	5.741	=	527.11	527.11	/	5.74	=	91.8
A-2	95.03	x	5.991	=	569.34	1096.45	/	11.73	=	93.5
A-3	96.46	x	5.996	=	578.36	1674.81	/	17.73	=	94.5
A-4	95.50	x	6.379	=	609.22	2284.03	/	24.11	=	94.7
A-5	95.42	x	6.545	=	624.52	2908.54	/	30.65	=	94.9
A-6	105.38	x	6.862	=	723.18	3631.72	/	37.51	=	96.8
B-1	104.48	x	6.787	=	709.13	4340.85	/	44.30	=	98.0
B-2	102.14	x	6.960	=	710.90	5051.75	/	51.26	=	98.5
B-3	90.84	x	7.088	=	643.87	5695.61	/	58.35	=	97.6
B-4	94.51	x	7.085	=	669.56	6365.17	/	65.43	=	97.3
B-5	97.94	x	7.635	=	747.80	7112.97	/	73.07	=	97.3
B-6	96.16	x	7.785	=	748.62	7861.59	/	80.85	=	97.2
C-1	103.21	x	6.680	=	689.42	8551.00	/	87.53	=	97.7
C-2	95.37	x	6.492	=	619.15	9170.15	/	94.03	=	97.5
C-3	93.13	x	6.648	=	619.14	9789.29	/	100.67	=	97.2
C-4	99.15	x	7.707	=	764.13	10553.42	/	108.38	=	97.4
C-5	100.92	x	7.844	=	791.58	11345.00	/	116.22	=	97.6
C-6	108.07	x	8.724	=	942.78	12287.77	/	124.95	=	98.3
D-1	83.07	x	6.767	=	562.13	12849.91	/	131.72	=	97.6
D-2	101.65	x	6.697	=	680.73	13530.64	/	138.41	=	97.8
D-3	99.20	x	6.642	=	658.89	14189.53	/	145.05	=	97.8
D-4	88.45	x	7.195	=	636.39	14825.92	/	152.25	=	97.4
D-5	97.08	x	7.897	=	766.64	15592.56	/	160.15	=	97.4
D-6	95.97	x	7.812	=	749.70	16342.26	/	167.96	=>	97.3
Last Pt										

Percent Isokinetic (%)   (intermediate equation, all points)
[equivalent to taking an average of point-by-point isokinetics
without weighting the average (e.g. all points equal)]

$$I(\%) = \frac{K_4 \times \left((t_s)_{avg} + T_u\right) \times V_{m(std)}}{\left(\Theta \times \left(v_{s(l)}\right)_{avg} \times P_s \times \pi \times \left(\frac{D_{na}}{2} \times \frac{1}{12}\right)^2\right) \times \left(1 - \frac{B_{ws}}{100}\right)}$$

$$I(\%) = \frac{\dfrac{0.0945 \text{ min•in. Hg}}{\text{sec•}^\circ R} \times (\,194.08 \quad ^\circ F + 460\ ^\circ R) \times \quad 168.00 \quad dscf}{180.00 \text{ min} \times \dfrac{66.99 \text{ ft}}{\text{sec}} \times 29.24 \text{ in. Hg} \times 3.14 \times \left(\dfrac{0.25 \text{ in.}}{2} \times \dfrac{\text{ft.}}{12 \text{ in.}}\right)^2 \times \left(1 - \dfrac{11.18\ \%}{100}\right)} = 97.00\ \%$$

Raw Data Percent Isokinetic (%)
[utilizes the raw data equation for isokinetics from Method 5]

$$I(\%) = \frac{100\left((t_s)_{avg} + T_u\right)\left[K_4 V_{1c} + \dfrac{V_m Y}{(t_m)_{avg} + T_u}\left(P_{bar} + \dfrac{\Delta H}{13.6}\right)\right]}{60\left(\Theta \times \left(v_{s(l)}\right)_{avg} \times P_s \times \pi \times \left(\dfrac{D_{na}}{2} \times \dfrac{1}{12}\right)^2\right)}$$

$$I(\%) = \frac{100 \times (\,194.08 \quad ^\circ F + 460\ ^\circ R) \times \left[\dfrac{0.002669 \text{ ft}^3\text{•in. Hg}}{ml\text{•}^\circ R} \times 449.3 \text{ ml} + \dfrac{176.95 \text{ dcf} \times 0.975}{75.25\ ^\circ F + 460\ ^\circ R}\left(29.30 \text{ in Hg} + \dfrac{3.187}{13.6}\right)\right]}{60 \times 180.00 \text{ min} \times \dfrac{66.99 \text{ ft}}{\text{sec}} \times 29.24 \text{ in. Hg} \times 3.14 \times \left(\dfrac{0.25 \text{ in.}}{2} \times \dfrac{\text{ft.}}{12 \text{ in.}}\right)^2} = 96.95\ \%$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (Gravimetric Analysis) [Values from Run 1 test]

Blank Concentration [Acetone Blank Weight of Solids] (mg/ml)

$$C_x (mg/ml) = \frac{1000 \times w_x}{v_x}$$

$$C_x \text{ (mg/ml)} = \frac{1000 \text{ mg}}{g} \times \frac{0.0008 \quad g}{275.00 \quad ml} = \frac{0.0031 \quad mg}{ml} \qquad = \frac{\qquad mg}{ml}$$

Blank Adjustment [Acetone Blank Weight of Solids and Probe Wash] (mg)

$$W_x (mg) = v_x \times C_x$$

W_x (mg) = 90.00 ml x 0.0031 mg/ml = 0.28 mg < Sample Gain

Sample Gain [Probe Wash] (mg)

$$m_x (mg) = \left(m_{fx} - m_{tx} \right) \times 1000$$

m_x (mg) = $\dfrac{1000 \text{ mg}}{g}$ x (54.62 g - 54.61 g) = 2.55 mg

Adjusted Sample Gain [Probe Wash] (mg)

$$m_{xadj} (mg) = m_x - W_x$$

m_{xadj} (mg) = 2.55 mg - 0.28 mg = 2.27 mg

0.1N NH$_4$OH Correction (mg)

$$m_c (mg) = 17.03 \times V_t \times N$$

m_c (mg) = 17.03 x 0.00 ml x 0.1 N = 0.00 mg

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

EXAMPLE CALCULATIONS (Analysis) [Values from Run 1 test - Total PM$_{10}$/PM$_{2.5}$ Mass]

Stack Total Concentration (g/dscf)

$$c_s(g/dscf) = 0.001 \times \frac{M_n}{V_{m(std)}}$$

$$c_s \text{ (g/dscf)} = \frac{g}{1000 \text{ mg}} \times \frac{5.92 \quad mg}{168.00 \quad dscf} = \frac{3.53E\text{-}05 \text{ g}}{dscf}$$

Stack Total Concentration (gr/dscf)

$$c'_s(gr/dscf) = 0.001 \times \frac{M_n}{V_{m(std)}} \times \frac{7000}{453.592}$$

$$c'_s \text{ (gr/dscf)} = \frac{g}{1000 \text{ mg}} \times \frac{5.92 \quad mg}{168.00 \quad dscf} \times \frac{7000 \text{ gr}}{lb} \times \frac{lb}{453.592 \text{ g}} = \frac{5.44E\text{-}04 \text{ gr}}{dscf}$$

Total Emissions Rate (kg/hr)

$$E(kg/hr) = c_s \times Q_{sd} \times \frac{kg}{1000\,g}$$

$$E \text{ (kg/hr)} = \frac{kg}{1000 \text{ g}} \times \frac{3.52E\text{-}05 \text{ g}}{dscf} \times \frac{62,312,410 \text{ dscf}}{hr} = \frac{2.20 \text{ kg}}{hr}$$

Total Emissions Rate (lb/hr)

$$E'(lb/hr) = \frac{M_n \times Q_{sd}}{V_{m(std)}} \times \frac{lb \times g}{453.592\,g \times 1000\,mg}$$

$$E' \text{ (lb/hr)} = \frac{g}{1000 \text{ mg}} \times \frac{lb}{453.592 \text{ g}} \times \frac{5.92 \quad mg}{168.00 \quad dscf} \times \frac{62,312,410 \text{ dscf}}{hr} = \frac{4.84 \text{ lb}}{hr}$$

Total Emissions Rate (tpy)

$$E''(ton/yr) = E' \times \frac{8760}{2000}$$

$$E'' \text{ (tpy)} = \frac{ton}{2000 \text{ lb}} \times \frac{8,760 \text{ hr}}{yr} \times \frac{4.84 \text{ lb}}{hr} = \frac{21.21 \text{ ton}}{yr}$$

Total Emissions Rate (lb/MMBtu)

Oxygen Based:
$$E'''(lb/MMBtu) = \frac{M_n \times F_d}{V_{m(std)} \times 1000 \times 453.592} \times \left(\frac{20.9}{20.9 - \%O_2} \right)$$

$$E''' \text{ (lb/MMBtu)} = \frac{g}{1000 \text{ mg}} \times \frac{lb}{453.592 \text{ g}} \times \frac{5.92 \quad mg}{168.00 \quad dscf} \times \frac{8,647.63 \text{ dscf}}{MMBtu} \times (\frac{20.9}{20.9 - 11.8 \text{ \%}}) = \frac{0.0015 \text{ lb}}{MMBtu}$$

Note: Lack of significant figures may cause rounding errors between actual calculations and example calculations.

TEST RESULTS AND CALCULATIONS

SAM
Emissions Data

METHOD 8A (CONTROLLED CONDENSATE) - RESULTS

Plant Name	Indeck Niles Energy Center
Sampling Location	CTG2
Project #	kie-22-niles.mi-start#1

Historical Data	CTG2_100_wdb_8A-1	CTG2_100_wdb_8A-2	CTG2_100_wdb_8A-3	Average	Units
Run Start Time	09:54	16:50	01:18		hh:mm
Run Stop Time	15:46	00:47	04:42		hh:mm
Test Date	06/21/22	06/21/22	06/22/22		mm/dd/yy
Load	BaseDB	BaseDB	BaseDB		% or w/DB
Meter Calibration Factor	0.984	0.984	0.984		
Stack Test Data	CTG2_100_wdb_8A-1	CTG2_100_wdb_8A-2	CTG2_100_wdb_8A-3	Average	Units
Initial Meter Volume	569.920	612.300	658.530		ft³
Final Meter Volume	610.030	653.080	696.230		ft³
Total Meter Volume	40.110	40.780	37.700	39.530	ft³
Total Sampling Time	120.00	120.00	120.00	120.00	min
Average Meter Temperature	74.92	72.92	72.00	73.28	°F
Average Stack Temperature	196.21	187.83	179.25	187.76	°F
Barometric Pressure	29.30	29.18	29.18	29.22	in Hg
Stack Static Pressure	-0.78	-0.78	-0.78	-0.78	in H$_2$O
Absolute Stack Pressure	29.24	29.12	29.12	29.16	in Hg
Average Orifice Pressure Drop	0.40	0.40	0.40	0.40	in H$_2$O
Absolute Meter Pressure	29.43	29.31	29.31	29.35	in Hg
Avg Square Root Pitot Pressure	0.63	0.63	0.63	0.63	√(in H$_2$O)
Moisture Content Data	CTG2_100_wdb_8A-1	CTG2_100_wdb_8A-2	CTG2_100_wdb_8A-3	Average	Units
Impinger Water Weight Gain	99.00	85.50	96.70	93.73	g
Silica Gel Weight Gain	12.60	8.40	7.50	9.50	g
Total Water Volume Collected	111.80	94.07	104.39	103.42	ml
Standard Water Vapor Volume	5.26	4.43	4.91	4.87	scf
Standard Meter Volume	38.2	38.8	35.9	37.6	dscf
Standard Metric Meter Volume	1.1	1.1	1.0	1.1	dscm
Calculated Stack Moisture	12.11	10.24	12.03	11.46	%
Saturated Stack Moisture	74.06	62.21	51.53	62.60	%
Reported Stack Moisture Content	12.11	10.24	12.03	11.46	%
Gas Analysis Data	CTG2_100_wdb_8A-1	CTG2_100_wdb_8A-2	CTG2_100_wdb_8A-3	Average	Units
Carbon Dioxide Content	5.4	5.4	5.4	5.4	%
Oxygen Content	11.8	11.8	11.8	11.8	%
Carbon Monoxide Content	0.0	0.0	0.0	0.0	ppm
Nitrogen Content	82.8	82.8	82.8	82.8	%
Stack Dry Molecular Weight	29.34	29.34	29.34	29.34	lb/lb-mole
Stack Wet Molecular Weight	27.96	28.18	27.97	28.04	lb/lb-mole
Calculated Fuel Factor	1.685	1.685	1.685	1.685	
Fuel F-Factor	8647.63	8647.63	8647.63	8647.63	dscf/MMBtu
Percent Excess Air	117.3	117.3	117.3	117.3	%

METHOD 8A (CONTROLLED CONDENSATE) - RESULTS

Plant Name	Indeck Niles Energy Center
Sampling Location	CTG2
Project #	kie-22-niles.mi-start#1

Volumetric Flow Rate Data (M5)	CTG2_PM-1	CTG2_PM-2	CTG2_PM-2	Average	Units
Average Stack Gas Velocity	66.99	69.36	69.36	68.57	ft/sec
Stack Cross-Sectional Area	368.70	368.70	368.70	368.70	ft²
Actual Stack Flow Rate	1,482,034	1,534,283	1,534,283	1,516,867	acfm
Wet Standard Stack Flow Rate	70,156	73,731	73,731	72,539	wkscfh
Dry Standard Stack Flow Rate	62,312,410	66,195,904	66,195,904	64,901,406	dscfh
Emission Rate Data	CTG2_100_wdb_8A-1	CTG2_100_wdb_8A-2	CTG2_100_wdb_8A-3	**Average**	**Units**
SAM (as H_2SO_4) Mass	0.0093	0.0092	0.0099	0.0095	mg
SAM (as H_2SO_4) Concentration	2.43E-07	2.37E-07	2.75E-07	2.52E-07	g/dscf
	3.75E-06	3.65E-06	4.25E-06	3.89E-06	gr/dscf
SAM (as H_2SO_4) Emission Rate	0.02	0.02	0.02	0.02	kg/hr
	0.03	0.03	0.04	0.04	lb/hr
	0.15	0.15	0.18	0.16	tpy
	0.00001	0.00001	0.00001	0.00001	lb/MMBtu

Note: All results reported at RL