

**Air Emissions Testing  
of  
Crumb-Rubber-Modified  
Asphalt Process  
and  
Counter Flow Drum Mixer  
Dust Collector**

**RECEIVED**

DEC 09 2014

**AIR QUALITY DIV.**

Prepared for  
**Michigan State University**  
Lansing, Michigan

Bureau Veritas Project No. 11013-000218.00  
December 8, 2014



**BUREAU  
VERITAS**

***Move Forward with Confidence***

Bureau Veritas North America, Inc.  
22345 Roethel Drive  
Novi, Michigan 48375  
248.344.1770  
[www.us.bureauveritas.com/hse](http://www.us.bureauveritas.com/hse)



RECEIVED

DEC 09 2014

AIR QUALITY DIV.

## Executive Summary

Michigan State University retained Bureau Veritas North America, Inc. to perform air emissions testing at the Michigan Paving and Materials Company's Spartan Asphalt Plant located at 16777 Wood Road, in Lansing, Michigan. The purpose of the testing was to measure air emissions from the plant's dust collector during the manufacturing of crumb-rubber-modified asphalt.

Michigan Paving and Materials Company's Spartan Asphalt Plant manufactures asphalt aggregates and liquid asphalt cement. At the facility, emissions from a counter flow drum dryer/mixer exhaust to a dust collector for particulate matter control prior to discharge to the atmosphere via a 67-inch-internal-diameter exhaust stack. The stack is approximately 133 feet high. The source was tested for:

- Benzene
- Ethylbenzene
- Toluene
- Xylenes
- Naphthalene
- Formaldehyde

The testing followed United States Environmental Protection Agency (USEPA), Occupational Health and Safety Administration (OSHA), National Institute of Occupational Safety and Health (NIOSH), National Council for Air and Stream Improvement (NCASI), and California Air Resource Board (CARB) sampling methods.

Two 120-minute test runs were performed at the dust collector exhaust. Detailed results are presented in Tables 1 through 8 after the Tables tab of this report. The following table summarizes the results of the testing conducted October 19, 2014:

### Summary of Air Emission Test Results

Parameter	Average Result			
	mg/dscm	ppmv	lb/hr	lb/ton
Benzene	1.9	0.59	0.22	0.00059
Toluene	0.56	0.15	0.064	0.00017
Ethylbenzene	0.16	0.037	0.019	0.000050
Xylenes	0.35	0.080	0.041	0.00011
Naphthalene	0.33	0.062	0.038	0.00010
Formaldehyde	3.9	3.1	0.44	0.0012

mg/dscm: milligram per dry standard cubic meter

ppmv: part per million by volume

lb/hr: pound per hour

lb/ton: pound per ton of crumb-rubber-modified asphalt produced



# 1.0 Introduction

## 1.1 Summary of Test Program

Michigan State University retained Bureau Veritas North America, Inc. to perform air emissions testing at the Michigan Paving and Materials Company's Spartan Asphalt Plant located at 16777 Wood Road, in Lansing, Michigan. The purpose of the testing was to measure air emissions during the manufacturing of crumb-rubber-modified asphalt.

Michigan Paving and Materials Company's Spartan Asphalt Plant manufactures asphalt aggregates and liquid asphalt cement. At the facility, emissions from a counter flow drum dryer/mixer exhaust to a dust collector for particulate matter control prior to discharge to the atmosphere via one 67-inch exhaust stack. The stack is approximately 133 feet high. The source was tested for:

- Benzene
- Ethylbenzene
- Toluene
- Xylenes
- Naphthalene
- Formaldehyde

The testing followed United States Environmental Protection Agency (USEPA), Occupational Health and Safety Administration (OSHA), National Institute of Occupational Safety and Health (NIOSH), National Council for Air and Stream Improvement (NCASI) and California Air Resource Board (CARB) sampling methods. Table 1-1 lists the emission source tested, parameters, and test dates.

**Table 1-1  
Sources Tested, Parameters, and Test Dates**

Source	Test Parameter	Test Date (2014)
Counter Flow Drum Mixer Dust Collector Exhaust	Benzene Ethylbenzene Toluene Xylenes Naphthalene Formaldehyde	October 19, 2014



## 1.2 Key Personnel

The key personnel involved in this test program are listed in Table 1-2. Mr. Thomas Schmelter, Senior Project Manager with Bureau Veritas led the emission testing program under the direction of Dr. Derek Wong. Dr. M. Emin Kutay, Associate Professor at Michigan State University, and Mr. Aaron Downing, Area Manager with Michigan Paving & Materials Company's Spartan Asphalt Plant, provided process coordination. Ms. Rhonda Oyer, Sustainable Materials Management Unit Chief, and Mr. Daniel A. McGeen, Environmental Quality Analyst, both with Michigan Department of Environmental Quality, witnessed the testing and recorded production parameters.

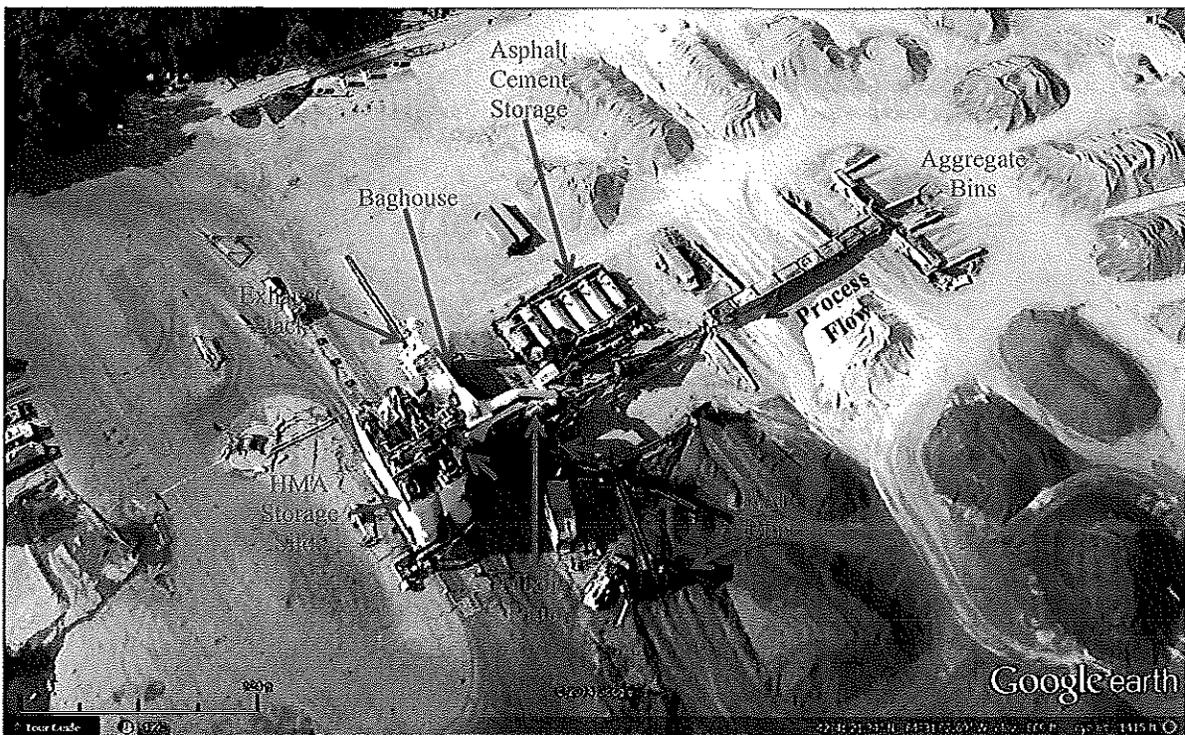
**Table 1-2  
Key Personnel**

<p>M. Emin Kutay, Ph.D., P.E. Associate Professor Department of Civil and Environmental Engineering Michigan State University Engineering Building 428 South Shaw Lane, Room 3546 Lansing, Michigan 48824 Tel: 517.353.9297 Fax: 517.353.9297 kutay@egr.msu.edu</p>	<p>Aaron Downing Manager Michigan Paving &amp; Materials Company Spartan Asphalt Plant 16777 Wood Road Lansing, Michigan Tel: 517.246.5104 Fax: 517.482.4854 adowning@mipmc.com</p>
<p>Rhonda S. Oyer Sustainable Materials Management Unit Chief Michigan Department of Environmental Quality Office of Waste Management &amp; Radiological Protection Constitution Hall 525 West Allegan Street, 4<sup>th</sup> Floor South Lansing, Michigan 30241 Tel: 517.284.6638 Fax: 517.241.3571 oyerr@michigan.gov</p>	<p>Daniel A. McGeen Environmental Quality Analyst Michigan Department of Environmental Quality Air Quality Division Lansing District Office P.O. Box 30242 Tel: 517.284.6638 Fax: 517.241.3571 mcgeend@michigan.gov</p>
<p>Derek Wong, Ph.D., P.E. Director and Vice President Bureau Veritas North America, Inc. 22345 Roethel Drive Novi, Michigan 48375 Tel. 248.344.2669 Fax. 248.344.2656 derek.wong@us.bureauveritas.com</p>	<p>Thomas Schmelter Senior Project Manager Bureau Veritas North America, Inc. 22345 Roethel Drive Novi, Michigan 48375 Tel: 248.344.3003 Fax: 248.344.2656 thomas.schmelter@us.bureauveritas.com</p>



crumb-rubber-modified asphalt (CRMA). CRMA is also referred to as asphalt rubber hot mix and recycled-tire-rubber-modified asphalt. CRMA is approximately 95% aggregate and 5% asphalt cement.

After the hot mix asphalt exits the mixing drum it is conveyed to storage silos where it is loaded into trucks for transport. In this system, the air emissions are captured at the entrance of the mixing drum and directed to a dust filtration collector (aka baghouse) for pollution control. Figure 2-2 presents an aerial photograph of the facility.



**Figure 2-2. Aerial Photograph of Facility**

CRMA produced during this study was used to pave test sections on portions of Kinawa Drive between Okemos Drive to Dobie Road, and Hagadorn Road in Meridian Township, Michigan. The recycled tire rubber was ground at Cobalt Holdings in Sturgis, Michigan, and mixed with the asphalt cement at a terminal in Toledo, Ohio.



Advantages of CRMA include:

- Improved cracking and rutting resistance
- Reduced aging (oxidation) because of the antioxidants in the scrap tire rubber
- Improved skid resistance
- Decreased tire/pavement noise levels
- Beneficial reuse of 1,000 to 2,000 scrap tires per land mile (depending on the technology)

The maximum production rate for the process is 650 tons per hour. The production rate was 375 tons per hour during testing.

Operating parameters recorded during testing are included in Appendix E. Graphs of the exhausted VOC concentration and production rate are provided after the Graphs tab in the Appendix. Table 2-1 summarizes the process operating parameters.

**Table 2-1  
Summary of Process Operating Parameters**

Parameter	Units	Run 1	Run 2	Average
Total asphalt production rate	ton/hr	376	374	375
Virgin aggregate feedrate	ton/hr	203	205	204
Virgin aggregate moisture content	%	5.7	5.7	5.7
Recycled asphalt product feedrate	ton/hr	146	147	147
Recycled asphalt moisture content	%	5.4	5.4	5.4
Liquid asphalt cement feedrate	ton/hr	22	22	22
Mix temperature	°F	323	333	328
Burner	% open	31	29	30
Notes: CRMA type/grade being produced during testing was SEIHRC				

## 2.2 Control Equipment

A pulse-jet fabric filter dust collector baghouse controls particulate matter emissions from the process. Ductwork above the entrance to the mixing drum collects emissions generated when aggregate is conveyed into mixing process. The captured emissions enter a primary collector cyclone where aggregate dust is reclaimed and returned to the process. After passing through the primary collector, the emissions pass through a fabric filter dust collector.

High-temperature filter bags filter dust from the process air. The material collected on the filters is recovered by pulsing the bags every 20 seconds with high-pressure air, causing the material to



be released from the bags and fall into storage hoppers below. The recovered material can be reused in the process or disposed. Air that is drawn from the mixing drum through the cyclone and baghouse is exhausted to atmosphere using a fan positioned near the bottom of the exhaust stack.

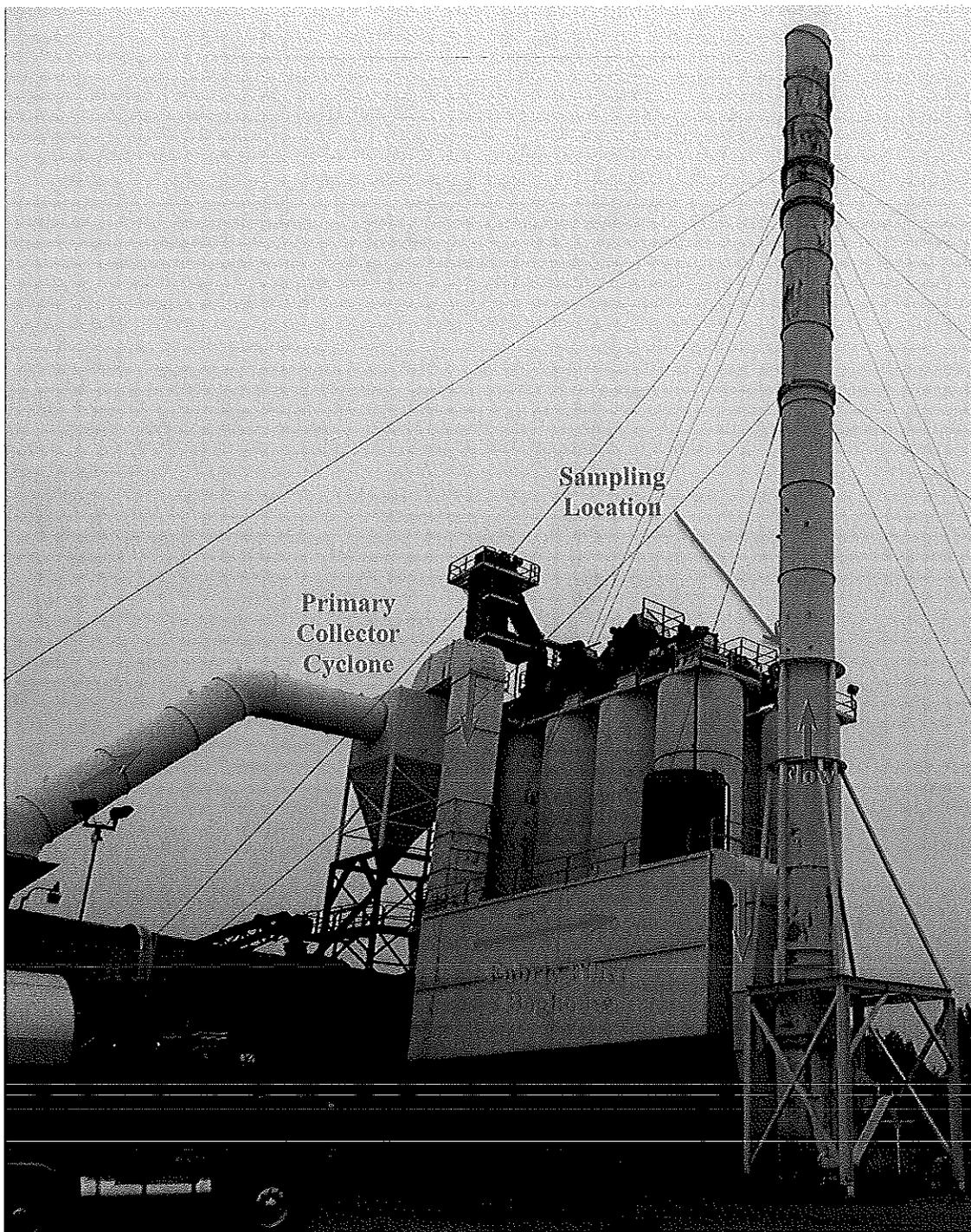
The normal differential pressure across the baghouse is 2 to 10 inches of water, which is measured by a magnehelic gauge. The differential pressure of the baghouse can be adjusted by opening or closing the exhaust damper. The fabric filter dust collector is equipped with a high-temperature sensor and alarm that alerts the operators when the stack temperature exceeds set points (375-400 °F). The operating parameters of the dust collector during testing are presented in Appendix E and summarized in Table 2-2.

**Table 2-2  
Baghouse Operating Parameters**

Parameter	Units	Run 1	Run 2	Average
Differential pressure	in H <sub>2</sub> O	3.07	3.12	3.09
Exhaust damper position	% open	70	70	70
Baghouse inlet temperature	°F	305	311	308
Baghouse exit temperature	°F	225	244	235

### 2.3 Flue Gas Sampling Location

The hot mix asphalt plant drum mixer dust collector baghouse exhaust duct is 67 inches in diameter and has three 3-inch-diameter sampling ports. The downstream and upstream distances from the sampling ports to the closest air flow disturbances meet USEPA Method 1 minimum criteria. Sixteen traverse points (8 traverse points per sampling port) were used to measure stack gas velocity. Figure 2-3 is a photograph of the dust collector sampling location. Figure 1 in the Appendix is a drawing of the sampling ports and traverse point locations.



**Figure 2-3. Dust Collector Exhaust Stack**



## 3.0 Summary and Discussion of Results

### 3.1 Objective

The purpose of the testing was to measure air emissions during the manufacturing of crumb-rubber-modified asphalt. The specific objective was to:

- Measure concentrations and calculate mass emission rates of benzene, toluene, ethylbenzene, naphthalene, and formaldehyde from the exhaust stack of the fabric filter dust collector, which controls emissions from the hot mix asphalt process.

Table 3-1 summarizes the sampling and analytical matrix.

**Table 3-1  
Test Matrix**

Sampling Location	Sample/Type of Pollutant	Sampling Method	No. of Test Runs and Duration	Analytical Method	Analytical Laboratory
Dust Collector Exhaust Stack	Sample location Flowrate O <sub>2</sub> and CO <sub>2</sub> Moisture Benzene Toluene Ethylbenzene Xylenes Naphthalene Formaldehyde	EPA 1 EPA 2 EPA 3 EPA 4 EPA 18, OSHA 7 TO-15A OSHA 35 CARB 430 NIOSH 2016 NCASI 98.01	Two 2-hour runs  Run 1 7:18-9:18  Run 2 10:29-12:29	Differential pressure, chemical absorption, gravimetric, gas chromatography-flame ionization detector, high performance liquid chromatography, gas chromatography-mass spectrometry, purge and trap gas chromatography-mass spectrometry, spectrophotometry	Bureau Veritas and Maxxam Analytics

### 3.2 Field Test Changes and Issues

Significant field test changes were not required to complete the emissions testing. Communication between the Michigan State University, Spartan Asphalt Plant, Michigan Department of Environmental Quality, and Bureau Veritas allowed the testing to be completed as proposed.



### 3.3 Summary of Results

The results of the testing are presented in Table 3-2. Detailed results are presented in Tables 1 through 8 after Table tab of this report. Sample calculations are presented in Appendix B.

**Table 3-2**  
**Summary of Air Emission Test Results**

Parameter	Average Result			
	mg/dscm	ppm	lb/hr	lb/ton
Benzene	1.9	0.59	0.22	0.00059
Toluene	0.56	0.15	0.064	0.00017
Ethylbenzene	0.16	0.037	0.019	0.000050
Xylenes	0.35	0.080	0.041	0.00011
Naphthalene	0.33	0.062	0.038	0.00010
Formaldehyde	3.9	3.1	0.44	0.0012

mg/dscm: milligram per dry standard cubic meter

ppmv: part per million by volume

lb/hr: pound per hour

lb/ton: pound per ton of crumb-rubber-modified asphalt produced

The results indicate emissions of benzene, toluene, ethylbenzene, , xylenes, naphthalene, and formaldehyde are less than 0.01 pounds per ton of crumb-rubber-modified asphalt produced.

BTEX and naphthalene were measured using Method TO-15 (using an evacuated canister) as a quality control procedure. The Method TO-15 results correlated to the USEPA Method 18 results presented above for benzene, ethylbenzene, toluene, xylenes, and naphthalene (see Table 7 in the Appendix). Formaldehyde cannot be measured using Method TO-15; however, formaldehyde was detected in the sampling train condensates (see Table 8 in the Appendix).



## 4.0 Sampling and Analytical Procedures

Bureau Veritas measured flue gas velocity, molecular weight, moisture content, total VOC, benzene, toluene, ethylbenzene, xylenes, naphthalene, and formaldehyde concentrations. The testing followed United States Environmental Protection Agency (USEPA), Occupational Health and Safety Administration (OSHA), National Institute of Occupational Safety and Health (NIOSH), National Council for Air and Stream Improvement (NCASI), and California Air Resource Board (CARB) sampling methods. Table 4-1 presents the emissions test parameters and sampling methods.

**Table 4-1  
Emissions Test Parameters and Sampling Methods**

Parameter	Source	Reference	
	Dust Collector Exhaust	Method	Title
Sampling ports and traverse points	●	EPA 1	Sample and Velocity Traverses for Stationary Sources
Velocity and flowrate	●	EPA 2	Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)
Molecular weight	●	EPA 3	Gas Analysis for the Determination of Dry Molecular Weight
Moisture content	●	EPA 4	Determination of Moisture Content in Stack Gases (approximation method)
Benzene, toluene, ethylbenzene, xylenes, naphthalene	●	EPA 18	Measurement of Gaseous Organic Compound Emissions by Gas Chromatography
Benzene, toluene, ethylbenzene, xylenes, naphthalene	●	EPA TO-15A	Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry
Total volatile organic compounds (VOC)	●	EPA 25A	Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer
Benzene, toluene, ethylbenzene, xylenes (in condensate)	●	EPA 8260	Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)
Naphthalene (in condensate)	●	EPA 8270	Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)
Benzene, toluene, ethylbenzene, xylenes	●	OSHA 7	Organic Vapors
Naphthalene	●	OSHA 35	Naphthalene
Formaldehyde	●	CARB 430	Determination of Formaldehyde and Acetaldehyde in Emissions from Stationary Sources
Formaldehyde	●	NCASI 98.01	Chilled Impinger Method for Use at Wood Products Mills to Measure Formaldehyde, Methanol, and Phenol
Formaldehyde	●	NIOSH 2016	Formaldehyde



## 4.1 Test Methods

### 4.1.1 Volumetric Flowrate (USEPA Methods 1 and 2)

Method 1, "Sample and Velocity Traverses for Stationary Sources," from 40 CFR 60, Appendix A, was used to evaluate the sampling location and the number of traverse points for the measurement of velocity profiles. Details of the sampling location and number of velocity traverse points are presented in Table 4-2.

**Table 4-2**  
**Sampling Location and Number of Traverse Points**

Sampling Locations	Duct Diameter (inch)	Distance from Ports to Upstream Flow Disturbance (diameter)	Distance from Ports to Downstream Flow Disturbances (diameter)	Number of Ports Used	Traverse Points per Port	Total Points
Dust Collector Exhaust Stack	67	5.4	13.4	2	8	16

Figure 1 in the Appendix depicts the sampling location and traverse points for the sources tested.

Method 2, "Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)," was used to measure flue gas velocity and calculate volumetric flowrate. An S-type Pitot tube and thermocouple assembly were connected to a digital manometer and thermometer. Because the dimensions of the Pitot tube met the requirements outlined in Method 2, Section 10.0, a baseline Pitot tube coefficient of 0.84 (dimensionless) was assigned.

The digital manometer and thermometer were calibrated using calibration standards, which are traceable to National Institute of Standards (NIST). Refer to Appendix A for the calibration and inspection sheets. Sample calculations and field data sheets are included in Appendices B and C. Appendix D provides the computer-generated data sheets.

**Cyclonic Flow Check.** Bureau Veritas evaluated whether cyclonic flow is present at the sampling location.

Cyclonic flow is defined as a flow condition with an average null angle greater than 20°. The direction of flow can be determined by aligning the Pitot tube to obtain zero (null) velocity head readings—the direction would be parallel to the Pitot tube face openings or perpendicular to the null position. By measuring the angle of the Pitot tube face openings in relation to the stack



walls when a null angle is obtained, the direction of flow is measured. If the absolute average of the flow direction angles is greater than 20 degrees, the flue gas flow is considered to be cyclonic at that sampling location and an alternative location should be found.

The average of the measured traverse point flue gas velocity null angles was 4°. Because the average null angle is less than 20°, the measurements indicate the absence of cyclonic flow.

#### **4.1.2 O<sub>2</sub> and CO<sub>2</sub> Concentrations (USEPA Method 3)**

Molecular weight was measured using USEPA Method 3, "Gas Analysis for the Determination of Dry Molecular Weight." Flue gas was extracted from the stack through a probe positioned near the centroid of the duct and directed into a Fyrite® gas analyzer. The concentrations of carbon dioxide (CO<sub>2</sub>) and oxygen (O<sub>2</sub>) were measured by chemical absorption with a Fyrite® gas analyzer to within ±0.5%. The average CO<sub>2</sub> and O<sub>2</sub> result of the grab samples were used to calculate the stack gas molecular weight.

#### **4.1.3 Moisture Content (USEPA Method 4)**

The moisture content at the outlet of the incinerator was measured using USEPA Method 4, "Determination of Moisture Content in Stack Gases." Bureau Veritas' modular USEPA Method 4 stack sampling system consisted of:

- A stainless steel probe
- Tygon® umbilical line connecting the probe to the impingers
- A set of four Greenburg-Smith (GS) impingers with the modified configuration shown in Table 4-3 situated in a chilled ice bath
- A sample line
- An Environmental Supply® control case equipped with a pump, dry-gas meter, and calibrated orifice

Prior to initiating a test run, the sampling train was leak-checked by capping the nozzle tip and applying a vacuum of approximately 15 inches of mercury to the sampling train. The dry-gas meter was then monitored for approximately 1 minute to measure that the sample train leak rate was less than 0.02 cubic feet per minute (cfm). The sample probe was then inserted into the sampling port near the centroid of the stack in preparation of sampling. Flue gas was then extracted at a constant rate from the stack, with moisture removed from the sample stream by the chilled impingers.



**Table 4-3**  
**USEPA Method 4 Impinger Configuration**

Impinger	Type	Contents	Amount
1	Modified	Empty	0 milliliters
2	Greenburg Smith	Empty	0 milliliters
3	Modified	Empty	0 milliliters
4	Modified	Silica desiccant	~300 grams

At the conclusion of the test run, a post-test leak check was conducted and the impinger train was disassembled. The weight of liquid and silica gel in each impinger was measured with a scale capable of measuring  $\pm 0.5$  gram. The weight of water collected within the impingers and volume of flue gas sampled were used to calculate the percent moisture content. One moisture content sample was collected during each test run. Figure 2 in the Appendix depicts the USEPA Method 4 sampling train.

The condensate was collected and analyzed for benzene, toluene, ethylbenzene, xylenes, naphthalene, and formaldehyde. Table 8 summarizes the results of the Method 4 sample train condensate and condensate samples collected using the other sampling methods in this test program.

#### **4.1.4 Organic Compounds (USEPA Method 18)**

Benzene, toluene, ethylbenzene, xylenes, and naphthalene concentrations were measured following procedures in USEPA Method 18, "Measurement of Gaseous Organic Compound Emissions by Gas Chromatography." The sampling and analytical procedures followed guidelines in:

- USEPA Method 8260, "Volatile Organic compounds by gas chromatography/Mass Spectrometry (GC/MS)"
- USEPA Method 8270, "Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)"
- National Council for Air and Stream Improvement, Inc., Method 98.01, "Chilled Impinger Method for Use at Wood Products Mills to Measure Formaldehyde, Methanol, and Phenol"
- Occupational Safety and Health Administration (OSHA), "Sampling and Analytical Method 7: Organic Vapors"



- OSHA, “Sampling and Analytical Method 35: Naphthalene”

Impingers and sorbent tubes were used to sample for the compounds of interest. Bureau Veritas’ modular USEPA Method 18 sampling train consisted of:

- Two empty impingers in series
- Sorbent tubes for each targeted analyte
- Critical orifices used to set sample flow rate
- Teflon® tubing connecting the critical orifices to a rotameter
- Sample pump

Flue gas was drawn through sorbent tubes situated upstream of critical orifices (Gemini® twin-port sampler), which controlled flowrate. The sorbent tubes were connected to a rotameter and sampling pump. The rotameter was used to monitor the sampling rate. A similar sampling train using spiked or duplicate sorbent tubes was placed parallel to the unspiked sorbent tubes for quality control/quality assurance (QA/QC) purposes. Figure 3 depicts the sampling train.

Based on expected concentrations and analytical detection limits, the USEPA Method 18 sampling trains were set up to collect approximately 25 liters of flue gas at 0.2 liters per minute for a 120-minute test run. The mass of pollutant on the spiked sample media was targeted to be 40 to 60% of the mass expected to be collected or meet the equivalent spiking levels of NCASI Method A105.01.

Before testing, the flowrate through each set of sorbent tubes was measured using a rotameter and verified with a BIOS International DryCal® calibrator. The critical orifices were adjusted so that the sampling flowrate was within 20% of the sampling rate specified by the method. The pre-test flowrates were recorded on a test run data sheet. After the sampling rate was measured, the sampling train was positioned to sample the flue gas. Flue gas was sampled through the impingers and into the sorbent tubes for 120 minutes per test run.

At the conclusion of each test run, the sampling train flowrate was measured using the DryCal calibrator. The average of the pre- and post-test flowrates was used to calculate the flue gas sample volume for the test duration. The contents of the impingers were recovered and the sorbent tube was capped and stored in a chilled cooler. The samples were analyzed by Bureau Veritas’ laboratory in Novi, Michigan, and Bureau Veritas’ Maxxam Analytics laboratory in Mississauga, Ontario, Canada.

Laboratory analytical results are presented in Appendix E.

Because the mass was collected on co-located unspiked and spiked sorbent media, spike recovery calculations were completed for quality control/quality assurance information. The

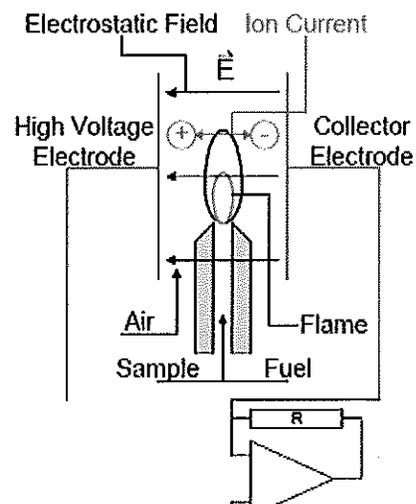
spike recovery calculation compares the concentration measured by the unspiked and spiked sorbent tubes and corrects the results based on the fraction of spiked compound recovered.

#### 4.1.5 Total Volatile Organic Compounds (USEPA Method 25A)

Total VOC sampling followed procedures in USEPA Method 25A, "Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer." Total VOCs were measured in order to monitor process operations. Samples were collected through a stainless steel probe and heated sample line into the analyzer. Bureau Veritas used a J.U.M 3-300A flame ionization detector.

A flame ionization detector (FID) determines the average hydrocarbon concentration in part per million by volume (ppmv) of VOC as the calibration gas (i.e., propane). The FID is fueled by 100% hydrogen, which generates a flame with a negligible number of ions. Flue gas is introduced into the FID and enters the flame chamber. The combustion of flue gas generates electrically charged ions. The analyzer applies a polarizing voltage between two electrodes around the flame, producing an electrostatic field. Negatively charged ions, anions, migrate to a collector electrode, while positive charged ions, cations, migrate to a high-voltage electrode. The current between the electrodes is directly proportional to the hydrocarbon concentration in the sample. The flame chamber is depicted at right.

Using the voltage analog signal, measured by the FID, the concentrations of VOCs were recorded by a data acquisition system (DAS). The average concentration of VOCs is reported as the calibration gas (i.e., propane) in equivalent units.



**Figure 4-1. FID Flame Chamber**

Figure 4 in the Appendix depicts the USEPA Method 25A sampling train.

Before testing, the FID analyzer was calibrated by introducing a zero-calibration range gas (<1% of span value) and high-calibration range gas (80-90% span value) to the tip of the sampling probe. The span value was set to 1.5 to 2.5 times the expected concentration (e.g., 0-100 ppmv). Next, a low-calibration range gas (25-35% of span value) and mid-calibration range gas (45-55% of span value) were introduced. The analyzer was considered calibrated when the response was  $\pm 5\%$  of the calibration gas value.

At the conclusion of the testing, a calibration drift test was performed by introducing the zero- and mid-calibration gas to the tip of the sampling probe. The test run data was considered valid



when the calibration drift test demonstrated the analyzers were responding within  $\pm 3\%$  of calibration span from pre-test to post-test calibrations.

#### **4.1.6 Total Volatile Organic Compounds (USEPA Method TO-15)**

USEPA Method TO-15, "Determination of Volatile Organic Compounds in Air Collected in Specially Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry," was used to scan for volatile organic compounds that may be present in the emissions. Because truck traffic prevented access of the articulating boom lift to access the stack only one 120-minute integrated sample was collected.

Figure 5 depicts the Method TO-15 sampling train. Bureau Veritas' sampling system consisted of:

- A stainless steel ¼-inch-diameter probe
- Critical orifice flow controller with vacuum gauge
- An evacuated sampling canister

After the flow controller was connected to the air sampling container, the stainless steel probe was placed in the sampling port near the centroid of the stack. The valve on the canister was opened, allowing the vacuum to withdraw flue gas from the stack and into the canister.

After the 120-minute test run was completed, the valve on the air sampling canister was closed. The canister was labeled and stored. The air sampling canister was analyzed by Bureau Veritas' laboratory in Novi, Michigan. Refer to Appendix F for the laboratory's analytical report.

#### **4.1.7 Formaldehyde (CARB Method 430)**

Formaldehyde concentrations were measured following California Air Resource Board (CARB) Method 430, "Determination of Formaldehyde and Acetaldehyde in Emissions from Stationary Sources." A sample extracted from the flue gas was passed through two chilled aqueous impingers containing 2,4-dinitrophenyl-hydrazine (DNPH) solution. The aldehyde compounds react with the DNPH forming 2,4-dinitrophenylhydrazone, which is extracted in the laboratory and analyzed by reverse-phase high-performance liquid chromatography with an ultraviolet absorption detector.

Bureau Veritas positioned sorbent tubes after the DNPH impingers to evaluate the impinger's formaldehyde collection efficiency. The sorbent tubes were analyzed following National Institute for Occupational Safety and Health (NIOSH) "Manual of Analytical Methods: Formaldehyde, 2016."



Bureau Veritas' CARB 430 stack sampling system consisted of:

- A heated stainless steel probe positioned near the centroid of the duct.
- A heated filter
- Teflon® tubing connecting the heated filter to three 30-ml impingers partially submerged in an ice bath and configured as shown in Table 4-4 with regular tapered stems connected in series.
- Sorbent tubes to evaluate if formaldehyde was present after the DNPH impingers
- Critical orifices set to sample at 0.1 liter per minute.
- A vacuum gauge, rotameter, and sampling pump.

**Table 4-4**  
**CARB 430 Impinger Configuration**

Impinger	Type	Contents	Amount (ml)
1	Regular, tapered stem	Empty	0
2	Regular, tapered stem	DNPH solution	~10
3	Regular, tapered stem	DNPH solution	~10

Figure 6 in the Appendix depicts the CARB 430 sampling train.

Prior to initiating a test run, the sampling train was leak-checked by capping the probe tip and applying a vacuum to the sampling train. A vacuum gauge was monitored to measure that the sample train leak rate was less than 1 inch of mercury in 2 minutes. Three measurements of the flowrate were then recorded. The sampling probe was inserted into the sampling port near the centroid of the stack. Flue gas was extracted at a constant rate from the stack.

At the conclusion of the test run, flowrate was measured. With the probe inlet elevated, approximately 2 mL of DNPH was added to the inlet tip to rinse the line and drain the rinsate into the first impinger. The impinger contents were transferred to a labeled and pre-weighed container. The container and sorbent tubes were sealed, labeled, stored in a cooler with ice, and transported to the laboratory for analysis.

Appendix E includes the laboratory results.



---

## 4.2 Procedures for Obtaining Process Data

Daniel McGeen of MDEQ recorded process data during testing. MDEQ and Spartan Asphalt plant personnel verified the operating and process data were recorded appropriately. The process data are included within Appendix F.

## 4.3 Sampling Identification and Custody

Thomas Schmelter of Bureau Veritas was responsible for the handling and procurement of the data collected in the field. Mr. Schmelter ensured the data sheets were accounted for and completed.

Recovery and analytical procedures were applicable to the sampling methods used in this test program. Sampling and recovery procedures were described previously in this chapter.

Applicable Chain of Custody procedures followed guidelines outlined within ASTM D4840-99 (Reapproved 2010), "Standard Guide for Sample Chain-of-Custody Procedures."

For each sample collected (i.e., impinger, sorbent tube) sample identification and custody procedures were completed as follows:

- Containers were sealed with Teflon tape to prevent contamination.
- Containers were labeled with test number, location, and test date.
- The level of fluid was marked on outside of sample containers to evaluate whether the containers leaked before delivery of the samples to the laboratory.
- Containers were stored in a cooler.
- Samples were logged using guidelines outlined in ASTM D4840-99 (Reapproved 2010), "Standard Guide for Sample Chain-of-Custody Procedures."
- Samples were delivered to the laboratory.

Chains of custody and laboratory analytical results are included in Appendix E.



## 5.0 QA/QC Activities

Equipment used in this test program passed quality assurance/quality control (QA/QC) procedures. Refer to Appendix A for equipment calibrations.

### 5.1 Pretest QA/QC Activities

Before testing, the sampling equipment was cleaned, inspected, and calibrated according to procedures outlined in the applicable USEPA sampling method and USEPA's "Quality Assurance Handbook for Air Pollution Measurement Systems: Volume III, Stationary Source-Specific Methods."

### 5.2 QA/QC Audits

Quality assurance (QA) audit samples were not proposed during this test program. Currently, audit samples for the parameters to be measured are not available from the EPA Stationary Source Audit Program.

Onsite QA/QC procedures (i.e., Pitot tube inspections, leak checks, analyzer calibrations) were performed in accordance with the respective USEPA sampling methods. Equipment inspection and calibration measurements are presented in Appendix A.

Offsite QA audits include dry-gas meter and thermocouple calibrations.

#### 5.2.1 Sampling Train QA/QC Audits

The sampling trains described in Section 4.1 were audited for measurement accuracy and data reliability. Table 5-1 summarizes the QA/QC audits conducted for the Method 4 sampling train.

**Table 5-1  
Method 4 Sampling Train QA/QC Audits**

Parameter	Run 1	Run 2	Method Requirement	Comment
Sampling train leak check Post-test	0 ft <sup>3</sup> for 1 min at 6 in Hg	0 ft <sup>3</sup> for 1 min at 8 in Hg	<0.020 ft <sup>3</sup> for 1 minute at $\geq$ sample vacuum recorded during test	Valid
Sampling vacuum (in Hg)	<1	<1		



## 5.2.2 Instrument Analyzer QA/QC Audits

The Method 25A sampling train described in Section 4.1 was audited for measurement accuracy and data reliability. The analyzer passed the applicable calibration criteria. The following tables summarize gas cylinders used during this test program and QA/QC audits. Refer to Appendix A for additional calibration data.

**Table 5-2  
Calibration Gas Cylinder Information**

Parameter	Gas Vendor	Cylinder Serial Number	Cylinder Value	Expiration Date
Air	Airgas	CC106897	-	9/09/2022
Propane	Air Liquide	ALM002449	9.88 ppm	11/23/2018
Propane	Airgas	CC151103@	30.18 ppm	1/7/2022
Propane	Pangaea Gases, LLC	EB0049384	49.7 ppm	6/14/2021
Propane	Airgas	CC110618	89.46 ppm	7/25/2022

**Table 5-3  
Method 25A Sampling Train QA/QC Audits**

Parameter	Runs 1 and 2	Acceptable Tolerance	Comment
Low-level (zero) gas system bias (%)	0.9	≤5% of calibration gas value	Valid
Upscale gas system bias (%)	0.4	≤5% of calibration gas value	Valid
Low-level (zero) gas analyzer drift (%)	1.1	≤3% of calibration span	Valid
Upscale gas analyzer drift (%)	2.1	≤3% of calibration span	Valid

The QA/QC audits demonstrate sample collection accuracy for the test runs.



### 5.2.3 Dry-Gas Meter QA/QC Audits

Table 5-4 summarizes the dry-gas meter calibration checks in comparison to the acceptable USEPA tolerance. Refer to Appendix A for complete DGM calibrations.

**Table 5-4  
Dry-gas Meter Calibration QA/QC Audit**

<b>Dry-Gas Meter</b>	<b>Pre-test DGM Calibration Factor (Y) (dimensionless)</b>	<b>Post-Test DGM Calibration Factor (Y) (dimensionless)</b>	<b>Difference Between Pre- and Post-test DGM Calibrations</b>	<b>Acceptable Tolerance</b>	<b>Comment</b>
2	0.994 (10/10/14)	0.993 (11/14/14)	0.001	±0.05	Valid

### 5.2.4 Thermocouple QA/QC Audits

Temperature measurements using thermocouples and digital pyrometers were compared to a reference temperature (i.e., ice water bath, boiling water) prior to and after testing to evaluate accuracy of the equipment. The thermocouples and pyrometers measured temperature within ±1.5% of the reference temperatures and were within USEPA acceptance criteria. Thermocouple calibration sheets are presented in Appendix A.

### 5.2.5 QA/QC Blanks

Sample media blanks were analyzed for the parameters of interest. The results of the blanks are presented in the Table 5-5.

Refer to Appendix E for the laboratory results.



**Table 5-5  
QA/QC Blanks**

Sample Identification	Result (µg)	Comment
BTEX Trip Blank 1	<2 Benzene <4 Ethylbenzene <4 Toluene <8 Xylenes	Compounds of interest not detected
BTEX Trip Blank 2	<2 Benzene <4 Ethylbenzene <4 Toluene <8 Xylenes	Compounds of interest not detected
BTEX Spike Blank	29 Benzene 29 Ethylbenzene 29 Toluene 56 Xylenes	The average mass of BTEX spike Blanks 1 and 2 was used in blank correction calculations The average mass of BTEX spike Blanks 1 and 2 was used in blank correction calculations
BTEX Spike Blank	29 Benzene 29 Ethylbenzene 29 Toluene 57 Xylenes	
Naphthalene Trip Blank 1	<1	Compound of interest not detected
Naphthalene Trip Blank 2	<1	Compound of interest not detected
Naphthalene Spike Blank 2	28	The average mass of naphthalene spike Blanks 1 and 2 was used in blank correction calculations The average mass of naphthalene spike Blanks 1 and 2 was used in blank correction calculations
Naphthalene Spike Blank 2	29	
Formaldehyde Trip Blank 1	<0.1	Compound of interest not detected
Formaldehyde Trip Blank 2	<0.1	Compound of interest not detected
CARB 430 Blank 1	13	When the ratio of the average CARB 430 blank formaldehyde mass to the test run result is less than 5:1, a blank correction of 5 times the average blank result is applied.
CARB 430 Blank 2	8.4	
CARB 430 Blank 3	4.4	

### 5.3 QA/QC Checks for Data Reduction and Validation

The emissions testing Project Manager validated the computer spreadsheets onsite. The computer spreadsheets were used to evaluate the accuracy of field calculations. The field data sheets were reviewed to evaluate whether data has been recorded and inputted appropriately. The computer data sheets were checked against the raw field data sheets for accuracy during review of the draft report. Sample calculations were performed to verify computer spreadsheet computations.



---

## 5.4 QA/QC Problems

Equipment audits and QA/QC procedures demonstrate sample collection accuracy for the test runs.

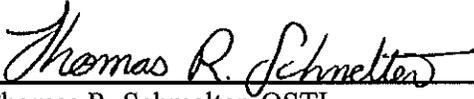
Low formaldehyde blank to sample ratios were encountered. The low blank to sample ratios caused a high blank correction to be applied; thus, the formaldehyde results are likely biased high. Sampling for a longer duration or faster sampling rate may reduce the low blank to sample ratios should future testing be performed using CARB 430.



---

## 6.0 Limitations

The information and opinions rendered in this report are exclusively for use by Michigan State University. Bureau Veritas North America, Inc. will not distribute or publish this report without Michigan State University's consent except as required by law or court order. The information and opinions are given in response to a limited assignment and should be implemented only in light of that assignment. Bureau Veritas North America, Inc. accepts responsibility for the competent performance of its duties in executing the assignment and preparing reports in accordance with the normal standards of the profession, but disclaims any responsibility for consequential damages.

This report prepared by:   
Thomas R. Schmelter, QSTI  
Senior Project Manager  
Health, Safety, and Environmental Services

This report reviewed by:   
Derek R. Wong, Ph.D., P.E.  
Director and Vice President  
Health, Safety, and Environmental Services