BTEC Inc.

Engine Test Cells 11, 13, & 14 Carbon Monoxide Emissions Report

Prepared for:

Kawasaki Motors Corp USA

Grand Rapids, Michigan

Kawasaki Motors Corp USA
5080 36th Street Southeast
Grand Rapids, Michigan

Project No. 17-5092.00
October 30, 2017

BT Environmental Consulting, Inc.
4949 Fernlee Avenue
Royal Oak, Michigan 48073
(248) 548-8070

EXECUTIVE SUMMARY

BT Environmental Consulting, Inc. (BTEC) was retained by Kawasaki Motors Corp USA (Kawasaki) to conduct an evaluation of carbon monoxide (CO) from three internal combustion engine test cells (EUTEST11, EUTEST13, EUTEST14) located at the Kawasaki test facility in Grand Rapids, Michigan. The emissions test program was conducted on September 20, 2017.

Testing of the internal combustion engine test cells consisted of triplicate test runs for each pollutant. The emissions test program was required by MDEQ Air Quality Division PTI 230-15A. The results of the emission test program are summarized by Table I.

Table I
Overall Emission Summary
Test Date: September 20, 2017

Emission Unit	Pollutant	Permit Limit	Test Result
Test Cell & Scavenge Air Exhaust	CO	3.94 lb/gal	6.49 lb/gal

1. Introduction

BT Environmental Consulting, Inc. (BTEC) was retained by Kawasaki Motors Corp USA (Kawasaki) to conduct an evaluation of carbon monoxide (CO) from three internal combustion engine test cells (EUTEST11, EUTEST13, EUTEST14) located at the Kawasaki test facility in Grand Rapids, Michigan. The emissions test program was conducted on September 20, 2017.

AQD has published a guidance document entitled "Format for Submittal of Source Emission Test Plans and Reports" (December 2013). The following is a summary of the emissions test program and results in the format suggested by the aforementioned document.

1.a Identification, Location, and Dates of Test

Sampling and analysis for the emission test program was conducted on September 20, 2017 at the Kawasaki facility located in Grand Rapids, Michigan.

1.b Purpose of Testing

AQD issued Permit To Install No. 230-15A to Kawasaki. The permit limits are summarized by Table 1.

Table 1
Emission Limitations
Kawasaki Motors Corp. USA – Grand Rapids, MI
PTI 230-15A Emission Limitations

Emission Unit	Pollutant	Permit Limit
Test Cell & Scavenge Air Exhaust	CO	3.94 lb/gal

1.c Source Description

AQD issued Permit No. 230-15A to Kawasaki for the installation of twenty internal combustion engine test cells. Although not all test cells have yet been fully installed, each engine test cell is designed to test engines up to 50 horsepower with the test cells dedicated to performance testing; durability and endurance testing; or rain, climactic, chassis, and anechoic testing.

Each of the twenty engine test cells exhausts to one of five exhaust headers with each header exhausting through a single stack. In addition, the test cells are equipped with scavenge air exhaust systems (i.e., exhaust from any test cell leaks that may occur). The emissions test program included measurement of CO emission rates at the main test cell exhaust (SV-EF5C) and scavenge air exhaust from Test Cells 11, 13, and 14.

During testing, each of the three test cells operated, Test Cell 11 operated a FX921V (34 hp) engine and Test Cells 13 and 14 operated a FXT00V (37 hp) engine. All three engines were operated continuously at 100% load and wide open throttle (WOT) conditions. Because the engines typically generate the greatest amount of CO at 100% load and WOT conditions (both in terms of total mass rate and in terms of lbs/gal), this provided a worst-case measurement of CO emissions. In addition, because these are the largest engines currently operated, this is also representative of the maximum annual fuel usage relative to other engine models.

1.d Test Program Contacts

The contacts for the source and test report are:

Mr. Kevin Kline
Senior Supervisor
R&D Testing
Kawasaki Motors Corp USA
5080 36th Street SE
Grand Rapids, Michigan 49512
c 616.460.9230

Mr. Randal Tysar
Senior Environmental Engineer
BT Environmental Consulting, Inc.
4949 Fernlee Avenue
Royal Oak, Michigan 48073
(248) 548-8070

Names and affiliations for personnel who were present during the testing program are summarized by Table 2.

Table 2
Test Personnel

Name and Title	Affiliation	Telephone
Mr. Steve Smith Project Manager	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Mike Nummer Environmental Technician	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Jake Zott Environmental Technician	BTEC 4949 Fernlee Royal Oak, MI 48073	(248) 548-8070
Mr. Jeremy Howe Air Quality Division	MDEQ	(231) 876-4416

2. Summary of Results

Sections 2.a through 2.d summarize the results of the emissions compliance test program.

2.a Operating Data

The average temperature for the test cell exhaust was 159 degrees Fahrenheit with an average moisture percentage of 3. The average temperature for the scavenge air exhaust was 76 degrees Fahrenheit with an average moisture percentage of 1.9.

2.b Applicable Permit

AQD issued Permit To Install No. 230-15A to Kawasaki.

2.c Results

See Table 3 in Section 5.a.

3. Source Description

Sections 3.a through 3.e provide a detailed description of the process.

3.a Process Description

See section 1.c for a process description.

3.b Process Flow Diagram

A process flow diagram is available on request.

3.c Raw and Finished Materials

During the emissions test program, the engines fired E10, a mixture of 90% gasoline and 10% ethanol. Fuel usage rates for each of the engines were monitored throughout the emissions test program as the average of individual fuel usage rates.

3.d Process Capacity

Each test cell is able to run up to a 50 horsepower engine.

3.e Process Instrumentation

Process instrumentation and data includes type of fuel used, fuel usage rates, and various other parameters for each of the test cells. Process data is provided in Appendix D.

4. Sampling and Analytical Procedures

Sections 4.a through 4.d provide a summary of the sampling and analytical procedures used.

4.a Sampling Train and Field Procedures

Measurement of exhaust gas velocity, molecular weight, and moisture content were conducted using the following reference test methods codified at Title 40, Part 60, Appendix A of the Code of Federal Regulations (40 CFR 60, Appendix A):

- Method 1 - *"Sample and Velocity Traverses for Stationary Sources"*
- Method 2 - *"Determination of Stack Gas Velocity and Volumetric Flowrate"*
- Method 3 - *"Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources" (Fyrite)*
- Method 4 - *"Determination of Moisture Content in Stack Gases"*

Stack gas velocity traverses were conducted in accordance with the procedures outlined in Method 1 and Method 2 (see Figure 3 and 4 for a schematic of the sampling location). S-type pitot tubes with thermocouple assemblies, calibrated in accordance with Method 2, Section 4.1.1, were used to measure exhaust gas velocity pressures (using a manometer) and temperatures during testing. The S-type pitot tube dimensions were within specified limits, therefore, a baseline pitot tube coefficient of 0.84 (dimensionless) was assigned.

A cyclonic flow check was performed at the sampling location. The existence of cyclonic flow is determined by measuring the flow angle at each sample point. The flow angle is the angle between the direction of flow and the axis of the stack. If the average of the absolute values of the flow angle is greater than 20 degrees, cyclonic flow exists. The null angle was determined to be less than 20 degrees at each sampling point.

Molecular weight was determined according to USEPA Method 3, "Gas Analysis for the Determination of Dry Molecular Weight." The equipment used for this evaluation consisted of a one-way squeeze bulb with connecting tubing and a set of Fyrite® combustion gas analyzers. Carbon dioxide and oxygen content were analyzed using the Fyrite® procedure.

Exhaust gas moisture content was evaluated using Method 4. Exhaust gas was extracted as part of the moisture sampling train and passed through the impinger configuration (see Figure 2). Exhaust gas moisture content was then determined gravimetrically.

4.b Carbon Monoxide (USEPA Method 10)

The CO content of the gas stream was measured using a Teledyne 300EM gas analyzer (test cell exhaust) and a Horiba VIA-510 gas analyzer (scavenge air exhaust). The gas stream was drawn through a stainless-steel probe with a heated in-line filter to remove any particulate, a heated Teflon® sample line, through a refrigerated Teflon® sample

conditioner to remove the moisture from the sample before it entered the analyzers. Data was recorded on a PC equipped with data acquisition software. Recorded CO concentrations were averaged and reported for the duration of each test (as drift corrected per Method 7E).

4.c Recovery and Analytical Procedures

No recovery is necessary for the executed methods.

4.d Sampling Ports

Diagrams of the stacks showing sampling ports in relation to upstream and downstream disturbances are included as Figures 3 and 4.

4.e Traverse Points

Diagrams of the stacks indicating traverse point locations and stack dimensions are included as Figures 3 and 4.

5. Test Results and Discussion

Sections 5.a through 5.k provide a summary of the test results.

5.a Results Tabulation

The overall results of the emissions test program are summarized by Table 3. Detailed results for the emissions test program are summarized by Table 4.

Table 3
Overall Emission Summary
Test Date: September 20, 2017

Emission Unit	Pollutant	Permit Limit	Test Result
Test Cell & Scavenge Air Exhaust	CO	3.94 lb/gal	6.49 lb/gal

5.b Discussion of Results

The test results for the total CO from the test cell and scavenge air exhaust were over the permit limit.

5.c Sampling Procedure Variations

Approximately 44 minutes into Test Run 3, the return (coolant) hose connection on the eddy current dynamometer broke requiring testing to be paused. Randal Tysar with BTEC received verbal confirmation from Karen Kajiya-Mills with the MDEQ to conclude Run 3 with only 44 minutes of data. In addition, Run 1 was paused after twenty-two minutes due to an exhaust leak inside the test cell that caused the life safety system to shut the test cell down.

A Method 205 validation check could not be performed on site. A validation check was performed on 10/3/2017 and is included in Appendix B.

5.d Process or Control Device Upsets

Approximately 44 minutes into Test Run 3, the return (coolant) hose connection on the eddy current dynamometer broke requiring testing to be paused. Randal Tysar with BTEC received verbal confirmation from Karen Kajiya-Mills with the MDEQ to conclude Run 3 with only 44 minutes of data. In addition, Run 1 was paused after twenty-two minutes due to an exhaust leak inside the test cell that caused the life safety system to shut the test cell down.

5.e Control Device Maintenance

No maintenance was performed on the sources being tested.

5.f Re-Test

The emissions test program was not a re-test.

5.g Audit Sample Analyses

No audit samples were collected as part of the test program.

5.h Calibration Sheets

Relevant equipment calibration documents are provided in Appendix B.

5.i Sample Calculations

Sample calculations are provided in Appendix C.

5.j Field Data Sheets

Field documents relevant to the emissions test program are presented in Appendix A.

Table 4
CO Emission Rates
Kawasaki
Grand Rapids, Michigan
BMC Project No. 17-5092
Sampling Date: September 20, 2017

Parameter	Run 1	Run 2	Run 3	Average
Test Run Date	9/20/2017	9/20/2017	9/20/2017	
Test Run Time	10:00-10:22 10:34-11:12	11:42-12:42	13:05-13:49	
Test Cell Outlet Flowrate (dscfm)	2,038	2,027	1,954	**2,006**
Scav Air Outlet Flowrate (dscfm)	2,065	2,008	2,003	**2,025**
L/hr	30	31	31	
Gal/hr	7.9	8.1	8.1	
Outlet Carbon Monoxide Concentration (ppmv)	5,586	5,698	5,603	**5,629**
Outlet CO Concentration (ppmv, corrected as per USEPA 7E)	5,815	6,039	5,955	**5,936**
CO Emission Rate (lb/hr)	**49.49**	**50.19**	**47.59**	**49.09**
CO Emission Rate (lb/hr) (corrected as per USEPA 7E)	**51.51**	**53.19**	**50.58**	**51.76**
Scav Air Outlet Carbon Monoxide Concentration (ppmv)	56.2	49.4	51.2	**52.3**
Scav Air Outlet CO Concentration (ppmv, corrected as per USEPA 7E)	56.6	50.8	52.6	**53.3**
CO Emission Rate (lb/hr)	**0.50**	**0.43**	**0.45**	**0.46**
CO Emission Rate (lb/hr) (corrected as per USEPA 7E)	**0.51**	**0.44**	**0.46**	**0.47**
lb/hr combined	**52.0**	**53.6**	**51.0**	**52.2**
Lbs/gal	**6.61**	**6.59**	**6.28**	**6.49**

scfm = standard cubic feet per minute
dscfm = dry standard cubic feet per minute
ppmv = parts per million on a volume-to-volume basis
lb/hr = pounds per hour
MW = molecular weight (CO = 28.01)
24.14 = molar volume of air at standard conditions (70°F, 29.92" Hg)
35.31 = ft^3 per m^3
453600 = mg per lb

Equations
lb/hr = ppmv * MW/24.14 * 1/35.31 * 1/453,600 * ***dcfm*** * 60

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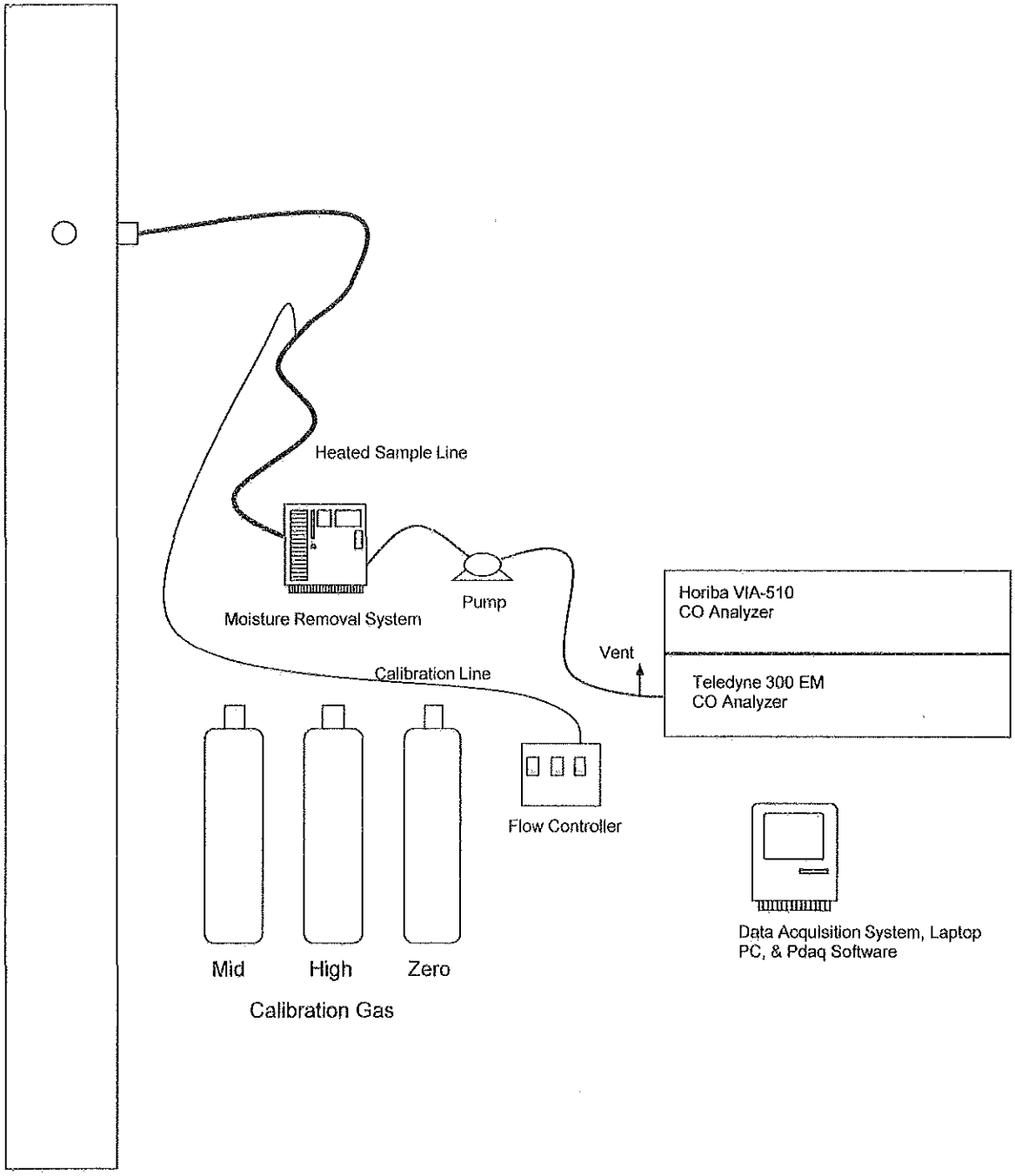

Figure No. 1

Site: **USEPA Method 10** **Kawasaki Motors Corp. USA** **Grand Rapids, MI**	**Sampling Date:** **September 20, 2017**	**BT Environmental Consulting Inc.** **4949 Fernlee Avenue** **Royal Oak, MI 48073**

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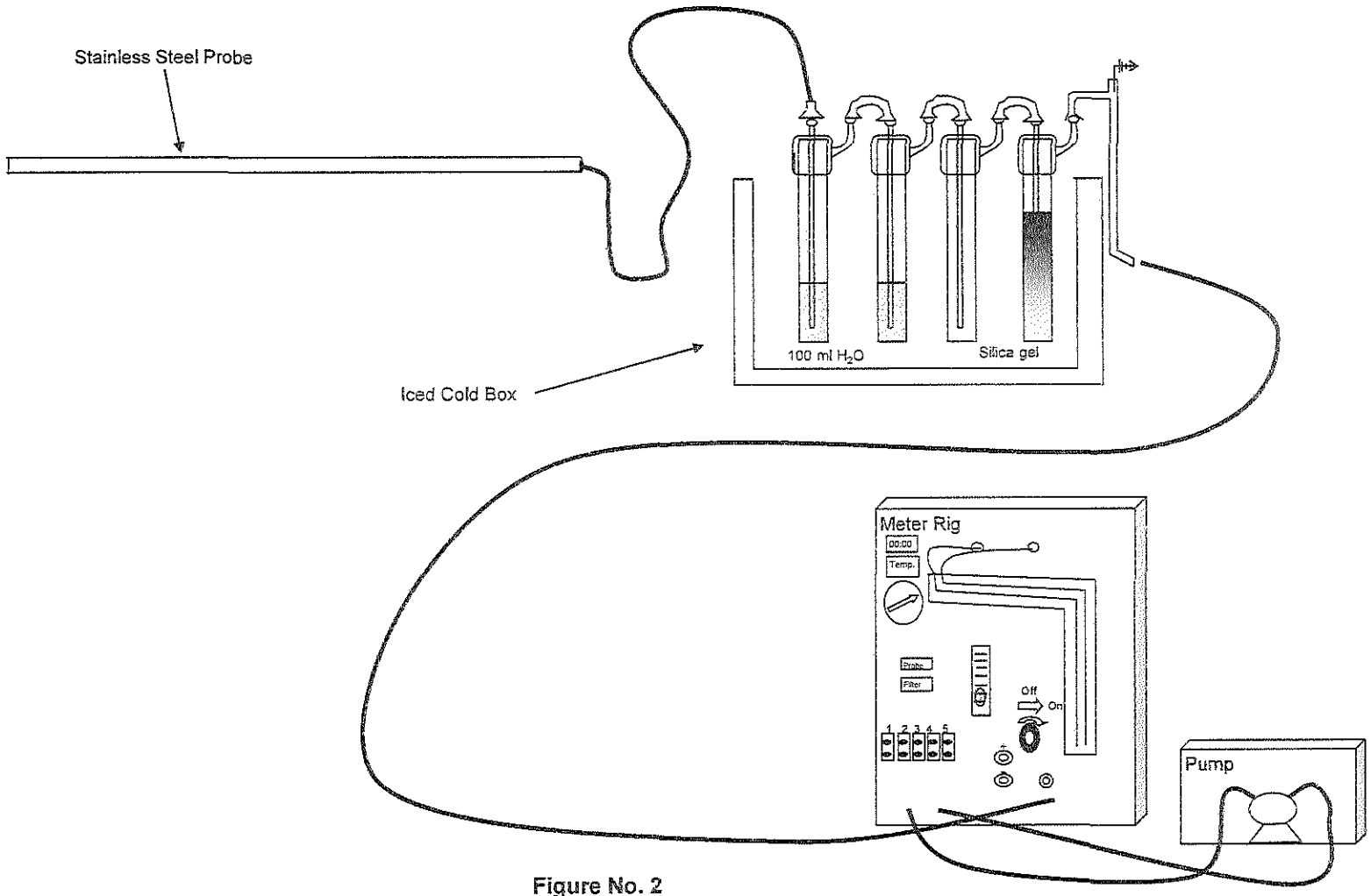

Figure No. 2

Site:	Sampling Date:	
USEPA Method 4 Kawasaki Motors Corp. USA Grand Rapids, MI	September 20, 2017	BT Environmental Consulting, Inc. 4949 Fernlee Avenue Royal Oak, Michigan 48073

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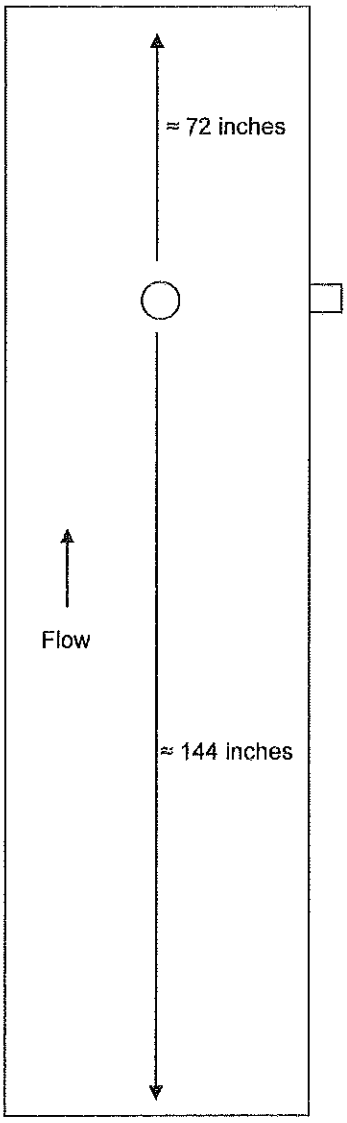
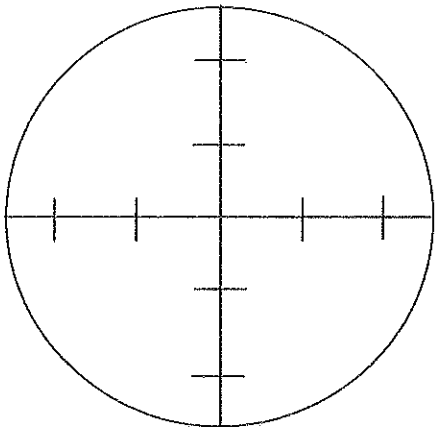
diameter = 18 inches





Not to Scale

Points	Distance "
1	1.2
2	4.5
3	13.5
4	17.9

Figure No. 3

Site: **Test Cell Exhaust** **Kawasaki Motors Corp. USA** **Grand Rapids, MI**	**Sampling Date:** **September 20, 2017**	**BT Environmental Consulting, Inc.** **4949 Fernlee Avenue** **Royal Oak, Michigan 48073**

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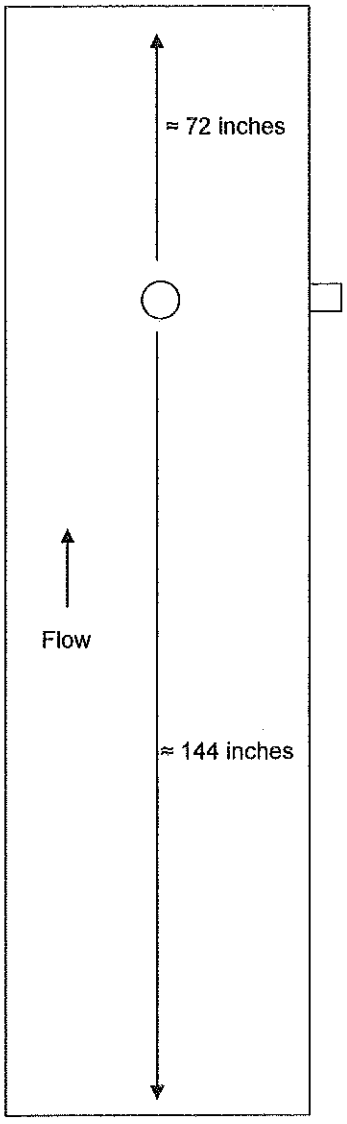
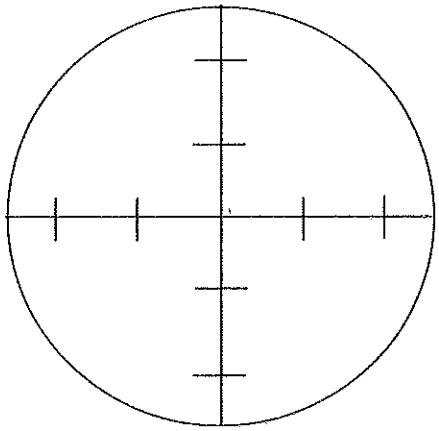
diameter = 16 inches





Not to Scale

Points	Distance "
1	1.1
2	4.0
3	12.0
4	15.9

Figure No. 4

Site: **Scavenge Air Exhaust** **Kawasaki Motors Corp. USA** **Grand Rapids, MI**	**Sampling Date:** **September 20, 2017**

BT Environmental Consulting, Inc.
4949 Fernlee Avenue
Royal Oak, Michigan 48073