2017-2021 North American Round-Robin Correlation Test Project for Off-Highway Recreational Vehicles

EPA United States Environmental Protection Agency

2017-2021 North American Round-Robin Correlation Test Project for Off-Highway Recreational Vehicles

Compliance Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

California Air Resources Board

Environment and Climate Change Canada

EPA-420-R-22-018
July 2022

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I. PROGRAM OVERVIEW

The 2017-2021 North American Round-Robin Correlation Test Project for off-highway recreational vehicles (OHRV) is a collaborative program developed, organized, and managed by the U.S. Environmental Protection Agency (U.S. EPA), California Air Resources Board (CARB), and Environment and Climate Change Canada (ECCC). This program is the first round-robin correlation study involving the measurement of OHRV exhaust emission rates among the agencies. The main objective of this program was to evaluate the correlation and variability of exhaust emissions measurements among North American OHRV's testing laboratories. It is important to note that this program was not designed as a laboratory audit or a durability test of the test vehicles. Instead, the results of this program are intended to be used as a high-level tool for participating laboratories to gauge their performance and identify opportunities for improvement.

The test procedures described in this program are based on Title 40 of the Code of Federal Regulations (CFR) Part 86, Subpart F (*Emission Regulations for 1978 And Later New Motorcycles*). The associated regulations in California are the *California Exhaust Emissions Standards and Test Procedures for 1997 and Later Off-Highway Recreational Vehicles and Engines*. Furthermore, in Canada there are the *Marine Spark-Ignition Engine, Vessel and Off-Road Recreational Vehicle Emission Regulations,* which are harmonized with the U.S. EPA's regulations. It should also be noted that the term 'OHRV' is used as a generic term for the vehicles described in this report; The detailed guidance on which procedures to use for the various defined classes of recreational vehicles can be found in the aforementioned regulations.

II. VEHICLE DESCRIPTIONS AND SPECIFICATIONS

Three (3) OHRVs were tested on chassis dynamometers at multiple North American emission testing laboratories. The OHRVs included a 2017 Arctic Cat Alterra, a 2018 Polaris Outlaw, and a 2017 Polaris Ranger XP 1000 EPS with an engine displacement of 112 cc, 550 cc, and 999 cc, respectively.

Figure 1 (below) displays each of the three test vehicles and Table 1 provides the respective regulatory classifications by the three agencies.

Figure 1. *Test Vehicles*

Table 1. *Test vehicle classification regulatory references*

Agency	2017 Arctic Cat Alterra	2018 Polaris Outlaw	2017 Polaris Ranger
EPA	ATVb 40 CFR 1051.801 paragraph 2	ATVa 40 CFR 1051.801 paragraph.1	ATVb 40 CFR 1051.801 paragraph 2
CARB	ATVa 13 CCR 2411	ATVa 13 CCR 2411	Off-Road Sport Vehicle
ECCC	ATVb 40 CFR 1051.801 paragraph 2	ATVa 40 CFR 1051.801 paragraph.1	ATVb 40 CFR 1051.801 paragraph 2

The overall size of the 2017 Arctic Cat Alterra 550 is 91.1 in. (length) x 47.8 in. (width) x 57.4 in. (height). The vehicle has a four-stroke single-cylinder engine with an engine displacement of 550 cc, gross weight of 652 kg, and an equivalent inertial mass (EIM) of 460 kg. The maximum speed of this vehicle is 93.30 km/h. The capacity of the fuel tank is 20.10 liters (5.3 gallons). The vehicle was tested with a tire pressure of 10 pounds per square inch (psi) for both front and rear tires.

The 2018 Polaris Outlaw 110's dimensions are 61.25 in. (length) x 36.75 in. (width) x 38.50 in. (height). This vehicle is a four-stroke single-cylinder engine with an engine displacement of 112 cc and an EIM of 230 kg. The capacity of the fuel tank is 5.9 liters (1.6 gallons). The vehicle was tested with a tire pressure of 3 psi for both front and rear tires.

Finally, the overall size of the 2017 Polaris Ranger XP 1000 is 116.5 in. (length) x 60.0 in. (width) x 76.0 in. (height). The rear track width of the 2017 Polaris Ranger XP 1000 is 41 in. The 2017 Polaris Ranger XP 1000 has a four-stroke twin-cylinder engine with an engine displacement of 999 cc and an EIM of 810 kg. The capacity of the fuel tank is 37.9 liters (10 gallons). The tire pressure is 10 psi for the front tires and 12 psi for the rear tires.

Detailed information about the test specimens and their associated test parameters are provided in Table 2.

Table 2. *Vehicle Information and Test Parameters*

Vehicle (Year/Make/Model):	2017 Arctic Cat Alterra 550	2018 Polaris Outlaw 110	2017 Polaris Ranger XP 1000 EPS
Test Vehicle VIN or other ID:	4VF17ATV1HT201163	RF3YAK112JT021725	4XARTA996H8558638
Engine Displacement (cc):	550	112	999
Engine Family:	H3AXX.5452H1	JPOLX.112PFC	HPOLX.999PF1
Motorcycle Class:	I	I	I
Transmission:	NA*	NA	NA
Idle Speed (rpm)	NA	NA	1,250
Motorcycle Top Speed (km/h):	93.3	NA	NA
Tire Make & Model:	Carlisle Trail Pro	Duro	Maxxis Ceros
Front Tire Size:	25X8.0 - 12 NHS 78D	NA	NA
Rear Tire Size:	25X10 - 12 NHS 78D	NA	NA
Front and Rear Tire Pressure (psi):	10	3	10 and 12
GVWR (kg):	652	NA	NA
Dry Mass (kg):	328.9	126.0	689.6
Curb Mass (kg):	378	NA	NA
Loaded Vehicle Mass (kg):	458	NA	NA
Equivalent Inertia Mass (kg):	460	230	810
Force Coefficients			
A (N):	31.41	11.31	62
C ($N/(km/h)^2$)	0.0319	0.0260	0.0340
Force (Road Load) at 65 km/h (N):	166.0	121.2	206.7
70 to 60 km/h Coast down Target			
Time (s):	7.73	5.30	10.99
Allowable Tolerances			
Longest Time (s):	8.0	5.5	11.3
Shortest Time (s):	7.5	5.1	10.7
Fuel Tank Capacity (L):	20.1	5.9	37.9
50% Fuel Tank Capacity (L):	10.5	2.95	18.95

*NA: Not Available

III. PARTICIPATING LABORATORIES

The following fifteen laboratories have participated in the 2017-2020 North American Round Robin Correlation Test Project. They are listed in a randomized order.

a) U.S. EPA, National Vehicle and Fuel Emissions Laboratory (NVFEL), Ann Arbor, Michigan, U.S.A.
b) California Air Resources Board, Haagen-Smit Laboratory (HSL), El Monte, California, U.S.A.
c) Environment and Climate Change Canada, Ottawa, Ontario, Canada
d) Bombardier Recreational Products, Valcourt, Quebec, Canada
e) S&S Cycle, Inc., La Crosse, Wisconsin, U.S.A.
f) Transportation Research Center, Inc., East Liberty, Ohio, U.S.A.
g) Tovatt Engineering, Huntington Beach, California, U.S.A.
h) Roush, Livonia, Michigan, U.S.A.
i) California Environmental Engineering, Santa Ana, California, U.S.A.
j) Polaris Wyoming MN Product Development Center, Wyoming, Minnesota, U.S.A.
k) Minnesota Center for Automotive Research, Mankato, Minnesota, U.S.A.
l) Excel Engineering Emissions Testing, Diagonal, Iowa, U.S.A.
m) ESW America, Montgomeryville, Pennsylvania, U.S.A.
n) Automotive Testing and Development Service Inc., Ontario, California, U.S.A.
o) Tovatt Engineering Emissions Testing, Parker, Arizona, USA

IV. TEST FUEL

The test vehicles were filled with Tier 2 Certification Fuel (Indolene Clear), meeting the specifications described in 40 Code of Federal Regulations (CFR) §86.513.

V. DRIVE CYCLE

The test vehicles were tested on the Class I dynamometer schedule, Appendix I(b) of the 40 CFR Part 86, regardless of the engine displacement.

VI. TEST PROCEDURE

The test procedure was defined based on 40 CFR Part 86, Subpart F (Emission Regulations For 1978 And Later New Motorcycles; Test Procedures) and California Exhaust Emissions Standards and Test Procedures for 1997 and Later Off-Highway Recreational Vehicles and Engines, Amended October 25, 2012. Since the primary objective was to determine correlation and variability among laboratories, the defined test procedure was slightly modified compared to the CFR standard certification test procedures to provide participants a valuable tool for gauging their measurements compared to others in the program.

For all OHRVs, the following test procedures were used:

Pre-Test Check: Per 40 CFR §86.509-90 (b)(1), the static pressure variations at the tailpipe of the test vehicle remain within ±0.25 kPa (±1.00 in. H_2O).

Number of Tests: Three complete, valid exhaust test series are required per vehicle.

1. Drain fuel and re-fill tank to 50% capacity with Tier 2 Certification Fuel (Indolene Clear) meeting the specifications in 40 CFR §86.513.

2. Assure that the pressure of the drive tires is set to the pressure specified in the Vehicle Information and Test Parameters form (provided by EPA per vehicle).

3. Operate the OHRV through one (1) Urban Dynamometer Driving Schedule (UDDS) drive cycle (1,372 seconds) with a top speed of 58.7 km/h (36.5 mph) for OHRVs as specified in 40 CFR §86.515-78(a) [Appendix I(b) of 40 CFR Part 86 for Class I];

    a. Use the Equivalent Inertia Mass (EIM) and force coefficients specified on the Vehicle Information and Test Parameters form.
    b. All-terrain vehicles, off-road sport vehicles, off-road utility vehicles, and sand cars shall be tested on the Class I dynamometer schedule, Appendix I(b), regardless of the engine displacement.

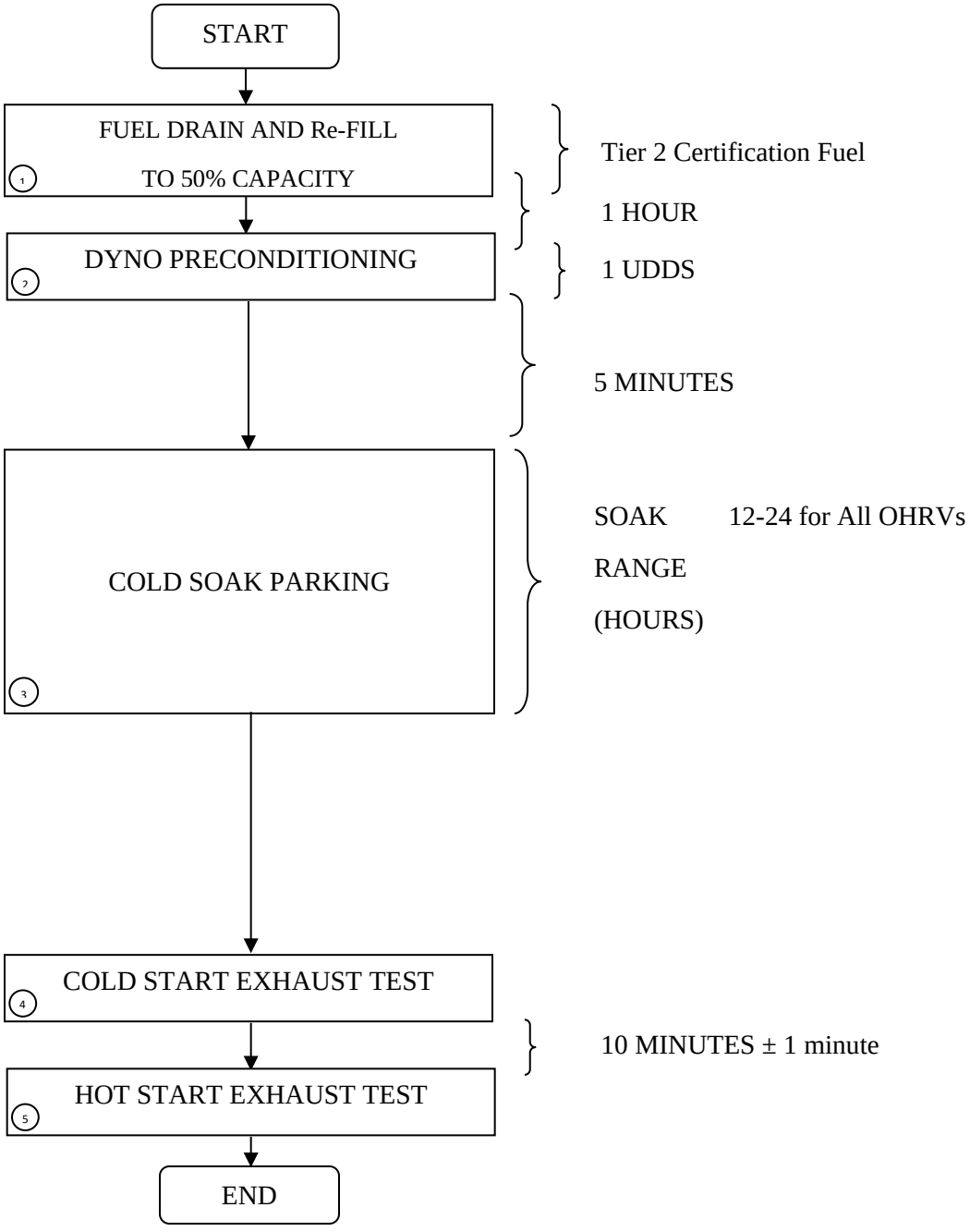
4. Push or drive the test OHRV into cold soak and soak (12 hours to 24 hours) at 68°F to 86°F (20°C to 30°C). Remove the test vehicle key from the ignition.

5. Push the vehicle onto dynamometer and perform cold start FTP exhaust emission test (Phase 1 and Phase 2) by operating the OHRV through one (1) UDDS drive cycle with a top speed of 58.7 km/h (36.5 mph) for OHRVs as specified in 40 CFR §86.515-78(a) [Appendix I(b) of 40 CFR Part 86 for Class I];

    a. Use the EIM and force coefficients specified on the Vehicle Information and Test Parameters form.
    b. All-terrain vehicles, off-road sport vehicles, off-road utility vehicles, and sand cars shall be tested on the Class I dynamometer schedule, Appendix I(b), regardless of the engine displacement.

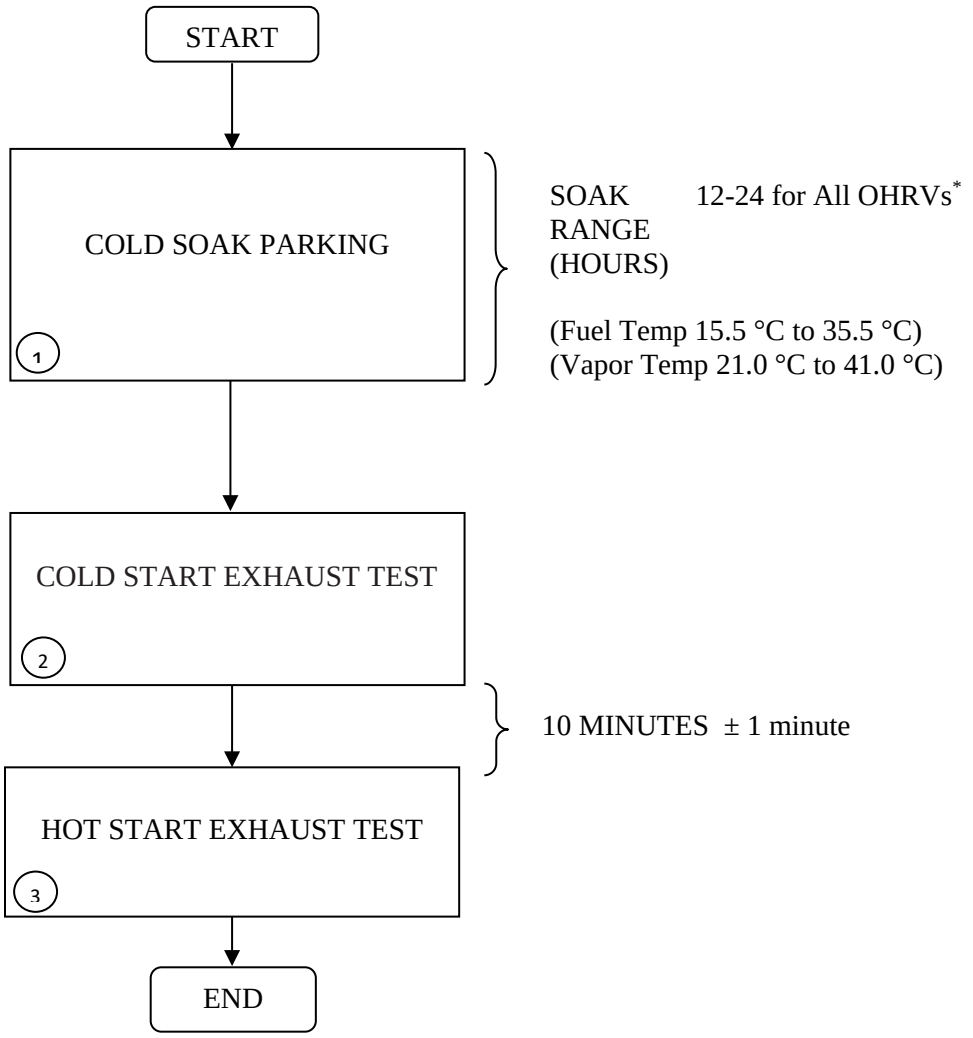
6. Perform a hot start FTP exhaust emission test (Phase 3) by operating the OHRV through the first 505 seconds of a UDDS drive cycle within 10 minutes ± 60 seconds of completing Phase 2 from step 5.
7. Repeat steps 4 through 6 until three valid exhaust tests are completed. If soak time in step 4 exceeds the upper limit (24 hours), repeat steps 1 through 6.

The exhaust emission test sequence is provided in Figure 2 and Figure 3 (OHRV Test Sequence Diagram).



Note: 3 valid tests were completed per vehicle.

Figure 2. *OHRV Exhaust Emission Test Sequence Diagram (If Soak Time exceeds the Upper Limit of 24 hours)*



Note: 3 valid tests were completed per vehicle.

Figure 3. *OHRV Exhaust Emission Test Sequence Diagram (If Soak Time is less than the Upper Limit of 24 hours)*

VII. DRIVER

Each laboratory used one of their drivers to conduct the tests.

VIII. MEASURED POLLUTANTS

All participants measured exhaust emission rates of carbon monoxide (CO), total hydrocarbon (THC), oxides of nitrogen (NO_x), and carbon dioxide (CO_2). Some participants also measured methane (CH_4), non-methane hydrocarbons (NMHC), and non-methane organic gas (NMOG).

IX. TRIANGLE PLOTS

The results are presented using triangle diagrams which illustrate three data points of emission rates for each OHRV and each laboratory, mean emission rates of U.S. EPA, ECCC, and CARB acceptance limits which are ±2 standard deviations (SD). Gaseous exhaust emission test results are illustrated in a random order and the identity of each laboratory remains undisclosed except for the three government agencies.

The triangle plots graphically illustrate the data collected at each lab and the mean value. Each data point is represented by a marker along the vertical side of the triangle. The remaining two sides converge at the right-hand test triangle vertex that denotes the mean of this set of data.

X. DATA ANALYSIS

Correlation between industry laboratories was assessed compared to U.S. EPA, CARB, and ECCC. The student t-distribution analysis determines a statistically significant difference between means. If the difference between means is determined to be statistically significant, at a confidence interval of 95%, the percentage difference is reported; otherwise, the means are considered to be statistically the same. The calculated deviation to the "average of U.S. EPA, CARB, and ECCC" is reported as a percentage difference.

XI. RESULTS AND DISCUSSION

2017 Arctic Cat Alterra 550

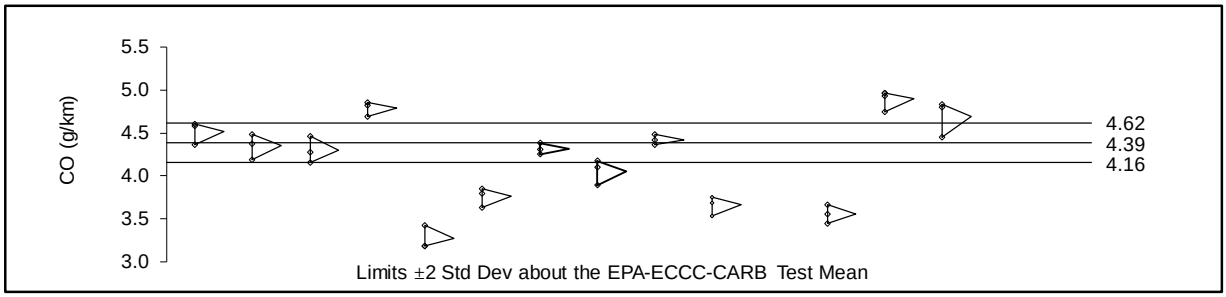
The 2017 Arctic Cat Alterra 550 was measured at 13 different laboratories across North America. Figures 4.1(a) through 4.1(f) show CO, THC, NO_x, CO_2, CH_4, and NMHC emission rates using triangle plots.

For the CO emission rates, only two out of ten private laboratories were within ± 2 standard deviations of the three agencies' emission rates. Although there are high inter-laboratory variabilities of CO emission rates, the two standard deviations band was narrow ranging from 4.1 g/km to 4.6 g/km. However, CO emission rates of all laboratories were well below the CO emission standard of 15 g/km. It is important to note that as the testing procedures in this study were slightly different from the certification procedures, no valid comparison can be made compared to the emission standard. The average of the three agencies' CO emission rates was 4.39 g/km, compared to the overall average of 4.20 g/km from all participants.

For the THC emission rates, except for only one private laboratory, all other laboratories were within ± 2 standard deviations of the three agencies' emission rates. THC emission rates of all laboratories were below the THC emission standard of 1.2 g/km. The average of the three agencies' THC emission rates was 0.36 g/km which is equivalent to the overall average from all participants.

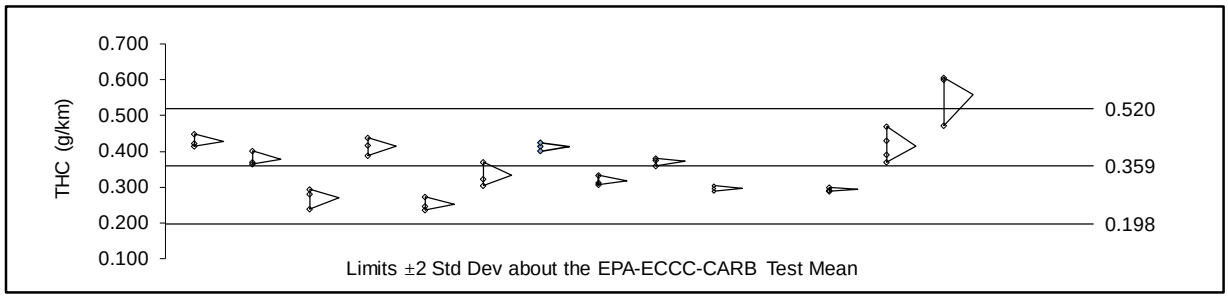
Similarly, for NO_x emission rates, except for only two private laboratories, all other laboratories were within ± 2 standard deviations of the three agencies' emission rates. The average of the three

agencies' NO_x emission rates was 0.17 g/km, compared to the overall average of 0.18 g/km from all participants.



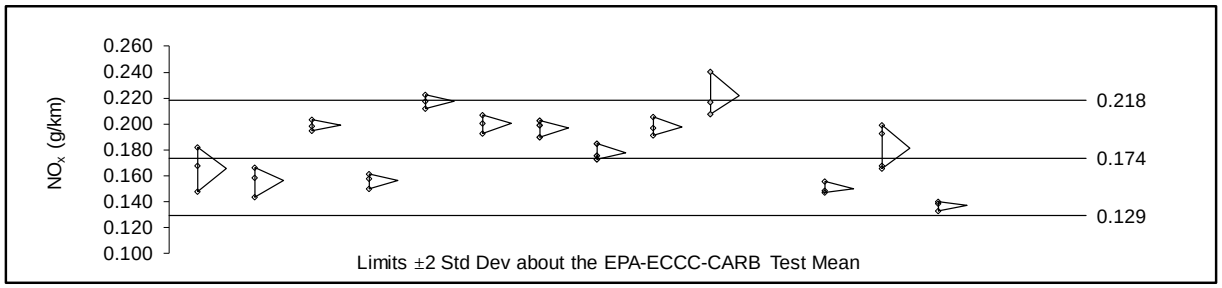
Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	4.52	4.35	4.30	4.79	3.27	3.76	4.32	4.06	4.42	3.66	---	3.55	4.90	4.69	---
STD DEV	0.137	0.149	0.152	0.085	0.139	0.111	0.066	0.147	0.064	0.111	---	0.109	0.104	0.207	---
Coeff. of Variation	3.02	3.43	3.53	1.77	4.27	2.96	1.53	3.63	1.46	3.04	---	3.06	2.12	4.42	---
% Diff to EPA-ECCC-CARB Mean	3.0	-0.9	-2.1	9.2	-25.6	-14.3	-1.6	-7.6	0.7	-16.6	---	-19.0	11.7	7.0	---
% Diff to EPA	No Diff	No Diff	No Diff	6.0	-27.7	-16.8	No Diff	-10.3	No Diff	-19.0	---	-21.3	8.5	No Diff	---
% Diff to ECCC	No Diff	No Diff	No Diff	11.5	-24.0	-12.5	No Diff	No Diff	No Diff	-14.9	---	-17.3	14.1	No Diff	---
% Diff to CARB	No Diff	No Diff	No Diff	10.2	-24.9	-13.5	No Diff	No Diff	No Diff	-15.8	---	-18.2	12.7	No Diff	---
Number of Tests	3	3	4	3	3	3	3	3	3	3	---	3	3	3	---

(a) CO Emission Rates



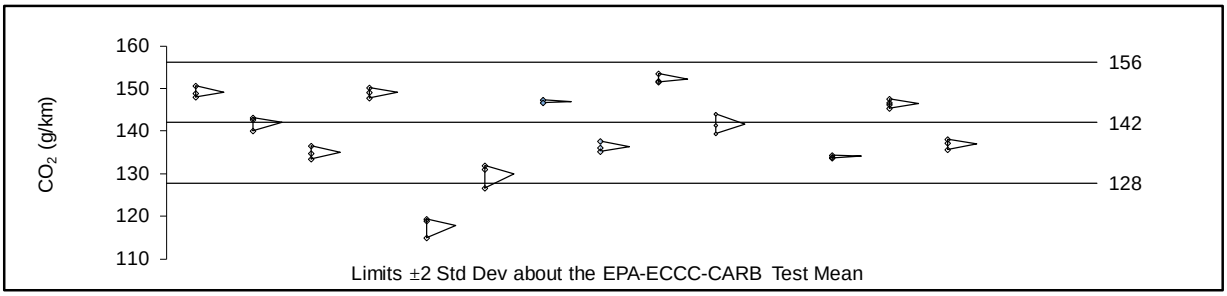
Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	0.428	0.379	0.271	0.414	0.251	0.332	0.413	0.317	0.372	0.296	---	0.293	0.415	0.559	---
STD DEV	0.017	0.019	0.030	0.025	0.019	0.033	0.012	0.015	0.011	0.009	---	0.006	0.045	0.077	---
Coeff. of Variation	4.08	5.13	10.91	6.04	7.48	10.00	2.80	4.71	3.06	2.89	---	2.05	10.78	13.68	---
% Diff to EPA-ECCC-CARB Mean	19.2	5.5	-24.7	15.3	-30.1	-7.6	15.1	-11.7	3.4	-17.5	---	-18.4	15.5	55.7	---
% Diff to EPA	No Diff	-11.5	-36.8	No Diff	-41.3	-22.5	No Diff	-26.0	-13.2	-30.8	---	-31.6	No Diff	30.6	---
% Diff to ECCC	58.2	40.0	No Diff	53.0	No Diff	No Diff	52.8	No Diff	37.3	No Diff	---	No Diff	53.3	106.7	---
% Diff to CARB	13.0	No Diff	-28.6	No Diff	-33.7	No Diff	No Diff	-16.3	No Diff	-21.7	---	-22.7	No Diff	47.7	---
Number of Tests	3	3	4	3	3	3	3	3	3	3	---	3	3	3	---

(b) THC Emission Rates



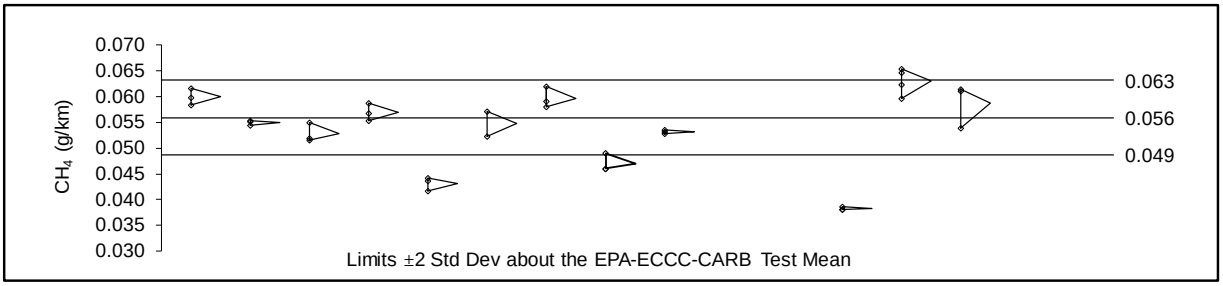
Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	0.166	0.156	0.199	0.156	0.218	0.200	0.197	0.178	0.198	0.222	---	0.150	0.181	0.137	---
STD DEV	0.017	0.012	0.004	0.005	0.005	0.007	0.007	0.006	0.007	0.017	---	0.005	0.017	0.004	---
Coeff. of Variation	10.19	7.44	2.13	3.50	2.42	3.58	3.37	3.51	3.47	7.46	---	3.00	9.38	2.76	---
% Diff to EPA-ECCC-	-4.5	-10.0	14.5	-10.0	25.1	15.2	13.5	2.4	13.9	27.6	---	-13.6	4.3	-21.0	---
% Diff to EPA	No Diff	No Diff	19.9	No Diff	31.0	20.6	18.8	No Diff	19.3	33.5	---	No Diff	No Diff	-17.3	---
% Diff to ECCC	-16.6	-21.4	No Diff	-21.4	9.3	No Diff	No Diff	-10.6	No Diff	No Diff	---	-24.5	No Diff	-31.0	---
% Diff to CARB	No Diff	No Diff	27.2	No Diff	39.1	28.0	26.1	13.8	26.6	41.7	---	No Diff	No Diff	No Diff	---
Number of Tests	3	3	4	3	3	3	3	3	3	3	---	3	3	3	---

(c) NO_x Emission Rates



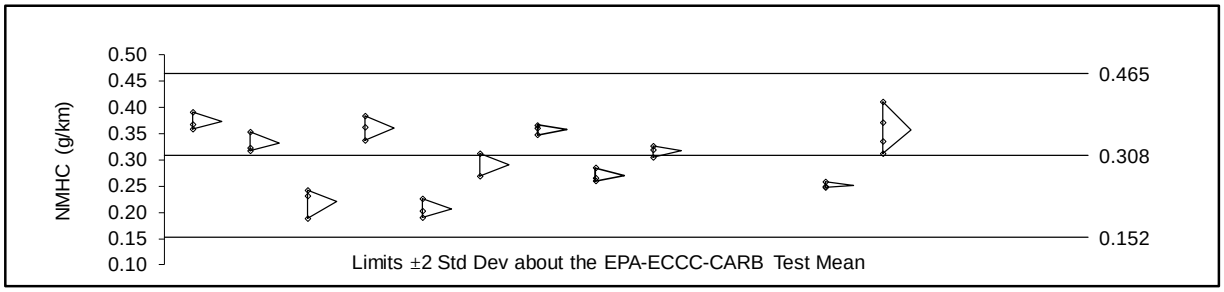
Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	149.20	142.06	134.98	149.10	117.76	129.93	146.96	136.37	152.25	141.66	---	134.06	146.46	136.93	---
STD DEV	1.31	1.65	1.61	1.20	2.40	2.84	0.40	1.24	1.09	2.40	---	0.37	0.90	1.23	---
Coeff. of Variation	0.88	1.16	1.19	0.80	2.04	2.18	0.27	0.91	0.72	1.69	---	0.28	0.61	0.89	---
% Diff to EPA-ECCC-	5.0	0.0	-5.0	4.9	-17.1	-8.6	3.4	-4.0	7.2	-0.3	---	-5.6	3.1	-3.6	---
% Diff to EPA	No Diff	-4.8	-9.5	No Diff	-21.1	-12.9	-1.5	-8.6	2.0	-5.1	---	-10.1	-1.8	-8.2	---
% Diff to ECCC	10.5	5.2	No Diff	10.5	-12.8	No Diff	8.9	No Diff	12.8	4.9	---	No Diff	8.5	No Diff	---
% Diff to CARB	5.0	No Diff	-5.0	5.0	-17.1	-8.5	3.4	-4.0	7.2	No Diff	---	-5.6	3.1	-3.6	---
Number of Tests	3	3	4	3	3	3	3	3	3	3	---	3	3	3	---

(d) CO_2 Emission Rates



Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	0.060	0.055	0.053	0.057	0.043	0.055	0.060	0.047	0.053	---	---	0.038	0.063	0.059	---
STD DEV	0.002	0.000	0.002	0.002	0.001	0.004	0.002	0.002	0.000	---	---	0.000	0.003	0.004	---
Coeff. of Variation	2.64	0.80	3.49	3.01	3.13	6.46	3.49	3.69	0.54	---	---	0.86	4.02	7.37	---
% Diff to EPA-ECCC-CARB Mean	7.1	-1.7	-5.5	1.9	-22.8	-2.2	6.7	-15.9	-4.9	---	---	-31.6	12.6	5.2	---
% Diff to EPA	No Diff	-8.2	-11.8	No Diff	-27.9	No Diff	No Diff	-21.5	-11.3	---	---	-36.1	No Diff	No Diff	---
% Diff to ECCC	13.4	No Diff	No Diff	7.8	-18.3	No Diff	12.9	-11.0	No Diff	---	---	-27.6	19.2	No Diff	---
% Diff to CARB	9.0	No Diff	No Diff	No Diff	-21.5	No Diff	8.5	-14.5	-3.3	---	---	-30.4	14.5	No Diff	---
Number of Tests	3	3	4	3	3	3	3	3	3	---	---	3	3	3	---

(e) CH_4 Emission Rates



Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	0.373	0.331	0.221	0.361	0.207	0.291	0.359	0.270	0.317	---	---	0.252	0.358	---	---
STD DEV	0.016	0.019	0.028	0.023	0.018	0.030	0.010	0.013	0.01	---	---	0.006	0.043	---	---
Coeff. of Variation	4.40	5.79	12.77	6.49	8.80	10.24	2.71	4.90	3.68	---	---	2.26	12.00	---	---
% Diff to EPA-ECCC-CARB Mean	20.8	7.4	-28.2	17.1	-32.9	-5.7	16.3	-12.4	2.82	---	---	-18.4	16.0	---	---
% Diff to EPA	No Diff	-11.1	-40.6	No Diff	-44.5	-21.9	No Diff	-27.5	-14.89	---	---	-32.5	No Diff	---	---
% Diff to ECCC	68.4	49.7	No Diff	63.2	No Diff	No Diff	62.1	No Diff	43.29	---	---	No Diff	61.7	---	---
% Diff to CARB	12.4	No Diff	-33.2	No Diff	-37.5	No Diff	No Diff	-18.5	No Diff	---	---	-24.1	No Diff	---	---
Number of Tests	3	3	4	3	3	3	3	3	---	---	---	3	3	---	---

(f) NMHC Emission Rates

Note:
(1) Mean value is the reported laboratory value without a DF applied.
(2) %Diff is the student "t" distribution analysis at a 95% confidence ratio.
(3) Dash lines indicate that the results are not available.

Figure 4.1. *2017 Arctic Cat Alterra 550 Exhaust Emission Rates; (a) CO; (b) THC; (c) NO_x; (d) CO_2; (e) CH_4; and (f) NMHC.*

2018 Polaris Outlaw 110

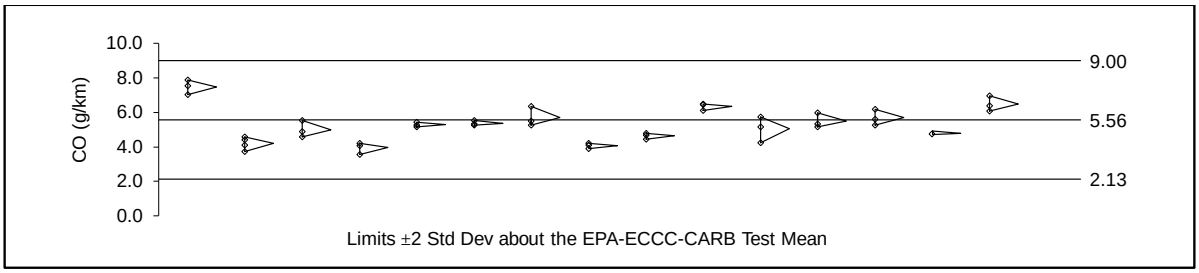
The 2018 Polaris Outlaw 110 was tested at 15 different laboratories across North America.

Figures 4.2(a) through 4.2(f) display the CO, THC, NO_x, CO_2, CH_4, and NMHC emission rates using triangle plots.

Regarding CO emission rates, all laboratories were within ± 2 standard deviations of the three agencies' emission rates. Generally, CO emission rates from all laboratories were well below the CO emission standard of 15 g/km. It is important to note that as the testing procedures in this study were slightly different from the certification procedures, no formal comparison can be made to the emission standard. The average of the three agencies' CO emission rates is 5.56 g/km. Based on all laboratories, the average CO emission rate of the 2018 Polaris Outlaw 110 was 5.30 g/km compared to 5.56 g/km of the three agencies' average.

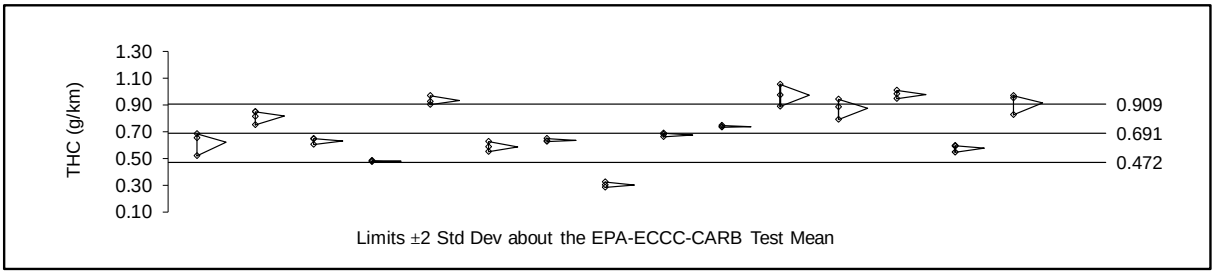
For the THC emission rates, 9 out of 15 laboratories were within ± 2 standard deviations of the three agencies' average. However, all laboratories THC emission rates were below than the 1.2 g/km THC emission standard. The average of the three agencies' THC emission rates was 0.69 g/km, while the average of all laboratories was 0.71 g/km.

There was high inter-laboratory variability with the NO_x results on this specimen ranging from 0.34 g/km to 0.59 g/km. This contrasts with highly consistent results from the respective government agencies. The respective government agencies had relatively consistent results, which ranged from 0.50 g/km to 0.52 g/km. The average of the three agencies' NO_x emission rates was 0.51 g/km; this compared to an average of 0.50 g/km for all participants.



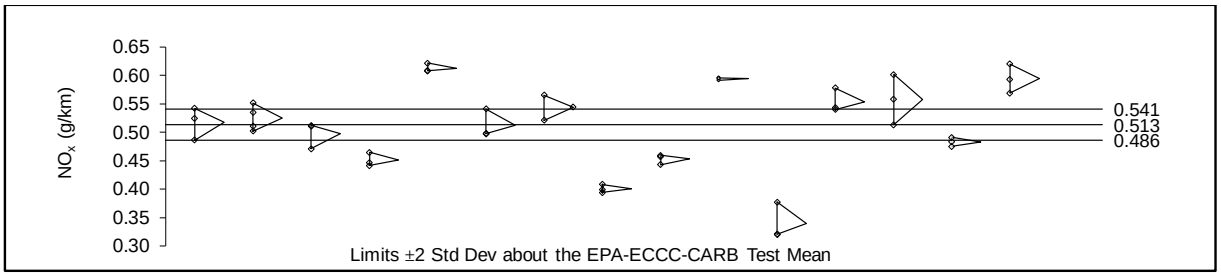
Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	7.49	4.20	5.00	3.95	5.28	5.37	5.71	4.06	4.64	6.35	5.05	5.49	5.69	4.79	6.48
STD DEV	0.425	0.373	0.494	0.341	0.136	0.150	0.567	0.157	0.167	0.218	0.747	0.426	0.465	0.106	0.436
Coeff. of Variation	5.67	8.89	9.88	8.62	2.57	2.79	9.94	3.87	3.59	3.42	14.80	7.76	8.18	2.21	6.72
% Diff to EPA-ECCC-CARB Mean	34.7	-24.5	-10.2	-28.9	-5.1	-3.4	2.6	-27.0	-16.5	14.2	-9.2	-1.3	2.3	-13.8	16.5
% Diff to EPA	No Diff	-43.9	-33.3	-47.2	-29.5	-28.3	-23.8	-45.8	-38.0	-15.2	-32.6	-26.7	-24.0	-36.0	-13.5
% Diff to ECCC	78.3	No Diff	No Diff	No Diff	25.7	27.9	35.8	No Diff	No Diff	51.3	No Diff	30.7	35.5	-36.0	-13.5
% Diff to CARB	49.9	No Diff	No Diff	-20.8	No Diff	No Diff	No Diff	-18.7	No Diff	27.2	No Diff	No Diff	No Diff	No Diff	29.7
Number of Tests	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3

(a) CO Emission Rates



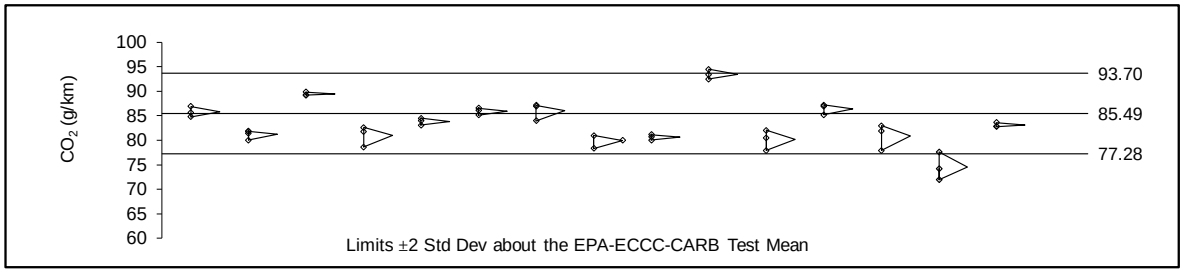
Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	0.621	0.817	0.634	0.480	0.933	0.589	0.636	0.304	0.678	0.741	0.973	0.875	0.980	0.579	0.918
STD DEV	0.087	0.046	0.025	0.005	0.034	0.037	0.012	0.021	0.014	0.006	0.082	0.076	0.030	0.028	0.078
Coeff. of Variation	13.98	5.69	4.00	1.14	3.64	6.19	1.86	6.85	2.12	0.78	8.43	8.70	3.04	4.92	8.51
% Diff to EPA-ECCC-CARB Mean	-10.0	18.3	-8.2	-30.5	35.1	-14.7	-7.9	-56.0	-1.9	7.3	40.9	26.8	41.9	-16.2	32.9
% Diff to EPA	No Diff	31.5	No Diff	-22.7	50.2	No Diff	No Diff	-51.1	No Diff	No Diff	56.7	40.9	57.8	No Diff	47.7
% Diff to ECCC	-23.9	No Diff	-22.4	-41.2	14.2	-27.8	-22.1	-62.8	-17.0	-9.3	19.2	No Diff	20.0	-6.9	No Diff
% Diff to CARB	No Diff	28.8	No Diff	-24.3	47.1	No Diff	No Diff	-52.0	No Diff	16.8	53.5	38.1	54.6	No Diff	44.7
Number of Tests	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3

(b) THC Emission Rates



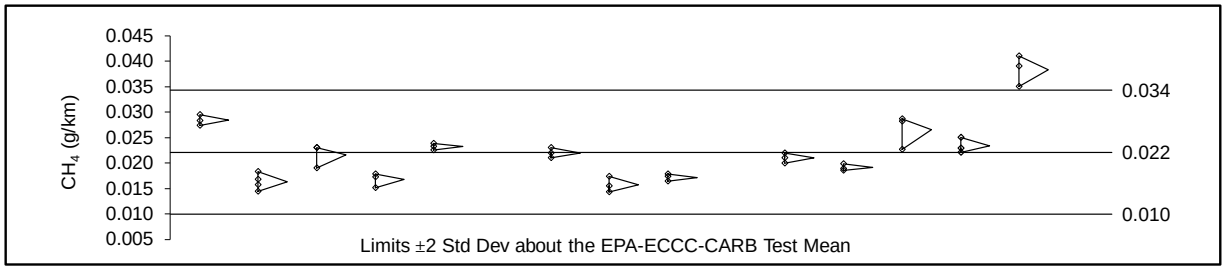
Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	0.517	0.525	0.498	0.451	0.613	0.512	0.544	0.400	0.453	0.594	0.339	0.554	0.557	0.483	0.594
STD DEV	0.029	0.023	0.023	0.012	0.007	0.025	0.022	0.007	0.009	0.002	0.033	0.021	0.044	0.008	0.026
Coeff. of Variation	5.521	4.339	4.696	2.686	1.212	4.906	4.064	1.812	1.969	0.360	9.614	3.785	7.930	1.656	4.295
% Diff to EPA-ECCC-	0.8	2.2	-3.0	-12.2	19.3	-0.3	6.0	-22.0	-11.7	15.7	-33.9	7.9	8.6	-5.9	15.7
% Diff to EPA	No Diff	No Diff	No Diff	-12.9	18.4	No Diff	No Diff	-22.6	-12.4	14.8	-34.4	No Diff	No Diff	No Diff	14.8
% Diff to ECCC	No Diff	No Diff	No Diff	-14.1	16.7	No Diff	No Diff	-23.7	-13.7	13.2	-35.3	No Diff	No Diff	-6.7	14.8
% Diff to CARB	No Diff	No Diff	No Diff	-9.4	23.0	No Diff	No Diff	-19.6	-9.0	19.3	-31.9	11.2	No Diff	No Diff	19.3
Number of Tests	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3

(c) NO_x Emission Rates



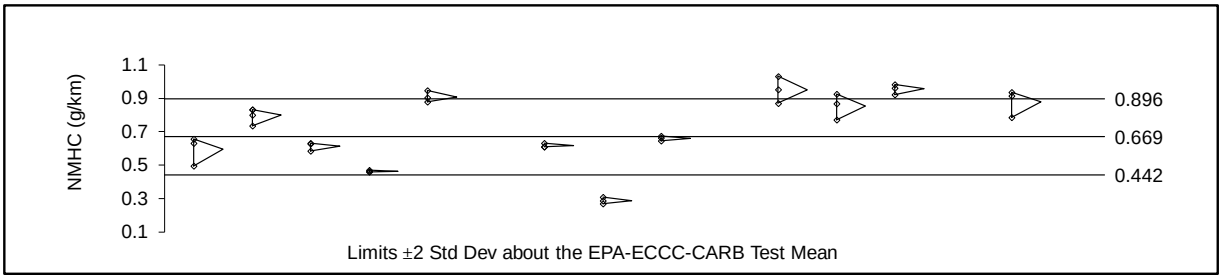
Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	85.77	81.25	89.45	81.02	83.87	85.92	86.03	79.95	80.62	93.45	80.15	86.43	80.94	74.58	83.08
STD DEV	1.07	0.84	0.35	2.13	0.71	0.72	1.78	1.41	0.55	0.99	2.09	1.07	2.67	2.81	0.46
Coeff. of Variation	1.25	1.03	0.39	2.63	0.85	0.83	2.07	1.76	0.69	1.05	2.61	1.24	3.30	3.76	0.55
% Diff to EPA-ECCC-CARB Mean	0.3	-5.0	4.6	-5.2	-1.9	0.5	0.6	-6.5	-5.7	9.3	-6.2	1.1	-5.3	-12.8	-2.8
% Diff to EPA	No Diff	-5.3	4.3	-5.5	No Diff	No Diff	No Diff	-6.8	-6.0	9.0	-6.5	No Diff	-5.6	-13.0	-3.1
% Diff to ECCC	5.6	No Diff	10.1	No Diff	3.2	5.7	5.9	No Diff	No Diff	15.0	No Diff	6.4	No Diff	-13.0	-3.1
% Diff to CARB	-4.1	-9.2	No Diff	-9.4	-6.2	-3.9	-3.8	-10.6	-9.9	4.5	-10.4	-3.4	-9.5	-16.6	-7.1
Number of Tests	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3

(d) CO_2 Emission Rates



Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	0.028	0.016	0.022	0.017	0.023	---	0.022	0.016	0.017	---	0.021	0.019	0.027	0.023	0.038
STD DEV	0.001	0.002	0.002	0.001	0.001	---	0.001	0.002	0.001	---	0.001	0.001	0.003	0.001	0.003
Coeff. of Variation	3.66	10.06	10.66	8.45	2.59	---	4.55	9.93	4.18	---	4.76	3.31	12.55	6.42	7.97
% Diff to EPA-ECCC-CARB Mean	28.4	-26.3	-2.1	-24.5	4.8	---	-0.6	-28.9	-22.4	---	-5.1	-13.8	19.9	5.4	73.2
% Diff to EPA	No Diff	-42.6	-23.8	-41.2	-18.4	---	-22.6	-44.6	-39.6	---	-26.1	-32.8	No Diff	-17.9	34.8
% Diff to ECCC	74.2	No Diff	32.8	No Diff	42.2	---	34.8	No Diff	No Diff	---	28.7	17.0	62.6	-17.9	34.8
% Diff to CARB	31.2	-24.7	No Diff	-22.8	No Diff	---	No Diff	-27.3	-20.7	---	No Diff	No Diff	No Diff	No Diff	76.9
Number of Tests	3	3	4	3	3	---	3	3	3	---	3	3	3	3	3

(e) CH_4 Emission Rates



Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	0.595	0.800	0.613	0.465	0.909	---	0.616	0.288	0.660	---	0.952	0.855	0.956	---	0.879
STD DEV	0.086	0.045	0.026	0.007	0.034	---	0.012	0.019	0.015	---	0.082	0.077	0.030	---	0.081
Coeff. of Variation	14.46	5.69	4.29	1.45	3.69	---	1.97	6.68	2.28	---	8.56	9.02	3.17	---	9.17
%Diff to EPA-ECCC-CARB Mean	-11.1	19.5	-8.4	-30.6	35.8	---	-8.0	-56.9	-1.4	---	42.2	27.7	42.9	---	31.4
%Diff to EPA	No Diff	34.5	No Diff	No Diff	52.8	---	No Diff	-51.5	No Diff	---	60.0	43.7	60.8	---	47.8
%Diff to ECCC	-25.6	No Diff	-23.3	-41.9	13.6	---	-23.0	-64.0	-17.5	---	19.0	No Diff	19.5	---	No Diff
%Diff to CARB	No Diff	30.4	No Diff	-24.3	48.2	---	No Diff	-53.0	No Diff	---	55.2	39.3	55.9	---	43.4
Number of Tests	3	3	4	3	3	---	3	3	3	---	3	3	3	---	3

(f) NMHC Emission Rates

Note:
(1) Mean value is the reported laboratory value without a DF applied.
(2) %Diff is the student "t" distribution analysis at a 95% confidence ratio.
(3) Dash lines indicate that the results are not available.

Figure 4.2. *2018 Polaris Outlaw 110 Exhaust Emission Rates; (a) CO; (b) THC; (c) NO_x; (d) CO_2; (e) CH_4; and (f) NMHC.*

2017 Polaris Ranger XP 1000 EPS

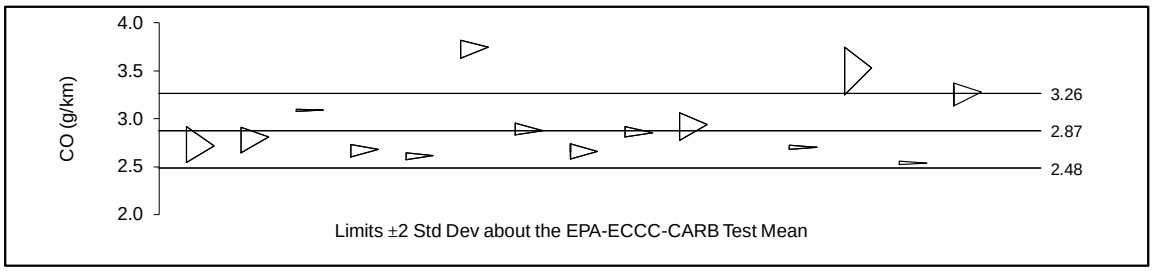
The 2017 Polaris Ranger XP 1000 EPS was tested at 14 different laboratories across North America.

Figures 4.3(a) through 4.3(f) display the CO, THC, NO_x, CO_2, CH_4, and NMHC emission rates using triangle plots.

Concerning CO emission rates, except for three private laboratories, participants were within ± 2 standard deviations of the three agencies' average. There was some variability, but generally, CO emission rates from all laboratories were observed to be well below the standard of 15 g/km. Once again, it is important to note that as the testing procedures in this study were slightly different from the certification procedures, no formal comparison can be made to the emission standard. The average of the three agencies' CO emission rates is 2.87 g/km. The average CO emission rate of the 2017 Polaris Ranger XP 1000 EPS from all laboratories was 2.93 g/km, compared to 2.87 g/km of the three agencies.

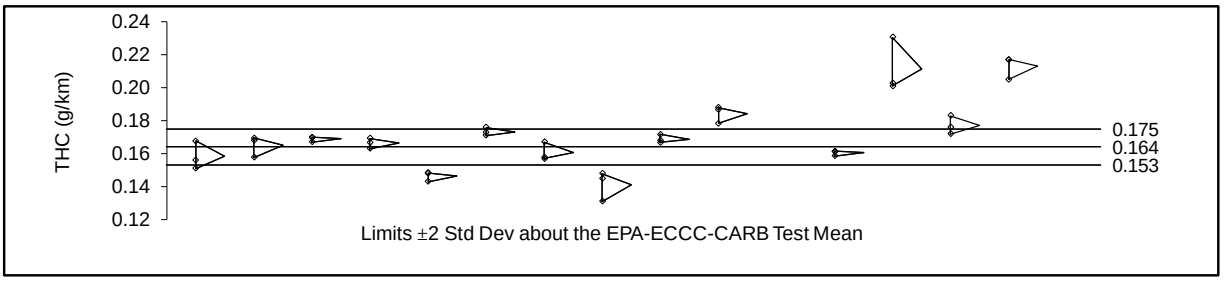
Regarding THC emission rates, 8 out of 14 laboratories were within ± 2 standard deviations of the three agencies' average while all laboratories were well below of the 1.2 g/km THC emission standard. The average of the three agencies' THC emission rates was 0.16 g/km, compared to 0.17 g/km from all participants averaged.

Furthermore, NO_x emission results varied between participants. However, there were 10 out of 14 laboratories that their NOx emission rates were within ± 2 standard deviations. The average of the three agencies' NO_x emission rates was 0.45 g/km, compared to an overall average of 0.47 g/km from all participants.



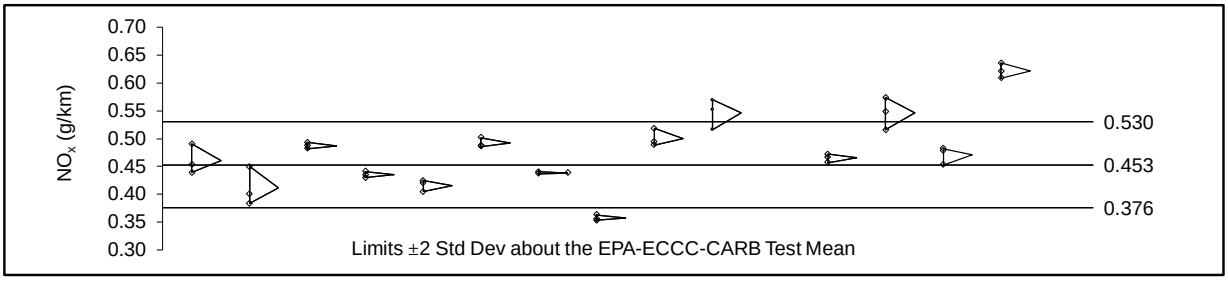
Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	2.72	2.81	3.09	2.68	2.61	3.75	2.87	2.66	2.85	2.94	---	2.70	3.53	2.54	3.28
STD DEV	0.19	0.15	0.01	0.07	0.04	0.10	0.07	0.08	0.06	0.15	---	0.02	0.25	0.02	0.13
Coeff. of Variation	6.96	5.20	0.34	2.54	1.48	2.69	2.44	2.90	2.14	5.13	---	0.80	7.20	0.68	3.97
% Diff to EPA-ECCC-CARB Mean	-5.4	-2.1	7.6	-6.6	-9.0	30.5	0.03	-7.5	-0.7	2.3	---	-5.9	23.1	-11.7	14.3
% Diff to EPA	No Diff	No Diff	13.8	No Diff	No Diff	38.0	No Diff	No Diff	No Diff	No Diff	---	No Diff	30.1	No Diff	20.8
% Diff to ECCC	-12.1	-9.0	No Diff	-13.2	-15.4	21.3	-7.0	-14.0	-7.7	No Diff	---	-12.5	14.4	-17.9	No Diff
% Diff to CARB	No Diff	No Diff	9.9	No Diff	No Diff	33.3	No Diff	No Diff	No Diff	No Diff	---	No Diff	25.7	-6.6	20.8
Number of Tests	3	3	4	3	3	3	3	3	3	3	---	3	3	3	3

(a) CO Emission Rates



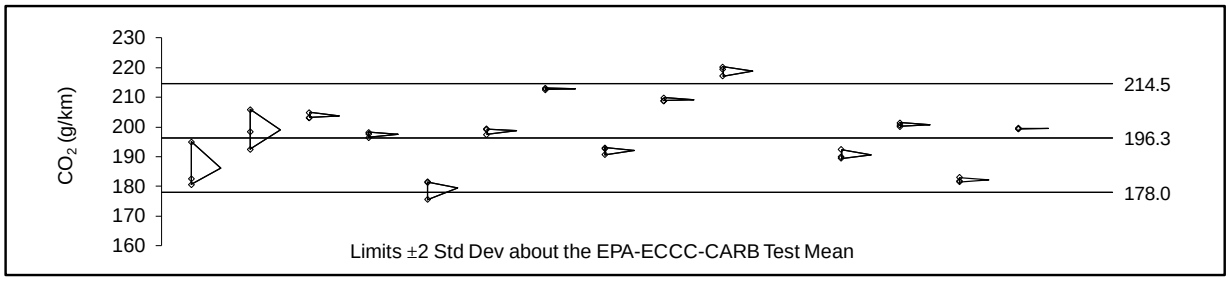
Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	0.158	0.165	0.169	0.166	0.146	0.173	0.161	0.141	0.169	0.184	---	0.161	0.211	0.177	0.213
STD DEV	0.009	0.006	0.002	0.003	0.003	0.003	0.006	0.009	0.003	0.005	---	0.002	0.017	0.006	0.007
Coeff. of Variation	5.41	3.92	1.02	1.89	2.05	1.45	3.43	6.42	1.51	2.83	---	1.01	7.84	3.15	3.25
% Diff to EPA-ECCC-CARB Mean	-3.5	0.6	2.9	1.3	-10.8	5.6	-2.1	-13.9	2.9	12.3	---	-2.2	28.8	7.8	29.7
% Diff to EPA	No Diff	No Diff	No Diff	No Diff	No Diff	9.5	No Diff	No Diff	No Diff	16.4	---	No Diff	33.5	11.8	34.5
% Diff to ECCC	No Diff	No Diff	No Diff	No Diff	-13.4	No Diff	No Diff	-16.4	No Diff	9.1	---	-5.0	25.1	No Diff	26.0
% Diff to CARB	No Diff	No Diff	No Diff	No Diff	-11.3	No Diff	No Diff	-14.4	No Diff	11.6	---	No Diff	28.0	No Diff	34.5
Number of Tests	3	3	4	3	3	3	3	3	3	3	---	3	3	3	3

(b) THC Emission Rates



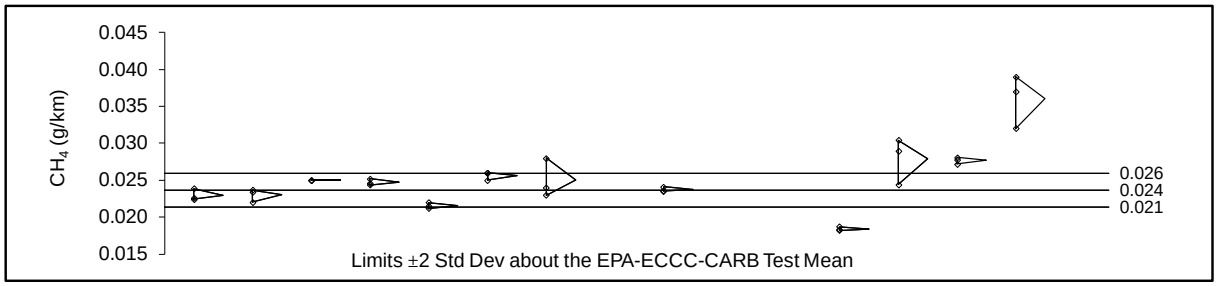
Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	0.461	0.411	0.487	0.435	0.416	0.492	0.438	0.357	0.500	0.546	---	0.465	0.546	0.471	0.622
STD DEV	0.027	0.034	0.006	0.006	0.010	0.009	0.002	0.005	0.016	0.027	---	0.008	0.029	0.016	0.014
Coeff. of Variation	5.80	8.32	1.13	1.34	2.44	1.82	0.40	1.44	3.12	4.97	---	1.69	5.33	3.34	2.17
% Diff to EPA-ECCC-CARB Mean	1.7	-9.2	7.6	-4.0	-8.1	8.5	-3.3	-21.1	10.4	20.5	---	2.7	20.5	4.0	37.3
% Diff to EPA	No Diff	No Diff	No Diff	No Diff	No Diff	No Diff	No Diff	-22.4	No Diff	18.5	---	No Diff	18.6	No Diff	35.0
% Diff to ECCC	No Diff	-15.6	No Diff	-10.7	-14.6	No Diff	-10.1	-26.7	No Diff	12.0	---	-4.6	12.1	No Diff	27.6
% Diff to CARB	No Diff	No Diff	18.5	No Diff	No Diff	19.6	No Diff	No Diff	21.7	32.8	---	No Diff	32.8	No Diff	35.0
Number of Tests	3	3	4	3	3	3	3	3	3	3	---	3	3	3	3

(c) NO_x Emission Rates



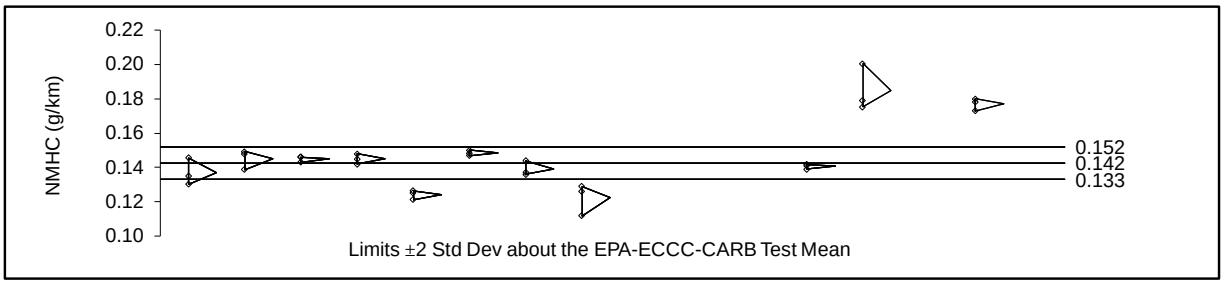
Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	186.1	199.0	203.7	197.4	179.5	198.7	212.8	192.2	209.2	218.9	---	190.6	200.7	182.1	199.5
STD DEV	7.75	6.74	1.02	0.89	3.37	1.02	0.24	1.30	0.60	1.58	---	1.61	0.64	0.75	0.18
Coeff. of Variation	4.17	3.39	0.50	0.45	1.88	0.51	0.11	0.67	0.29	0.72	---	0.84	0.32	0.41	0.09
% Diff to EPA-ECCC-CARB Mean	-5.2	1.4	3.8	0.6	-8.5	1.2	8.4	-2.1	6.6	11.6	---	-2.9	2.3	-7.2	1.6
% Diff to EPA	No Diff	No Diff	9.5	No Diff	No Diff	6.8	14.4	No Diff	12.4	17.6	---	No Diff	7.8	No Diff	7.2
% Diff to ECCC	-8.7	No Diff	No Diff	-3.1	-11.9	-2.5	4.5	-5.7	2.7	7.5	---	-6.5	-1.5	-10.6	-2.1
% Diff to CARB	No Diff	No Diff	No Diff	No Diff	-9.8	No Diff	7.0	No Diff	No Diff	10.0	---	No Diff	No Diff	-2.1	No Diff
Number of Tests	3	3	4	3	3	3	3	3	3	3	---	3	3	3	3

(d) CO_2 Emission Rates



Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	0.023	0.023	0.025	0.025	0.022	0.026	0.025	---	0.024	---	---	0.018	0.028	0.028	0.036
STD DEV	0.001	0.001	0.000	0.000	0.000	0.001	0.003	---	0.000	---	---	0.000	0.003	0.000	0.004
Coeff. of Variation	3.42	3.86	0.00	1.73	1.87	2.25	10.58	---	1.35	---	---	1.50	11.24	1.65	10.02
% Diff to EPA-ECCC-CARB Mean	-2.9	-2.7	5.6	4.4	-8.9	8.4	5.6	---	0.3	---	---	-22.2	18.0	17.0	52.1
% Diff to EPA	No Diff	No Diff	8.7	7.5	No Diff	11.6	No Diff	---	No Diff	---	---	-19.9	No Diff	20.5	56.6
% Diff to ECCC	-8.0	-7.9	No Diff	No Diff	-13.7	No Diff	No Diff	---	-5.1	---	---	-26.4	No Diff	10.8	44.0
% Diff to CARB	No Diff	No Diff	8.6	7.3	No Diff	11.5	No Diff	---	No Diff	---	---	-20.1	No Diff	20.5	56.6
Number of Tests	3	3	4	3	3	3	3	---	3	---	---	3	3	3	3

(e) CH_4 Emission Rates



Parameter	Lab 1 (EPA)	Lab 2 (ECCC)	Lab 3 (CARB)	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10	Lab 11	Lab 12	Lab 13	Lab 14	Lab 15
MEAN	0.137	0.145	0.145	0.145	0.124	0.148	0.139	0.122	---	---	---	0.141	0.185	---	0.177
STD DEV	0.0078	0.0057	0.0017	0.0030	0.0027	0.0015	0.0044	0.0091	---	---	---	0.0014	0.0135	---	0.0036
Coeff. of Variation	5.73	3.94	1.19	2.10	2.18	1.01	3.14	7.42	---	---	---	1.01	7.33	---	2.04
% Diff to EPA-ECCC-CARB Mean	-3.8	2.0	1.8	1.8	-12.7	4.2	-2.4	-14.1	---	---	---	-1.2	29.8	---	24.3
% Diff to EPA	No Diff	No Diff	No Diff	No Diff	No Diff	No Diff	No Diff	No Diff	---	---	---	No Diff	34.9	---	29.2
% Diff to ECCC	No Diff	No Diff	No Diff	No Diff	-14.3	No Diff	No Diff	-15.6	---	---	---	-3.0	27.4	---	22.1
% Diff to CARB	No Diff	No Diff	No Diff	No Diff	-14.4	No Diff	No Diff	-15.8	---	---	---	No Diff	27.2	---	29.2
Number of Tests	3	3	4	3	3	3	3	3	---	---	---	3	3	---	3

(f) NMHC Emission Rates

Note:
(1) Mean value is the reported laboratory value without a DF applied.
(2) %Diff is the student "t" distribution analysis at a 95% confidence ratio.
(3) Dash lines indicate that the results are not available.

Figure 4.3. *2017 Polaris Ranger XP 1000 EPS Exhaust Emission Rates; (a) CO; (b) THC; (c) NO_x; (d) CO_2; (e) CH_4; and (f) NMHC.*

XII. CONCLUSIONS

This multi-year program was a unique opportunity for collaboration between the U.S. EPA, ECCC, and CARB and participating private laboratories. To this end, this program highlighted the importance of continuing this type of collaborative effort among these organizations by sharing knowledge and resources to support common goals. One of these common goals is to promote high-quality and accurate measurements of exhaust emissions of vehicles and engines that emit to the atmosphere. This round-robin study provided valuable insight into the correlation and accuracy among both private and public OHRV exhaust emission testing facilities.

Overall, the results of this study revealed a high level of correlation between the three agencies (with few exceptions), therefore demonstrating highly consistent quality assurance and procedural adherence between the respective agencies. To this end, it should also be mentioned that besides the government participants, most private participants performed well in this program, which shows a high degree of competence within the OHRV exhaust emissions measurement landscape of North America.

As this was a voluntary program, the results will be used for informational purposes only. There are some examples of potential areas for improvements by various participants, which can be observed in the triangle plots in the results section. Specifically, measurements in some cases showed higher variability between test repeats than desired. This variability between test runs may result from inconsistent driving, instrument calibration, or other factors. Further efforts to reduce the variability of emission results between test runs are recommended. Furthermore, there are some instances where the emission results of certain participants were significantly above or below expected ranges. This is not necessarily the outcome of improper procedure adherence; though, it is indicative of a necessity for a deeper investigation for these cases. This four-year program provided many learning opportunities for the program organizers, including developing improved instructions and potentially providing additional opportunities for participants to find sources of variabilities between measurements (e.g. provisions of fuel analyses and driver metric data). These lessons learned will help organizers to better design future correlation efforts, including an upcoming round-robin test program in Asia.

XIII. PROGRAM COORDINATORS

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XIV. ACKNOWLEDGEMENTS

The program coordinators greatly appreciate the efforts of all who have participated in this program and hope we can continue working with them in the future. We would like to also thank all the individuals who assisted during the project planning and testing. We would like to acknowledge the following staff for their support of this study: EPA(Cleophas Jackson, Michael Delduca, John Spieth, NVFEL Staff); CARB (Thomas Valencia, Gary Mikailian, Thu Vo; Tuyen Dinh; Yilin Ma; Michael O'Connor, John Massetti; Travis Wong); ECCC (Norman Meyer; Aaron Loiselle; Debbie Rosenblatt; ERMS Technical Staff).