APPENDIX E1

State of California
Air Resources Board

Proposed Amendments to On-Road Motorcycle Emission Standards and Test Procedures and Adoption of New On-Board Diagnostics and Zero-Emission Motorcycle Requirements

Exhaust Emissions Test Results

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Contents

Introduction

The California Air Resources Board (CARB) has been regulating emissions from on-road motorcycles (ONMCs or motorcycles) since 1978. These regulations were last updated to the current emissions standards in 1998 and are largely harmonized with U.S. Environmental Protection Agency (U.S. EPA) exhaust standards. Since then, more stringent exhaust emissions standards have been developed by other jurisdictions around the world, most notably in the European Union.[1] A comparison between the current "Euro 5" European standard and the current CARB standard can be found in Table 1 for carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NOx), HC + NOx, and nonmethane hydrocarbons (NMHC).

Table 1. North American and European Emissions Standards

Emission Standards (g/km)	CO	HC	NOx	HC + NOx*	NMHC
U.S. EPA/CARB Limit	12	N/A	N/A	0.8	N/A
EU 5 Limit	1	0.1	0.06	0.16*	0.068

* The EU 5 standard does not have a combined HC + NOx Standard as CARB. But if you combine the separate HC and NOx limits, this gives an effective standard for comparison with the current CARB standard.

These stringent exhaust standards have prompted industry to develop ONMCs with lower emissions than what are currently required in California. Because California has not adopted new emissions standards for ONMCs since 1998, the allowable emissions rate in grams per kilometer for ONMCs is significantly higher than for other vehicle categories that are subject to more stringent regulatory standards.

In order to support a new regulation, it is necessary to collect emissions testing data from a variety of currently sold conventional ONMCs to better understand their emissions levels of regulated pollutants as related to the proposed lower limits and to compare impacts of changes in going from current certification testing procedures to proposed

[1] Regulation (EU) No 168/2013 Of The European Parliament And Of The Council of 15 January 2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles, Annex VI. Amended 11/14/2020.

certification testing procedures. Of primary concern in these testing changes are the emissions impacts from the change in drive cycle and the change in test fuels. The testing discussed in this paper addresses both of those needs.

This report includes results and observations from exhaust emissions testing of ONMCs that were conducted by CARB in support of the Proposed Amendments to ONMC Emission Standards and Test Procedures intended to be presented to the Board for consideration in December 2023. This testing was performed at CARB's Haagen-Smit Laboratory starting in 2019 and continuing through 2021.

Additionally, this report includes results submitted from a manufacturer as well as joint testing from the US Environmental Protection Agency and Environment Climate Change Canada (ECCC). The manufacturer testing provided data for a Euro 5 (EU 5)[2] type-approved ONMC tested to the CARB protocols discussed in

[2] The Euro 5 is terminology used to refer to motorcycles meeting European Union type approval standards for the REGULATION (EU) No 168/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 January 2013.

Appendix 2. The U.S. EPA/ECCC included a range of 7 ONMCs with testing following the CARB protocols described in

Appendix 2 with a few small exceptions detailed in the Test Fuels section and the Emissions Results.

Experimental Description

The initial objective of this testing was to draw exhaust and evaporative emissions comparisons between EU 5 and CARB ONMC certification test procedures and quantify certification impacts of drive cycle and fuel type on ONMC emissions. This paper only considers the exhaust observations. In order to accomplish this, staff generated the test plan given in

Appendix 2. It was amended with the changes not directly related to this exhaust testing, which are shown in Appendix 3 and Appendix 4 for completeness. This test plan was originally intended to perform multiple test runs of multiple ONMCs over different drive cycles and fuels as summarized in Table 2. However, in many cases, more runs were performed for certain drive cycle and fuel combinations as the testing evolved to capture additional data of interest for consideration in other CARB write-ups.

Table 2 CARB Test Matrix Summary

ONMC #	Test Constraints				
	TYPE I (WMTC) Drive Cycle			FTP Drive Cycle	Total # Tests Runs
	LEV III (E10 Fuel)	Indolene (E0 Fuel)	Euro 5 (E5 Fuel)	Indolene (E0 Fuel)	
C1	3	3	3	3	12
C2	3	3	3	3	12
C3	3	3	3	3	12
C4	3	3	3	3	12
Total # Test Runs	**12**	**12**	**12**	**12**	48

Relative effects from fuel changes between test procedures were made on the WMTC drive cycle as this is ultimately the drive cycle CARB is considering adopting for future certification testing. Indolene, often referred to as EPA Tier II (T2) test fuel, was used as it is the current CARB ONMC certification test fuel. LEV III test fuel was tested because it is the CARB certification test fuel for most other CARB vehicle categories using gasoline and is highly representative of California commercially available pump fuel. Euro 5 test fuel was used as this is the type approval test fuels for ONMCs in the European Union. These test variations will help staff in understanding how test results that are generated are impacted by drive cycle and fuel.

Drive cycle comparisons between the Federal Test Procedure (FTP) and Worldwide Harmonized Motorcycle Testing Cycle (WMTC) were intended to be made on T2 test fuel. T2 and the FTP drive cycle represent the testing constraints of the current CARB certification testing, giving a good baseline from which to compare the impact of the WMTC drive cycle. However, due to unanticipated testing difficulties which didn't allow for sufficient testing of T2 fuel on all ONMCs included in this test program, and further that additional test runs conducted for the purposes of evaporative and purge testing in which valid exhaust data was captured on LEV III and EU5, results using LEV III and the EU5 test fuel were also considered in this report.

Additional ONMCs were considered outside of this test plan as given by a manufacturer and the cooperative efforts of U.S. EPA and Environment Climate Change Canada (ECCC) at the request of CARB. These additional ONMCs are denoted as M1 (Manufacturer) and E1-E7 (U.S. EPA / ECCC). The results of E1-E3 were published from a U.S. EPA and ECCC joint investigation published in an SAE paper.[3] In that testing, Indolene Tier III (T3) fuel was also considered in some testing.

ONMCs Tested

A total of twelve ONMCs were tested in this program as shown in the Table 3. Ten were Class III (>/=280cc engine displacement), 1 was Class IB (50-125cc engine displacement), and 1 was Class IA (<50cc engine displacement). The test vehicles are anonymized in this report, as the goal of the testing was not to draw attention to specific manufacturers but rather to characterize emissions of representative ONMCs. Motorcycles C1-C3 are CARB-certified ONMCs, purchased by CARB new. Motorcycles E1- E5 and E7 were purchased new by the U.S. EPA and certified to EPA exhaust standards which are the same as CA for the test fuel. Motorcycles C4, M1 and E6 are designed for European Type Approval and owned by the manufacturer.[4] None of these vehicles had ever been owned by any other owners which is important for avoiding potential unknown variables in vehicle condition. Motorcycles C1 through C4 were tested at CARB's Haagen-Smit Laboratory in El Monte, California. Motorcycle M1 was tested at the manufacturer's test facility. Motorcycles E1-7 were tested in ECCC test facilities.

Table 3. Test Vehicle Descriptions

ONMC Tested	C1	C2	C3	C4	M1	E1	E2	E3	E4	E5	E6	E7
Compliance Jurisdiction*	CARB	CARB	CARB	EU 5	EU 5	EPA	EPA	EPA	EPA	EPA	EU 5	EPA
Model Year	2019	2018	2019	2020	2021	2017	2016	2015	2020	2019	2021	2020
Engine Displacement [cc]	1746	1000	847	765	1868	296	749	1198	125	330	1133	49
Equivalent Inertia Mass [kg]	400	290	290	280	500	250	310	350	180	270	340	163

[3] Rosenblatt, D., Stokes, J., Caffrey, C., and Brown, K., "Effect of North American Certification Test Fuels on Emissions from On-Road Motorcycles," SAE Technical Paper 2021-01-1225, 2021, doi:10.4271/2021-01-1225.

[4] Type Approval is the European emissions testing standards for vehicle certification. This is the equivalent of CARB emissions testing certification standards.

Test Fuels

Test fuels used by CARB, U.S. EPA/ECCC and manufacturer testing in this program included:

- Indolene (T2) test fuel
  - USEPA's Tier II test fuel
  - CARB's current ONMC certification test fuel
  - It is a 0% ethanol fuel (E0)
  - https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-86/subpart-B/section-86.113-94
- Euro 5 (EU 5) test fuel
  - European type approval test fuel for motorcycles
  - It is a 5% ethanol fuel (E5)
  - https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0134&qid=1533688421991&from=EN#page=54
- CARB LEV III test fuel
  - CARB's current certification test fuel for light duty vehicles
  - CARB's proposed future certification test fuel for ONMCs
  - It is a 10% ethanol fuel (E10)
  - https://ww2.arb.ca.gov/sites/default/files/2022-04/ldtps_2015%2BCP%262017%2BGHG_MY_leviii_12_21_ac.pdf#page=128

U.S. EPA/ECCC testing for bikes E1- E3 are the same with the exception that the EU 5 Test Fuel was replaced by:

- Indolene 10
  - U.S.EPA's Tier III test fuel
  - U.S. EPA's current passenger car certification test fuel
  - It is a 10% ethanol fuel (E10)
  - https://www.ecfr.gov/current/title-40/chapter-I/subchapter-U/part-1065/subpart-H/section-1065.710

The purpose of choosing these different test fuels was to evaluate the magnitude of the effects that variation in choice of test fuel may have on emissions certification testing. Key differences of these fuels that staff believes could make a difference in exhaust emissions during testing are given in Table 4.

Table 4. Test Fuel Key Parameters

Test Fuel Key Parameters	EPA Indolene Tier II*			Euro 5			CARB LEV III		
	Min	Max	Average	Min	Max	Average	Min	Max	Average
Ethanol Content (% Vol)	0	0	0	4.7	5.3	5	9.2	10	9.6
VP** (kPa)	60	63	62.0	56	60	58	48	50	49
VP** (psi)	8.7	9.2	9.0	8.1	8.7	8.4	6.9	7.2	7.1

*Tier III is same as Tier II in the above parameters with the exception of ethanol content, which is 9.6 -10%.

** VP is RVP for CARB LEV III and DVPE for Euro 5 and EPA Tier II/III. While similar, RVP correlates slightly lower at 100°F.

Note: Near the end of this test program, it was discovered that for CARB testing, the LEV III fuel was out of spec for some testing samples. This complication arose due to CARB's fuel lab being temporarily offline due to shifting facilities from El Monte to Riverside. Due to time constraints, the reported manufacturer numbers for a batch of fuel had to be relied upon which was determined to be out of spec only after testing was completed. The only constituent out of spec was the Olefins.[5] Staff determined from related research that Olefins being out of spec are a minor concern.[6] Therefore data generated with this fuel was considered in the results.

Drive Cycles

Drive Cycles in this testing included:

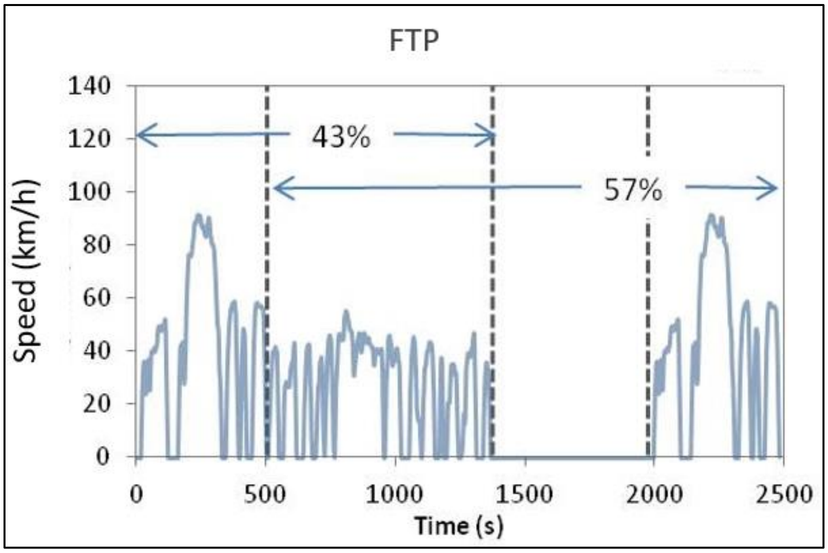
- FTP
  - CARB's current ONMC certification drive cycle
  - Originally developed as representative of driving characteristics of passenger cars
- WMTC
  - European type approval test cycle for motorcycles
  - Originally developed as representative of driving characteristics of ONMCs

[5] The LEV III Fuel Spec for Olefins is 4.0-6.0 vol%. Fuel batch tested at 3.4 vol %. Study in footnote 6 shows that there is little effect in exhaust emissions when changing olefin between 3-15 vol %.

[6] Maryam Hajbabaei, Georgios Karavalakis, J. Wayne Miller, Mark Villela, Karen Huaying Xu, Thomas D. Durbin. Impact of olefin content on criteria and toxic emissions from modern gasoline vehicles. May 2013.

The FTP (Figure 1) is the current ONMC certification drive cycle and includes both a cold start followed by a hot start. Emissions are collected in 3 phases and weighted such that 43% is weighted on the combined results of bags 1 and 2 while the 57% is weighted on the combined results of bags 2 and 3. The maximum speed of the FTP drive cycle is just over 56 miles per hour, which is much lower than typical ONMC recreational riding.

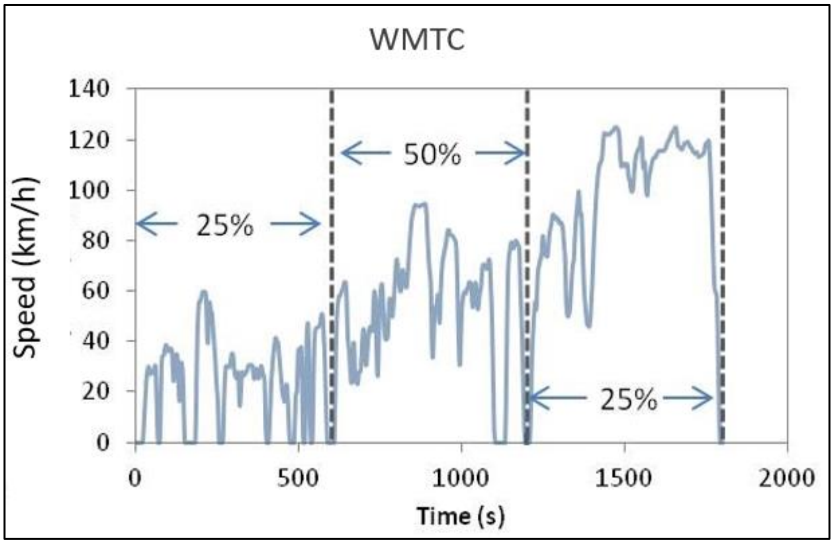
Figure 1. FTP Drive Cycle



The WMTC (Figure 2) is the current European Type Approval drive cycle and does not include a hot start. Emissions are collected in 3 phases and weighted such that 25% is weighted on the result of bag 1, 50% is weighted on the results of bag 2 and 25% is weighted on the results of bag 3. The maximum speed achieved is approximately 77.6 miles per hour, which is much more representative of actual ONMC recreational riding. Modified versions of the WMTC are run for Class IB and IA motorcycles that are incapable of reaching the maximum speed of the full WMTC.[7]

[7] Commission Delegated Regulation (EU) No 134/2014 of 16 December 2013 supplementing Regulation (EU) No 168/2013 of the European Parliament and of the Council with regard to environmental and propulsion unit performance requirements and amending Annex V thereof, Annex X, Appendix 1, Amended 2/28/2018.

Figure 2. WMTC Drive Cycle



A comparison of key differences between WMTC and FTP drive cycles are given in Table 5.

Table 5. Key Drive Cycle Differences

Key Drive Cycle Parameters	Max Speed (km/h)	Average Speed (km/h)	Distance (km)	Cold Start? (Y/N)	Hot Start? (Y/N)
FTP	91	34	18	Y	Y
WMTC	125	58	29	Y	N

M1* Note: During the early stages of testing, there was a complicating issue interpreting language of the EU test procedure regarding determination of equivalent inertia mass for dyno settings. This caused a few invalid runs where the incorrect dyno coefficients were used. Most notably were the test runs for M1. Due to resource constraints, only the WMTC run was redone for EU 5 test fuel using the correct dyno coefficients. Results for runs on LEV III and T2 fuels were adjusted proportionally from the difference observed in EU 5 testing with both the correct and incorrect EIMs on the WMTC. Results from these test runs are noted as adjusted by the asterisk M1*.

Emissions Results

Test results for each ONMC series of runs can be found summarized in Appendix 1. The results are analyzed in this section by impact of change in fuel or drive cycle for the following pollutants:

- HC

- NOx
- HC + NOx
- NMHC
- CO

All summaries of each run are also graphed with respect to pollutant so that the relative impact of the changes examined in each run can be visually understood. In the graphs where applicable, CARB and EU 5 limits are shown with horizontal lines. Twice the EU 5 limit is also shown to provide a sense of how close current ONMCs are to meeting the more stringent EU 5 standard. ONMCs tested are shown on the horizontal axis with a nomenclature designed to keep the makes/models anonymous but give sufficient information to understand the important characteristics of what was tested. The nomenclature tells which ONMC was tested, the drive cycle tested, the fuel used during that run, and the location of the testing. For example, C1-WMTC-T2-4-C would denote an average pollutant measure of 4 tests on test bike C1 on the WMTC with Indolene (T2) test fuel as tested by CARB. Error bars are given in one standard deviation. This nomenclature is used within Appendix 1 and throughout the graphs. Graphs are separated into two groups due to space limitations and the amount of data:

- C1-C4, M1
- E1-E7

Fuels Impact

Table 6 shows the impact of change of fuel on exhaust emissions. To isolate the impact of the fuel, all comparisons were made on the WMTC drive cycle. Emissions impacts were looked at across a variety of fuels that are discussed in detail in the Test Fuels section. However, the most important result for the purpose of CARB staff proposed ONMC regulations is the effect of going from EU5 to LEV III as the Proposal considers allowing use of results in certification testing that have been done on either LEVIII or EU 5 fuel.

Table 6. Emissions Impact of Change in Fuels as Measured Over the WMTC Drive Cycle

Bike #	Fuel Shift	# Runs Fuel 1	# Runs Fuel 2	HC	NOx	HC + NOx**	CO	NMHC
C1	T2 to EU5	4	3	0.3%	0.3%	-5.3%	0.1%	0.8%
C1	T2 to LEV III	4	4	12.9%	-11.5%	0.6%	18.0%	0.8%
C1	EU5 to LEV III	3	4	12.6%	-0.7%	6.2%	17.9%	12.2%
C2	T2 to EU5	3	5	-32.6%	52.0%	-21.3%	-11.5%	-30.8%
C2	T2 to LEV III	3	3	-22.5%	49.2%	-12.9%	-27.6%	-25.4%
C2	EU5 to LEV III	5	3	15.0%	-1.8%	10.6%	-18.2%	7.8%
C3	T2 to EU5	3	8	6.2%	24.5%	9.8%	0.7%	12.1%
C3	T2 to LEV III	3	3	-3.1%	43.0%	6.0%	-16.3%	-6.4%
C3	EU5 to LEV III	8	3	-8.7%	14.8%	-3.4%	-16.8%	-16.4%

C4	T2 to EU5	3	3	-18.6%	-7.5%	-17.0%	9.7%	-19.0%
C4	T2 to LEV III	3	4	-5.6%	11.6%	-3.0%	-7.8%	-6.8%
C4	EU5 to LEV III	3	4	16.0%	20.6%	16.8%	-15.9%	15.2%
M1*	T2 to EU5	3	3	-15.7%	13.2%	-8.4%	-31.5%	-15.0%
M1*	T2 to LEV III	3	3	0.6%	68.9%	17.9%	-27.8%	-0.7%
M1*	EU5 to LEV III	3	3	19.3%	49.1%	28.6%	5.4%	16.8%
E1	T2 to T3	5	2	-6.1%	5.4%	-2.1%	-24.4%	-5.6%
E1	T2 to LEV III	5	3	7.2%	10.2%	8.2%	-17.1%	7.8%
E1	T3 to LEV III	2	3	14.1%	4.5%	10.6%	9.7%	14.2%
E2	T2 to T3	6	6	-9.3%	0.0%	-3.0%	-15.5%	-10.6%
E2	T2 to LEV III	6	3	-3.7%	1.8%	0.0%	-6.6%	-4.3%
E2	T3 to LEV III	6	3	6.1%	1.8%	3.1%	10.6%	7.1%
E3	T2 to T3	3	3	-14.4%	-5.8%	-9.4%	4.1%	-17.9%
E3	T2 to LEV III	3	3	1.0%	11.7%	7.3%	6.1%	0.0%
E3	T3 to LEV III	3	3	18.1%	18.6%	18.4%	1.9%	21.7%
E4	T2 to EU5	3	3	-19.4%	-13.1%	-18.2%	-15.8%	-19.1%
E4	T2 to LEV III	3	3	-23.2%	-6.9%	-20.3%	-32.7%	-23.7%
E4	EU5 to LEV III	3	3	-4.8%	7.2%	-2.5%	-20.1%	-5.7%
E5	T2 to EU5	4	2	18.5%	-4.2%	9.1%	-3.6%	20.6%
E5	T2 to LEV III	4	3	22.9%	3.6%	14.9%	-3.4%	24.0%
E5	EU5 to LEV III	2	3	3.8%	8.2%	5.4%	0.1%	2.8%
E6	T2 to EU5	3	3	4.5%	11.5%	6.6%	-6.6%	6.4%
E6	T2 to LEV III	3	2	-13.6%	1.4%	-9.1%	-24.9%	-16.9%
E6	EU5 to LEV III	3	2	-17.3%	-9.0%	-14.7%	-19.6%	-21.9%
E7	EU5 to LEV III	3	4	-1.9%	-6.5%	-2.7%	-5.4%	-2.1%
All	Avg. Δ T2 to EU5	26	30	-7.1%	9.6%	-5.6%	-7.3%	-5.5%
All	Avg. Δ T2 to LEV III	40	34	-2.5%	16.6%	0.9%	-12.7%	-4.7%
All	Avg. Δ T2 to E10 (All)	54	45	-4.1%	13.0%	-0.4%	-12.6%	-6.1%
All	Avg. Δ EU5 to LEV III	25	29	3.8%	9.1%	4.9%	-8.1%	1.0%

See section Drive Cycles for M1 note.

**EU has separate ONMC limits for HC and NOx. They are combined into an effective limit for comparison purposes in this paper.

The largest individual fuel change combination for a particular ONMC in this test program is an increase of up to 69% (NOx) or a decrease of up to 33% (HC, CO) for a given pollutant. However, the average for all bikes on the fuel substitution being considered in the Proposal of EU5 to LEV III is an increase of 9.1% (NOx) and a decrease of 8.1% (CO).

It is important to note that the levels of emissions being measured are very small. This means that although the impact of a change of a particular fuel may seem high as a percentage of measured emissions for a ONMC, these changes may be very small in absolute terms, and relative to the EU emissions limits for ONMCs. Table 7 shows this impact of change on fuels relative to the Euro 5 standard.

Table 7. Emissions Impact of Change in Fuels Relative to the EU Emissions Limits

Bike #	Fuel Shift	# Runs Fuel 1	# Runs Fuel 2	HC	NOx	HC + NOx**	CO	NMHC
C1	T2 to EU5	4	3	0.2%	-12.2%	-4.5%	0.1%	0.7%
C1	T2 to LEV III	4	4	8.6%	-13.0%	0.5%	9.9%	11.3%
C1	EU5 to LEV III	3	4	8.4%	-0.7%	5.0%	9.8%	10.6%
C2	T2 to EU5	3	5	-32.8%	13.5%	-15.4%	-7.0%	-38.4%
C2	T2 to LEV III	3	3	-22.6%	12.7%	-9.4%	-16.7%	-31.6%
C2	EU5 to LEV III	5	3	10.1%	-0.7%	6.1%	-9.7%	6.7%
C3	T2 to EU5	3	8	4.4%	7.2%	5.5%	0.3%	10.3%
C3	T2 to LEV III	3	3	-2.2%	12.7%	3.4%	-7.7%	-5.4%
C3	EU5 to LEV III	8	3	-6.6%	5.4%	-2.1%	-8.0%	-15.8%
C4	T2 to EU5	3	3	-8.2%	-1.0%	-5.5%	6.4%	-10.7%
C4	T2 to LEV III	3	4	-2.5%	1.5%	-1.0%	-5.2%	-3.8%
C4	EU5 to LEV III	3	4	5.7%	2.5%	4.5%	-11.6%	6.9%
M1*	T2 to EU5	3	3	-5.9%	2.8%	-2.6%	-14.5%	-7.1%
M1*	T2 to LEV III	3	3	0.2%	14.6%	5.6%	-12.8%	-0.3%
M1*	EU5 to LEV III	3	3	6.1%	11.8%	8.2%	1.7%	6.8%
E1	T2 to T3	5	2	-17.0%	13.3%	-5.6%	-35.2%	-22.1%
E1	T2 to LEV III	5	3	20.0%	25.0%	21.9%	-24.6%	30.9%
E1	T3 to LEV III	2	3	37.0%	11.7%	27.5%	10.6%	52.9%
E2	T2 to T3	6	6	-5.0%	0.0%	-3.1%	-4.0%	-7.4%
E2	T2 to LEV III	6	3	-2.0%	3.3%	0.0%	-1.7%	-2.9%
E2	T3 to LEV III	6	3	3.0%	3.3%	3.1%	2.3%	4.4%
E3	T2 to T3	3	3	-14.0%	-13.3%	-13.8%	3.1%	-22.1%
E3	T2 to LEV III	3	3	1.0%	26.7%	10.6%	4.6%	0.0%
E3	T3 to LEV III	3	3	15.0%	40.0%	24.4%	1.5%	22.1%
E4	T2 to EU5	3	3	-16.7%	-4.2%	-12.0%	-24.5%	-22.5%
E4	T2 to LEV III	3	3	-20.0%	-2.2%	-13.3%	-50.6%	-28.0%
E4	EU5 to LEV III	3	3	-3.3%	2.0%	-1.3%	-26.1%	-5.4%
E5	T2 to EU5	4	2	13.7%	-3.7%	7.2%	-2.3%	21.0%
E5	T2 to LEV III	4	3	17.0%	3.2%	11.8%	-2.3%	24.5%
E5	EU5 to LEV III	2	3	3.3%	6.9%	4.6%	0.1%	3.5%
E6	T2 to EU5	3	3	2.1%	3.9%	2.8%	-4.2%	3.6%
E6	T2 to LEV III	3	2	-6.4%	0.5%	-3.8%	-16.0%	-9.5%
E6	EU5 to LEV III	3	2	-8.5%	-3.4%	-6.6%	-11.7%	-13.1%
E7	EU5 to LEV III	3	4	-6.3%	-7.8%	-6.9%	-4.1%	-9.9%
All	Avg. Δ T2 to EU5	26	30	-5.4%	0.8%	-3.1%	-5.7%	-5.4%
All	Avg. Δ T2 to LEV III	40	34	-0.8%	7.7%	2.4%	-11.2%	-1.4%
All	Avg. Δ T2 to E10 (All)	54	45	-3.2%	6.1%	0.3%	-11.4%	-4.7%
All	Avg. Δ EU5 to LEV III	25	29	1.0%	1.8%	1.3%	-6.6%	-1.1%

See section Drive Cycles for M1 note.

**EU has separate ONMC limits for HC and NOx. They are combined into an effective limit for comparison purposes in this paper.

It is important to note that although some changes in emissions relative to the standard may seem high, often this is because it was a modest change for a bike that was far exceeding the standard. If we look at the particular case of bike E1 going from T3 and LEV III, we notice that the change in NMHC relative to the standard would be 53%. While this seems high, it is because the bike as shown later in Figure 10 is exceeding the NMHC limit by more than a factor of three. Therefore, the actual increase in emissions from Table 6 is just 14%. Conversely, when we look at a bike that is experiencing a relatively large increase in percentage of emissions on a particular pollutant, it is because that bike is an extremely low emitter and thus the change relative to the Euro 5 standard is low. Consider bike M1* which shows in Figure 5 is emitting NOx at less than half the standard experienced an increase in NOx of 69% when going from T2 to LEV III fuel. However, when considering this EU limit on NOx, this change translates to an increase of 15%.

From Table 6 and Table 7 we can see that the change in fuels is relatively modest. When combining all the tests involving EU5 to LEV III fuel, we see that the impacts are extremely modest as summarized in Table 8, and not likely to be a large factor in determining compliance with staff's proposed ONMC certification emission limits.

Table 8. Summary of the Impact of Changing Fuels from EU 5 to LEV III

All Bikes EU 5 to LEV III	HC	NOx	HC + NOx**	CO	NMHC
% Δ Emissions	3.8%	9.1%	4.9%	-8.1%	1.0%
% Δ of EU Emissions Limit	1.0%	1.8%	1.3%	-6.6%	-1.1%

**EU has separate ONMC limits for HC and NOx. They are combined into an effective limit for comparison purposes in this paper.

Drive Cycle Impact

From Table 9, we can see the impact drive cycle change in going from an FTP to the WMTC in meeting emissions limits. Because we are only concerned with the relative change, we used testing results for many different fuels (Test Fuels section) to have a more robust data set. The constraint for comparison is simply that for any particular test run, the fuel be held constant. The WMTC was chosen as the reference drive cycle because that is the proposed drive cycle for future ONMC certification testing, while CARB currently uses the FTP drive cycle for certification testing. Emissions impacts were looked at across a variety of fuels that are discussed in detail in the Test Fuels section.

Table 9. Emissions Impact of Change in Drive Cycle from FTP to WMTC

Bike #	Fuel	# Runs FTP	# Runs WMTC	HC	NOx	HC + NOx	CO	NMHC
C1	LEVIII	3	4	26.4%	39.5%	31.9%	73.9%	30.3%
C2	T2	3	3	45.4%	-45.5%	18.9%	12.1%	58.6%
C2	EU5	2	5	23.6%	-25.9%	5.4%	34.3%	30.2%
C2	LEVIII	2	3	66.8%	-45.3%	13.4%	61.5%	78.9%

C3	T2	3	3	-6.8%	17.6%	-2.8%	-29.2%	-2.3%
C3	EU5	1	8	32.7%	46.8%	35.6%	8.4%	42.8%
C3	LEVIII	3	3	-16.0%	14.7%	-9.5%	2.3%	-19.0%
C4	T2	3	3	26.1%	11.2%	23.6%	23.5%	23.9%
C4	LEVIII	4	4	34.3%	30.1%	33.5%	28.2%	32.8%
M1*	T2	3	3	9.9%	-54.9%	-19.4%	89.2%	12.4%
E1	T2	3	5	1.5%	93.4%	21.4%	12.4%	1.9%
E1	T3	3	2	17.0%	96.2%	37.6%	44.0%	17.7%
E1	LEVIII	3	3	3.1%	80.0%	21.3%	24.0%	3.6%
E2	T2	6	6	0.0%	88.1%	46.0%	4.9%	2.2%
E2	T3	3	6	-9.3%	58.6%	29.0%	6.3%	-4.5%
E2	LEVIII	3	3	-1.9%	63.8%	35.2%	10.6%	4.7%
E3	T2	3	3	76.4%	80.3%	78.6%	38.4%	95.3%
E3	T3	4	3	56.6%	55.4%	55.9%	46.3%	72.5%
E3	LEVIII	3	3	88.5%	64.5%	73.1%	55.8%	110.0%
E4	T2	4	3	128.5%	85.6%	119.4%	335.1%	132.3%
E5	T2	3	4	34.5%	19.6%	27.9%	104.1%	35.9%
E6	T2	3	3	-1.5%	152.3%	20.5%	29.7%	1.0%
E7	LEVIII	3	4	44.7%	-7.4%	32.1%	-8.1%	45.4%
All	Avg. Total Δ	71	87	29.6%	39.9%	31.7%	43.8%	35.1%

See section Drive Cycles for M1 note.

**EU has separate ONMC limits for HC and NOx. They are combined into an effective limit for comparison purposes in this paper.

From Table 9, it is clear that the emissions impact of changing the drive cycle from the FTP to the WMTC is many times greater than that of changing the fuel as discussed above in Table 8. The largest individual change in emissions between the FTP and WMTC drive cycles for a particular bike is an increase of up to 335% (CO) or a decrease of up to 55% (NOx) for a given pollutant. However, the largest average increase in emissions for all bikes when running the WMTC as compared to the FTP is 44% for carbon monoxide (CO), with all other measured pollutants increasing on a similar scale.

It is important to note that the levels of emissions being measured are very small. This means that although the impact of a change in drive cycle may seem high for a motorcycle, these changes may not be as large relative to the EU emissions limits for ONMCs. Table 10 shows this impact of drive cycle change from FTP to WMTC relative to the Euro 5 standard itself.

Table 10. Emissions Impact of Change in Drive Cycles from FTP to WMTC Relative to the EU Emissions Limits

Bike #	Fuel	# Runs FTP	# Runs WMTC	HC	NOx	HC + NOx**	CO	NMHC
C1	LEVIII	3	4	15.7%	28.4%	20.4%	27.4%	22.9%
C2	T2	3	3	31.4%	-21.6%	11.5%	6.5%	46.0%
C2	EU5	2	5	12.9%	-13.7%	2.9%	13.6%	20.0%

C2	LEVIII	2	3	31.2%	-32.0%	7.5%	16.6%	41.0%
C3	T2	3	3	-5.2%	4.4%	-1.6%	-19.6%	-2.0%
C3	EU5	1	8	18.8%	11.7%	16.1%	3.7%	28.8%
C3	LEVIII	3	3	-13.2%	5.4%	-6.2%	0.9%	-18.7%
C4	T2	3	3	9.1%	1.3%	6.1%	12.7%	10.8%
C4	LEVIII	4	4	10.5%	3.3%	7.8%	13.5%	13.0%
M1*	T2	3	3	3.4%	-25.8%	-7.5%	21.7%	5.2%
E1	T2	3	5	4.0%	118.3%	46.9%	15.9%	7.4%
E1	T3	3	2	38.0%	126.7%	71.3%	33.3%	55.9%
E1	LEVIII	3	3	9.0%	120.0%	50.6%	23.1%	14.7%
E2	T2	6	6	0.0%	86.7%	32.5%	1.2%	1.5%
E2	T3	3	6	-5.0%	68.3%	22.5%	1.3%	-2.9%
E2	LEVIII	3	3	-1.0%	73.3%	26.9%	2.3%	2.9%
E3	T2	3	3	42.0%	101.7%	64.4%	20.9%	60.3%
E3	T3	4	3	30.0%	76.7%	47.5%	24.8%	42.6%
E3	LEVIII	3	3	46.0%	100.0%	66.3%	28.6%	64.7%
E4	T2	4	3	48.5%	14.6%	35.8%	119.0%	67.1%
E5	T2	3	4	19.0%	14.4%	17.3%	33.3%	27.0%
E6	T2	3	3	-0.7%	20.3%	7.2%	14.7%	0.5%
E7	LEVIII	3	4	101.2%	-8.9%	59.9%	-6.4%	146.9%
All	Avg. Total Δ	71	87	19.4%	38.0%	26.3%	17.8%	28.5%

See section Drive Cycles for M1 note.

**EU has separate ONMC limits for HC and NOx. They are combined into an effective limit for comparison purposes in this paper.

It is important to note that as with the discussion of changing fuels above, although some changes in emissions relative to the standard may seem high, often this is because it was a modest change for a bike that was far exceeding the standard. Similarly, when we look at a bike that is experiencing a relatively large increase in emissions on a particular pollutant, it is because that bike is an extremely low emitter and thus the change relative to the standard is low.

From Table 9 and Table 10 we can see that the change in drive cycles is significant and would be much more likely than fuels to be a factor in whether or not a particular bike would meet the Proposed ONMC certification emission limits. It is also important to note that the change in going from FTP to WMTC tends to cause an ONMC to emit more during the test, not less. This means that the bike would have to be designed with lower overall emissions in order to meet the standard when tested on the WMTC than the FTP, which translates to lower real-world emissions. The results of the impact of changing from the FTP to WMTC drive cycle are summarized in Table 8.

Table 11. Summary of the Impact of Changing the Drive Cycle from FTP to WMTC.

All Bikes	HC	NOx	HC + NOx**	CO	NMHC
% Δ Emissions	29.6%	39.9%	31.7%	43.8%	35.1%

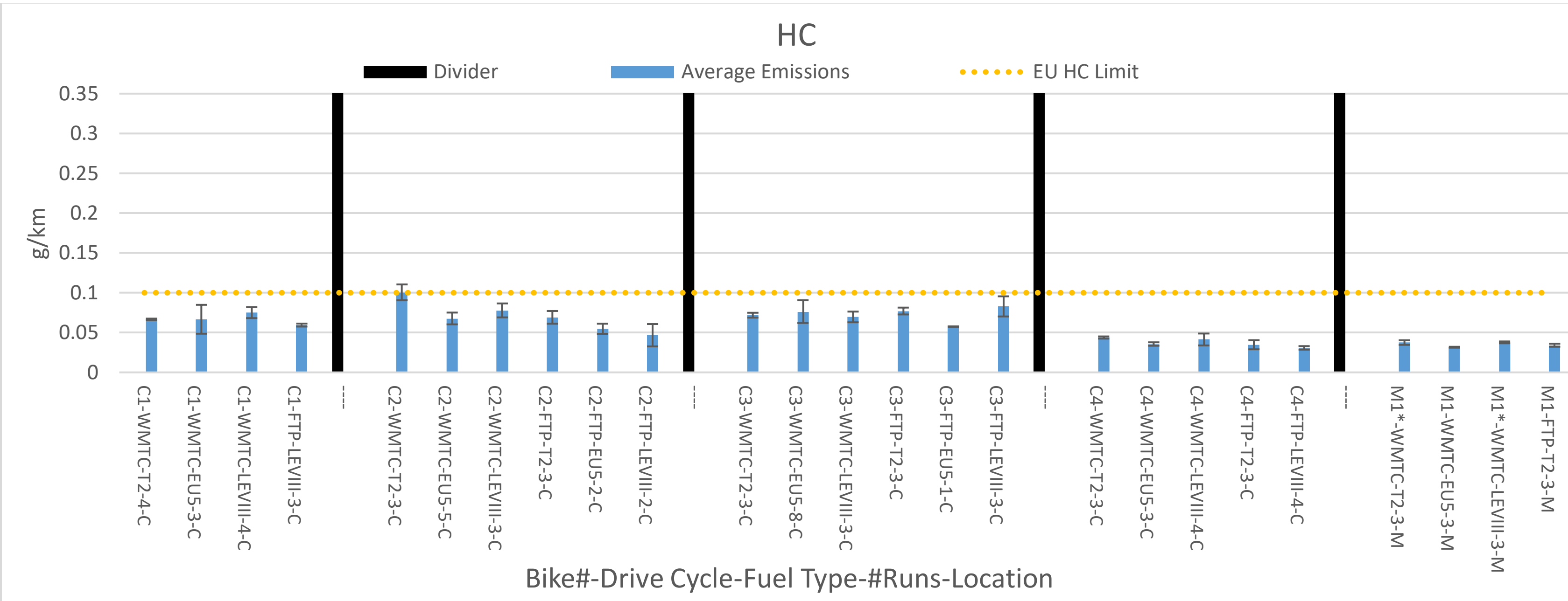
% Δ of EU Emissions Limit	19.4%	38.0%	26.3%	17.8%	28.5%

**EU has separate ONMC limits for HC and NOx. They are combined into an effective limit for comparison purposes in this paper.

HC Charts

Figure 3 (C1-C4, M1) and Figure 4 (E1-E7), show how each of the bikes performed vs the EU HC limit (yellow line).

Figure 3. CARB and Manufacturer ONMC Emissions Testing Results for HC



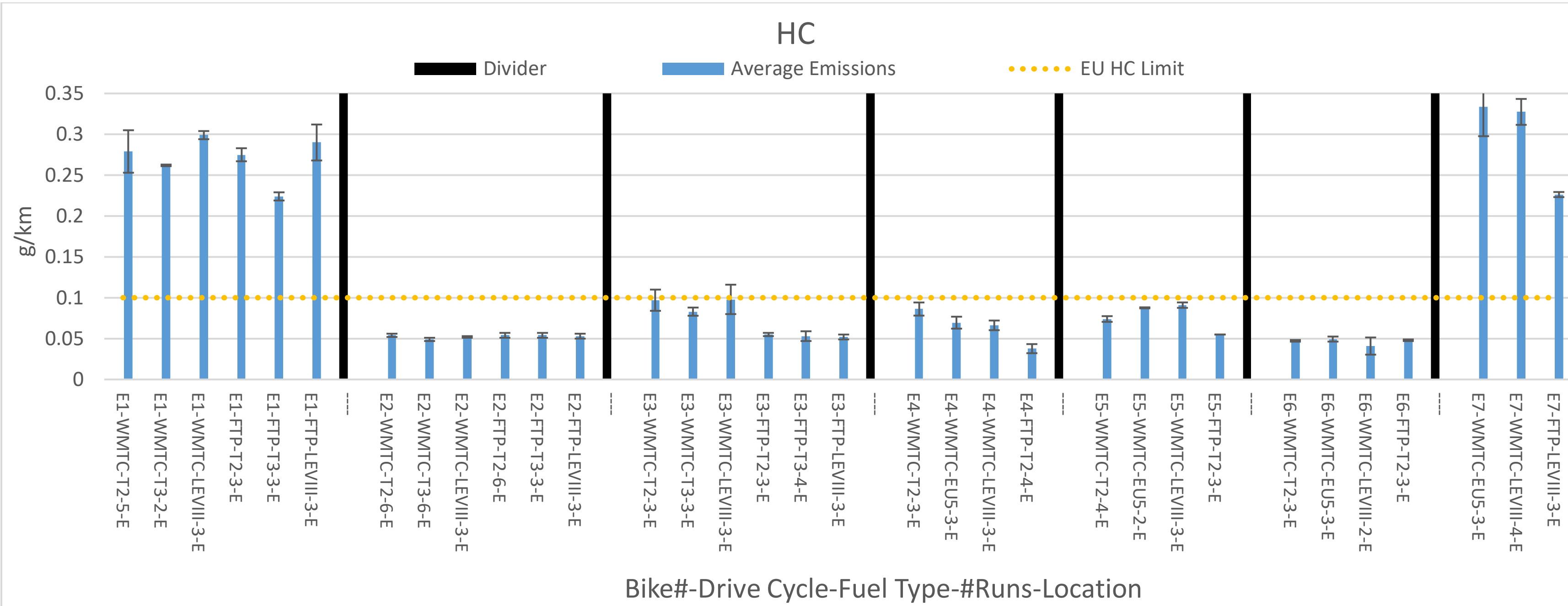
See section Drive Cycles for M1 note.

General takeaways from the charts include:

1) 10 of the 12 ONMCs tested would have met the more stringent EU HC standard on all combinations of fuel or drive cycle tested, suggesting that this standard is very achievable using currently available emissions control technologies.
2) EU type-approved ONMCs performed as well or better than all of the CARB/EPA certified ONMCs. In all runs, they were less than half the EU HC limit regardless of fuel or drive cycle.

3) Smaller ONMCs seemed to struggle more with the standard. The two ONMCs that emitted over the EU limit and at much higher levels than the other ONMCs were E1 (296cc) and E7 (49cc). However, E4 (125cc) did better than a few of the larger ONMCs.

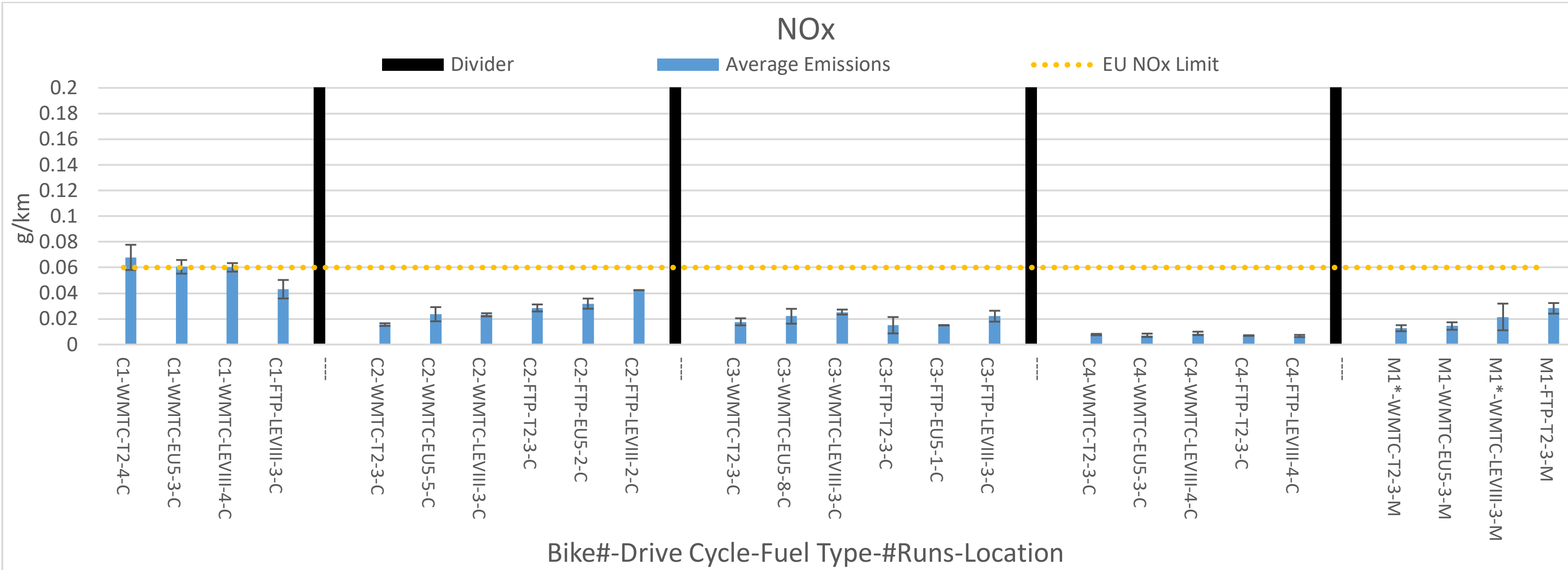
Figure 4. U.S. EPA/ECCC ONMC Emissions Testing Results for HC



NOx Charts

Figure 5 (C1-C4, M1) and Figure 6 (E1-E7), show how each of the bikes performed vs the EU NOx limit (yellow line).

Figure 5. CARB and Manufacturer ONMC Emissions Testing Results for NOx

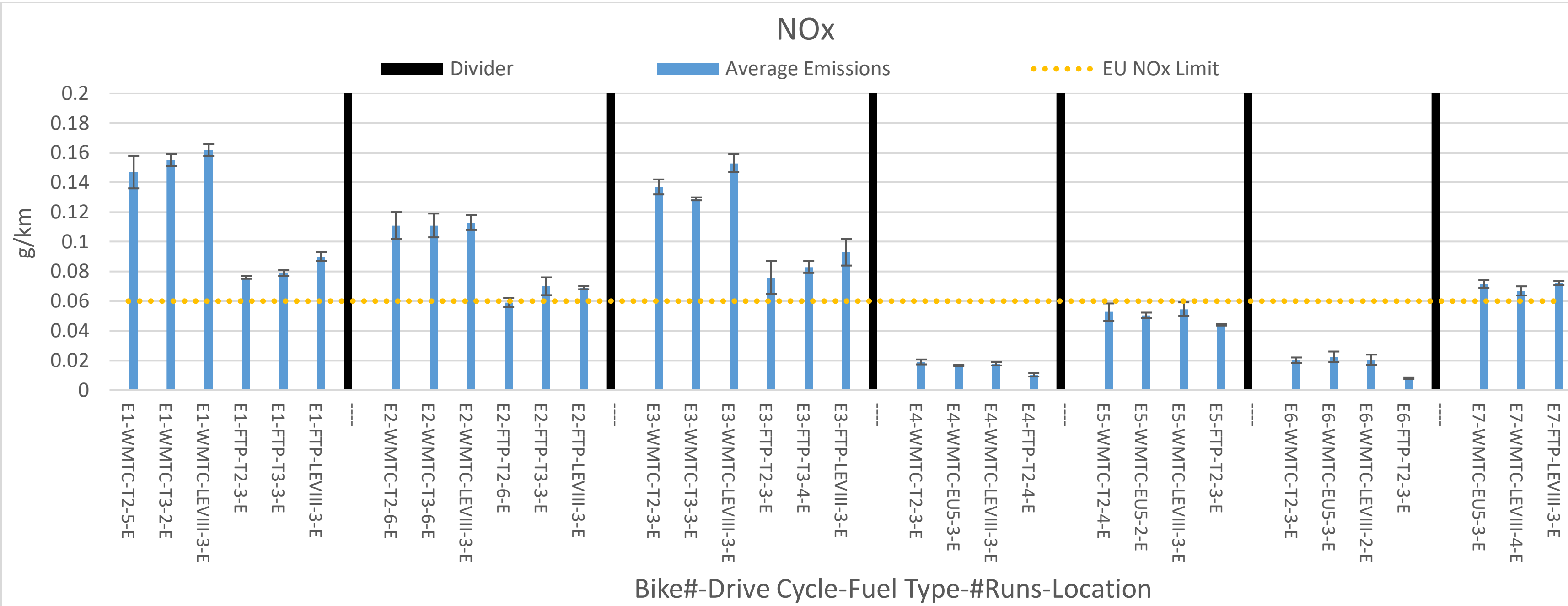


See section Drive Cycles for M1 note.

From a quick glance at the results, there are a few general takeaways:

1) 8 of the 12 ONMCs tested would have met the more stringent EU NOx standard on all combinations of fuel or drive cycle tested, suggesting that this standard is very achievable using currently available emissions control technologies.
2) EU type-approved ONMCs performed as well or better than most of the CARB/EPA certified ONMCs. In all runs, they were less than half the NOx level regardless of fuel or drive cycle. Two of the CARB/EPA certified ONMCs achieved similar levels of low emissions.

Figure 6. U.S. EPA/ECCC ONMC Emissions Testing Results for NOx



HC + NOx Charts

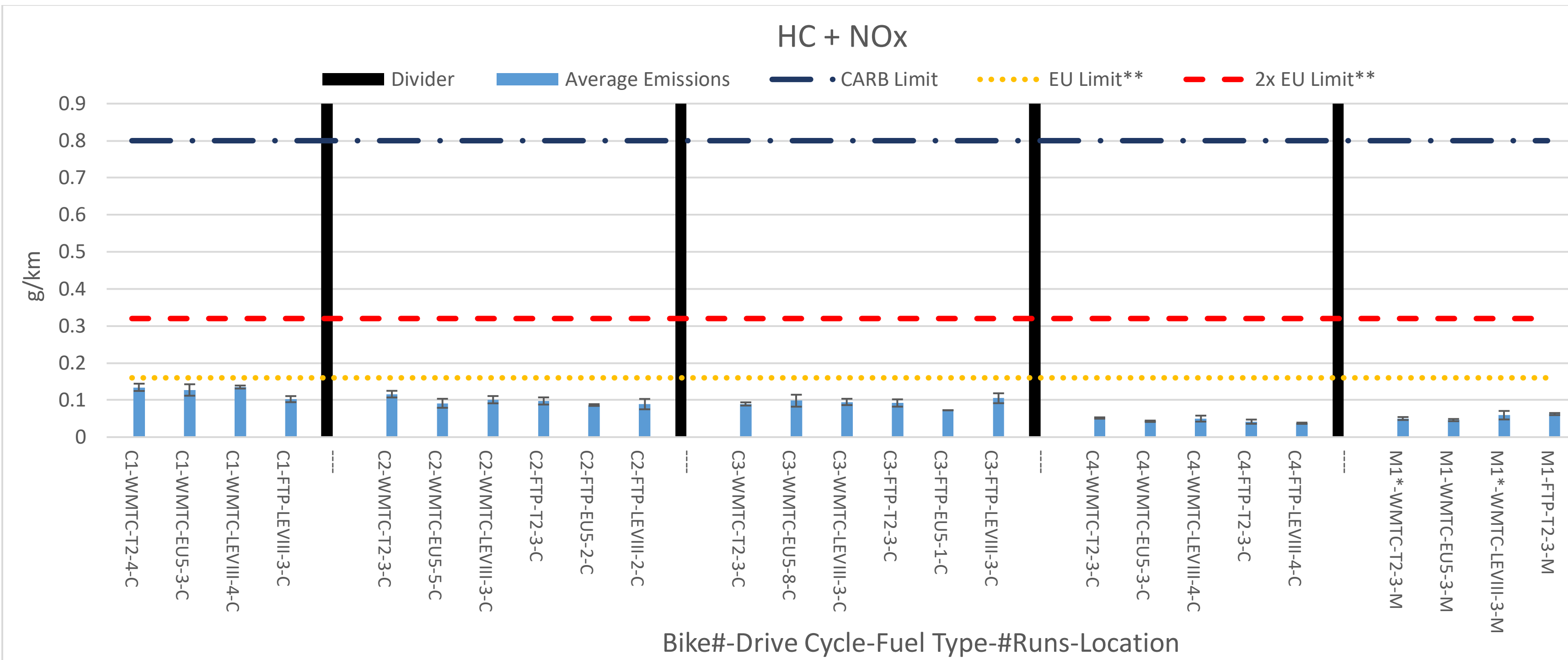
Figure 7 (C1-C4, M1) and Figure 8 (E1-E7), show how each of the bikes performed vs the CARB HC + NOx limit (dark blue dashed line) and the effective combined EU HC + NOx limit (yellow line). Because the proposed standard will be the EU limit, for visual reference, a red line denoting 2x effective EU limit is included to aid readers in visually understanding how close most ONMCs are to meeting the effective EU HC+NOx limit. From a quick glance at the results, there are a few conclusions:

1) All ONMCs tested are well under the CARB/EPA limit on all fuels with all drive cycles. The worst performer barely exceeds half the CARB/EPA limit.
2) 9 of the 12 ONMCs tested would have met the more stringent effective combined EU HC + NOx limit on all combinations of fuel or drive cycle tested, suggesting that this standard is very achievable using currently available

emissions control technologies. Of the three that did not meet this effective limit, only two exceeded twice the effective limit.

3) EU type-approved ONMCs performed as well or better than all the CARB/EPA certified ONMCs on combined HC + NOx emissions. In all runs, they were less than half the effective combined EU HC + NOx limit regardless of fuel or drive cycle.

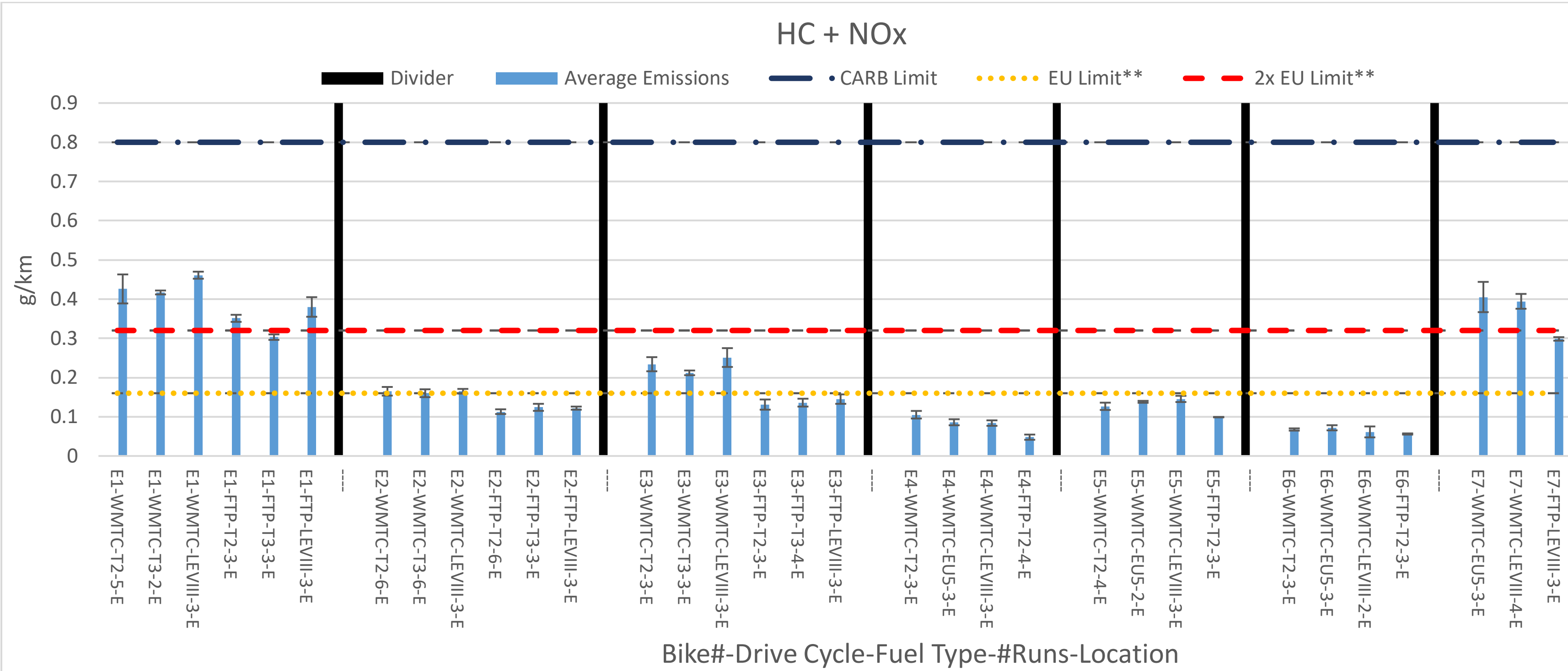
Figure 7. CARB and Manufacturer ONMC Emissions Testing Results for HC + NOx



See section Drive Cycles for M1 note.

**EU has separate ONMC limits for HC and NOx. They are combined into an effective limit for comparison purposes in this paper.

Figure 8. U.S. EPA/ECCC ONMC Emissions Testing Results for HC + NOx



**EU has separate ONMC limits for HC and NOx. They are combined into an effective limit for comparison purposes in this paper.

NMHC Charts

Figure 9 (C1-C4, M1) and Figure 10 (E1-E7), show how each of the bikes performed vs the EU NMHC limit (yellow line). NMHC is a disaggregation of HC that CARB does not currently regulate on ONMCs.

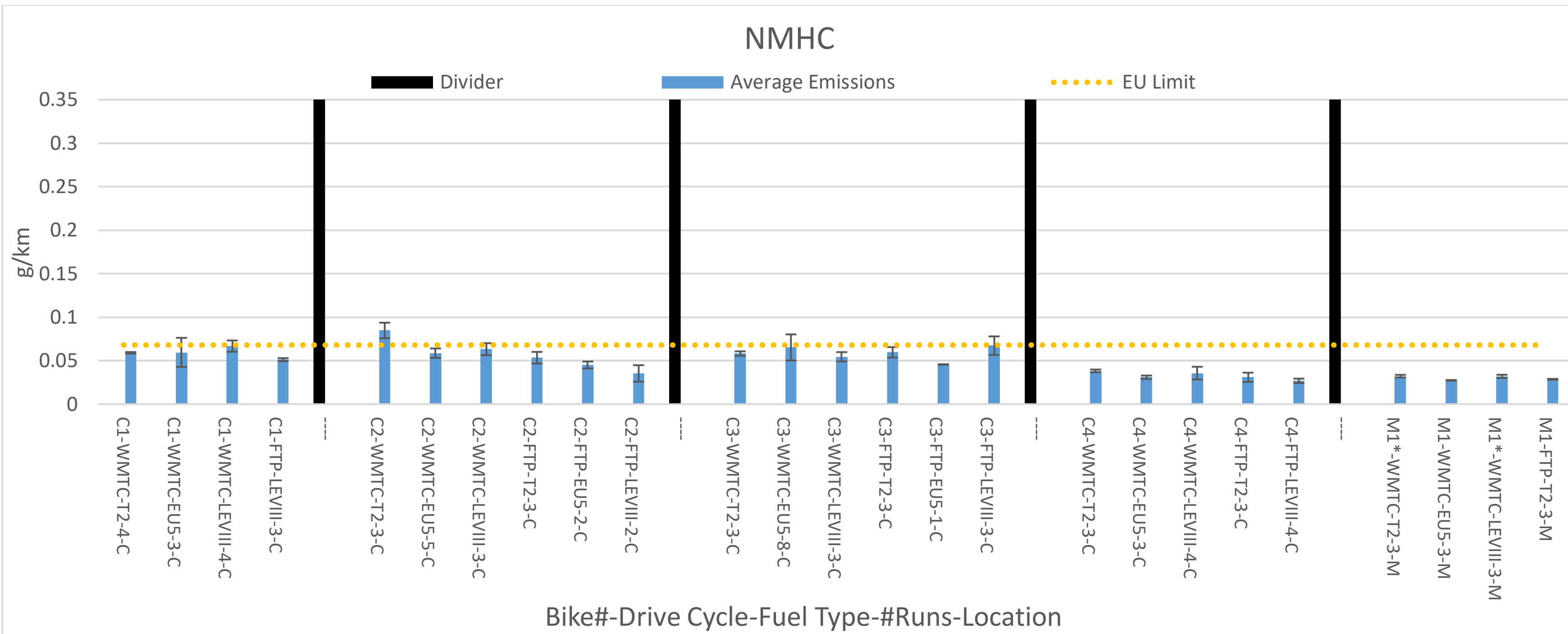
From a quick glance at the results, there are a few general takeaways:

1) 6 of the 12 ONMCs tested would have met the EU NMHC limit on all combinations of fuel or drive cycle tested, suggesting that this standard is very achievable using currently available emissions control technologies. Of the

six ONMCs that did not meet this effective limit for all drive cycles and fuels considered, two would have passed on the proposed fuel (LEV III) and drive cycle (WMTC) effectively bringing that to a total of 8 of 12 ONMCs tested that would have met the EU NMHC limit.

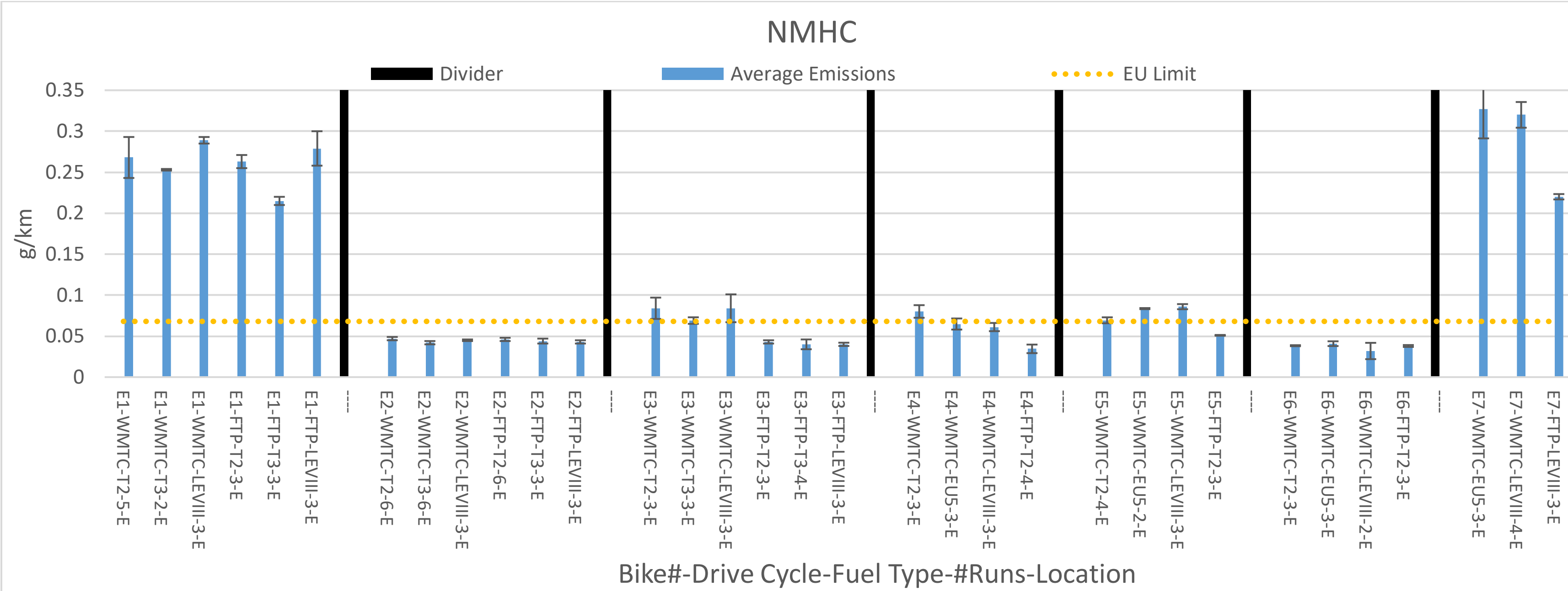
2) EU type-approved ONMCs performed better than all the CARB/EPA certified ONMCs on EU NMHC emissions limits. In all runs, they were near or less than half the EU NMHC limit regardless of fuel or drive cycle.

Figure 9. CARB and Manufacturer ONMC Emissions Testing Results for NMHC



See section Drive Cycles for M1 note.

Figure 10. U.S. EPA/ECCC ONMC Emissions Testing Results for NMHC



CO Charts

Figure 11 (C1-C4, M1) and Figure 12 (E1-E7), show how each of the bikes performed vs the EU CO limit (yellow line).

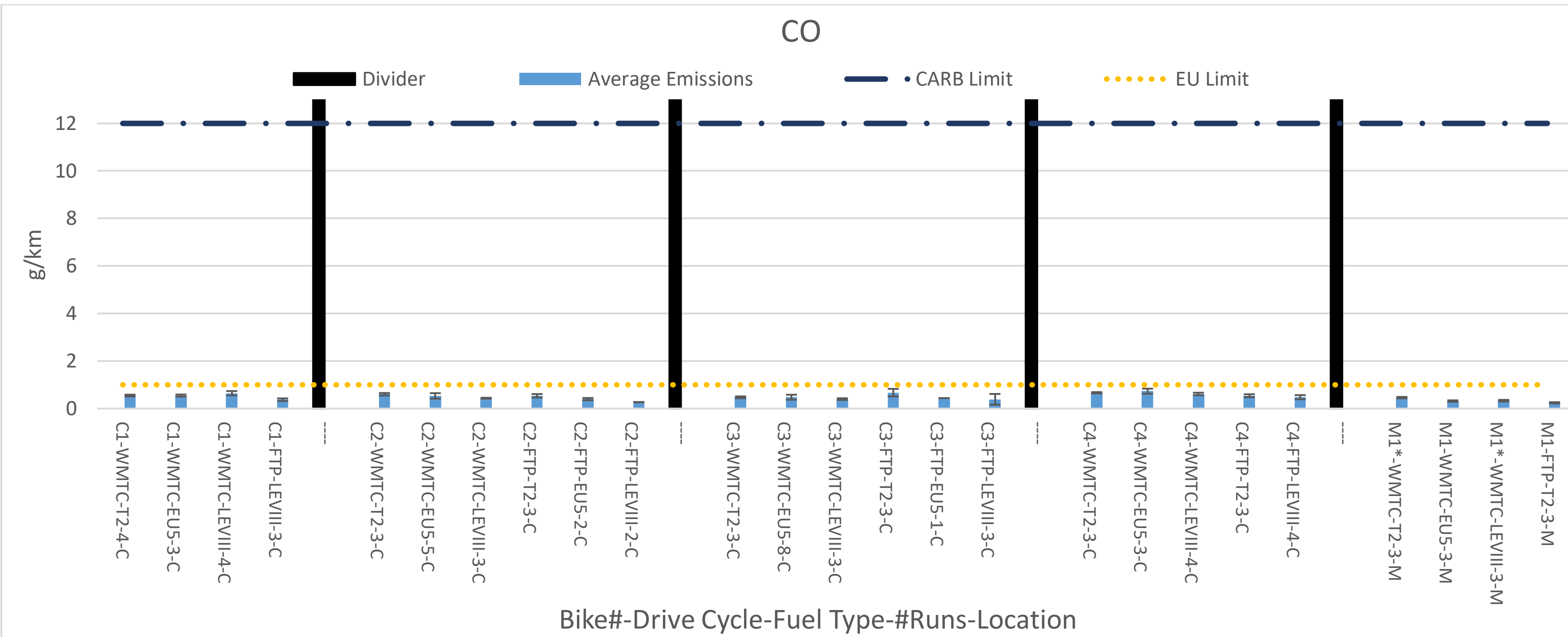
From a quick glance at the results, there are a few general takeaways:

1) All ONMCs tested are well under the CARB/EPA CO limit on all fuels with all drive cycles. The worst performer is less than 13% of the CARB/EPA limit. This clearly shows the current limits are far above the limit of available control technologies. A lower CO standard could help to ensure that current CO emissions levels are maintained.
2) 10 of the 12 ONMCs tested would have met the more stringent EU CO limit on all combinations of fuel or drive cycles tested, suggesting that this standard is very achievable using currently available emissions control

technologies. Of the two that did not meet this CO limit, they did not exceed the standard by more than 0.2 g/km on the proposed standard using the WMTC and LEV III fuel.

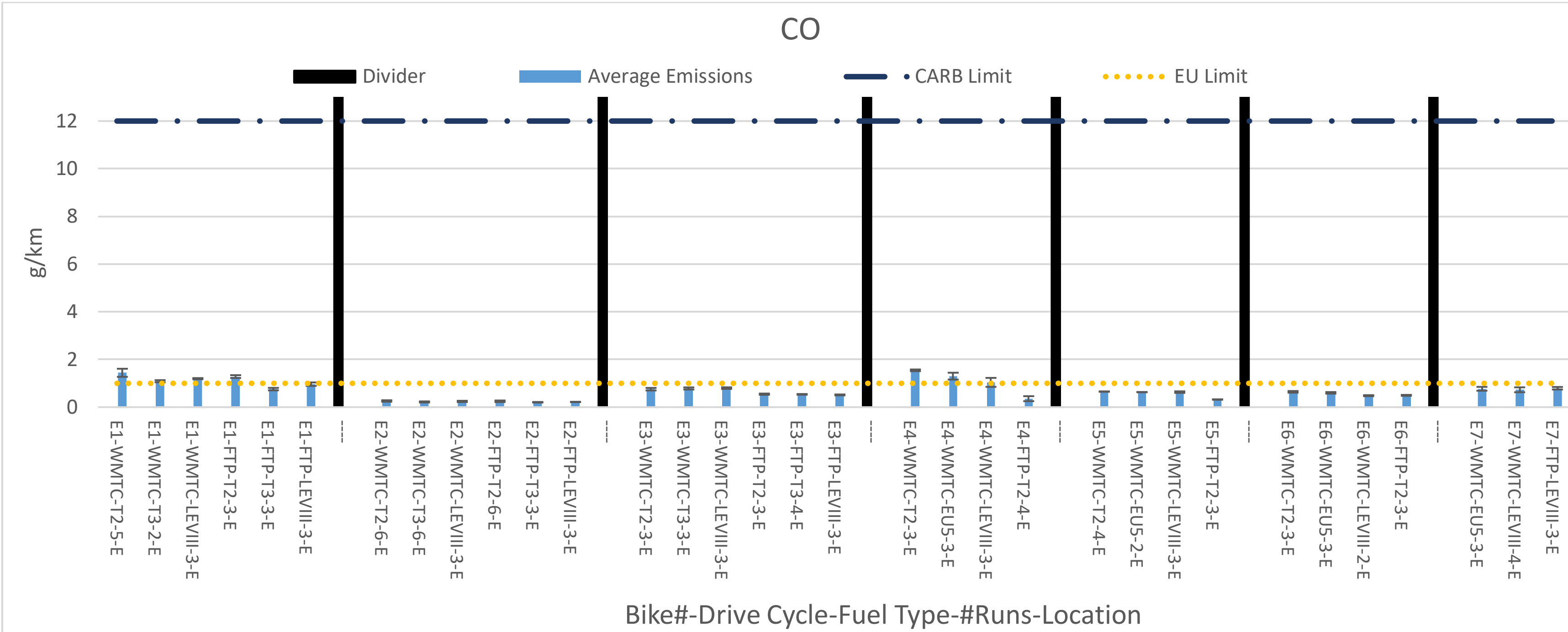
3) EU type-approved ONMCs were under the EU CO limit on all combinations of drive cycle and fuel and performed similarly to other CARB/EPA certified ONMCs that met the EU CO emissions limit. This suggests that current manufacturers of California certified ONMCs could easily meet the proposed standard.

Figure 11. CARB and Manufacturer ONMC Emissions Testing Results for CO



See section Drive Cycles for M1 note.

Figure 12. U.S. EPA/ECCC ONMC Emissions Testing Results for CO



Modal Analysis

CARB performed modal analysis (second by second results) for motorcycles C1 – C4. The manufacturer collected cumulative modal data for M1. These are important for showing how differences in the drive cycle may impact how regulated emissions are generated. Due to laboratory equipment limitations, the emissions results could not be perfectly synchronized to the drive trace. Often, they may have been off sync several seconds for any given run and had to be resynced with engineering judgment in the data analysis. This was an additional issue with the third phase of the FTP drive cycle which follows an engine-off hot-soak period that allows slight variations in duration. Therefore, results in this modal analysis are mostly limited to qualitative analysis.

The results are laid out separately in graphs for each ONMC on each drive cycle. THC (green) and NOx (red) are combined as the scales are similar and in some cases the standard is combined. Because the scales are too dissimilar for CO (yellow) and too many pollutants would be too much information to include on one chart, CO was shown on its own separate chart. Results are given separately for both instantaneous and cumulative emissions.

Chart scales are harmonized in order that viewers may more easily make direct comparisons. Compromise was made to see best resolution of the majority of the data while still emphasizing where emissions spikes occurred. For some charts, this causes instantaneous data spikes to be cut off short of their peak. Because the results are only being used for qualitative and not quantitative purposes, it is not critically important to capture every data point in the chart. In no case did THC or NOx exceed 0.06 g/s or CO exceed 0.8 g/s.

All charts are set to 3000 seconds on the horizontal axis in order to allow for better comparisons about when emissions occur between FTP and WMTC, which have different durations.

Vehicle instantaneous speed (blue) is given on the secondary vertical axis and presented to 150 kilometers per hour (kmph) to allow the charts to easily show the higher top speeds of the WMTC while seeing the appropriate scale with the FTP.

Pollutants are measured on the primary vertical axis in grams per second (g/s) for the instantaneous charts and total grams (g) for the cumulative charts. For instantaneous charts displays for THC and NOx results were limited to 0.015 g/s and CO was limited to 0.3 g/s. For cumulative charts THC and NOx were set to 4.0 g and CO was set to 20.0 g. Specific maximum and average instantaneous emissions rates for each bike along with cumulative totals can be found in Table 12, which follows all of the individual emissions traces for each ONMC.

Individual Modals

Instantaneous charts for C1 in Figure 13 and Figure 14 show much of the THC coming at the beginning of the WMTC and the FTP cold and hot starts whereas NOx and CO emissions seem to correlate with hard acceleration. The higher speed section of the WMTC seems to also correlate with higher emissions of all types. Higher peak emissions were generated on the WMTC for NOx and CO.

Figure 13. C1 Instantaneous WMTC Emissions

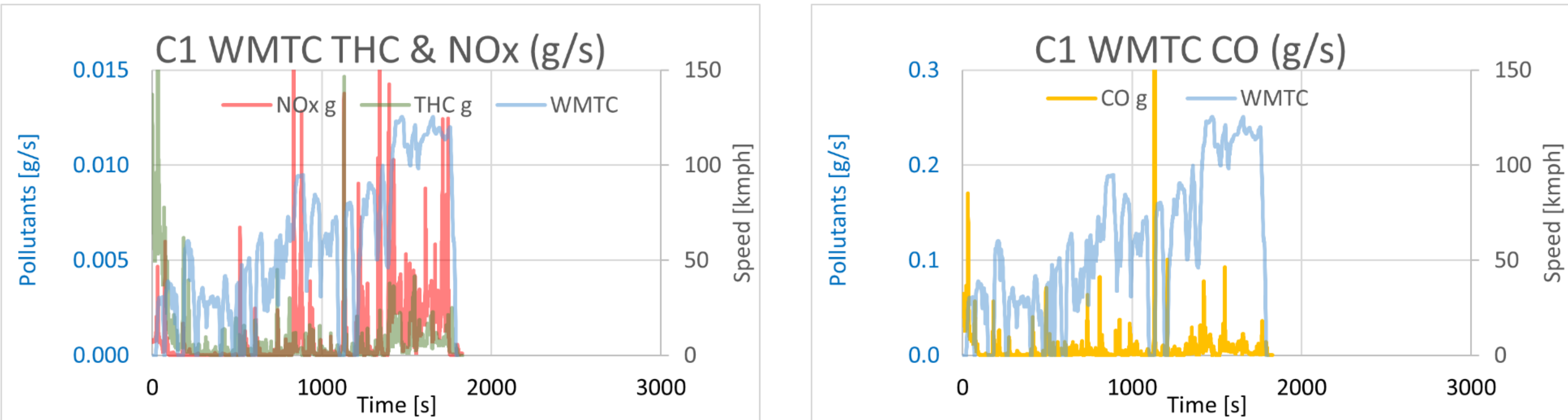
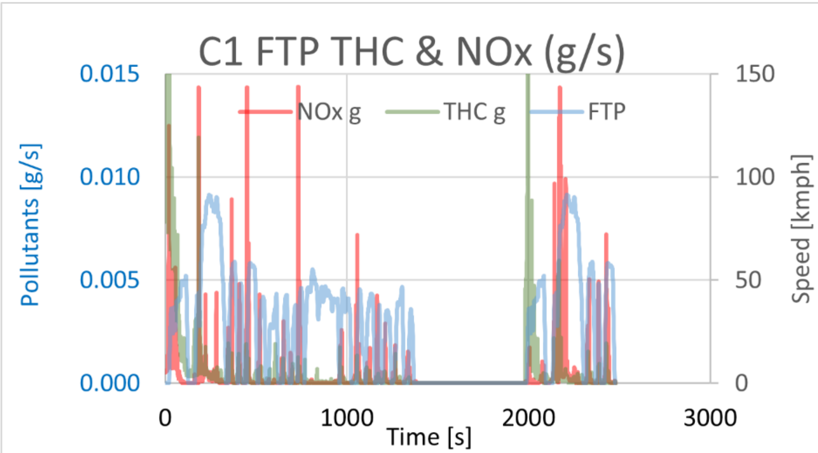
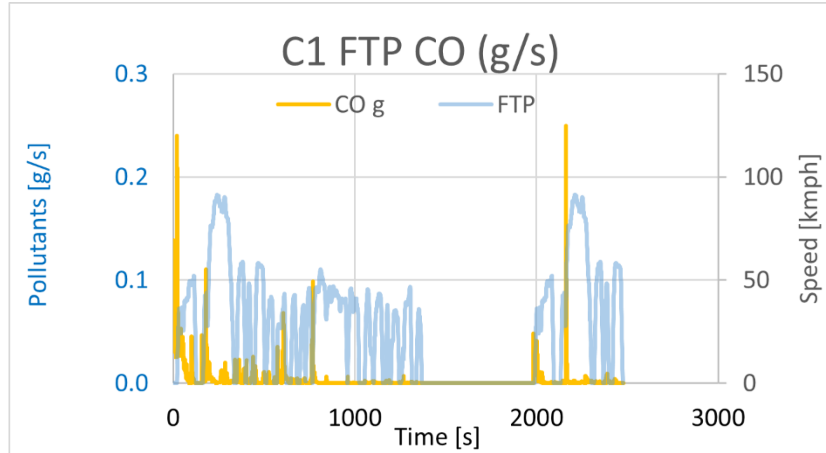


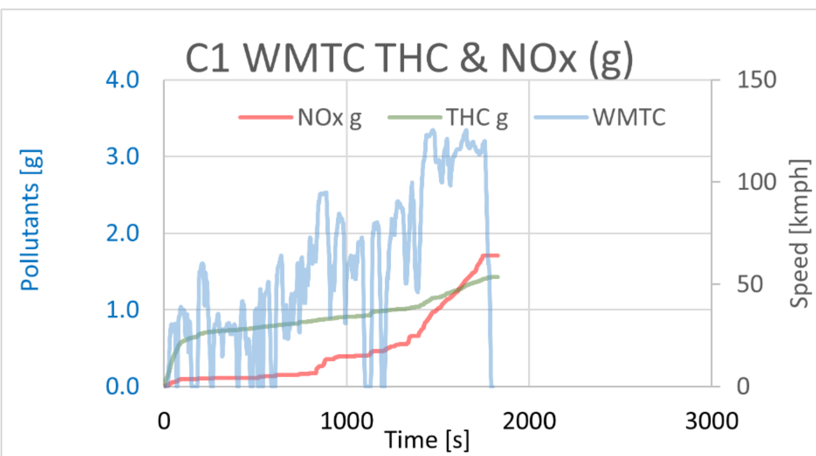
Figure 14. C1 Instantaneous FTP Emissions





Cumulative charts for C1 in Figure 15 and Figure 16 show that most of the HC emissions occur during cold start for both cycles. NOx and CO emissions occur during the higher speed portion of the WMTC. Overall, the WMTC generated more of all emissions considered here than the FTP, with nearly twice as much NOx.

Figure 15. C1 Cumulative WMTC Emissions



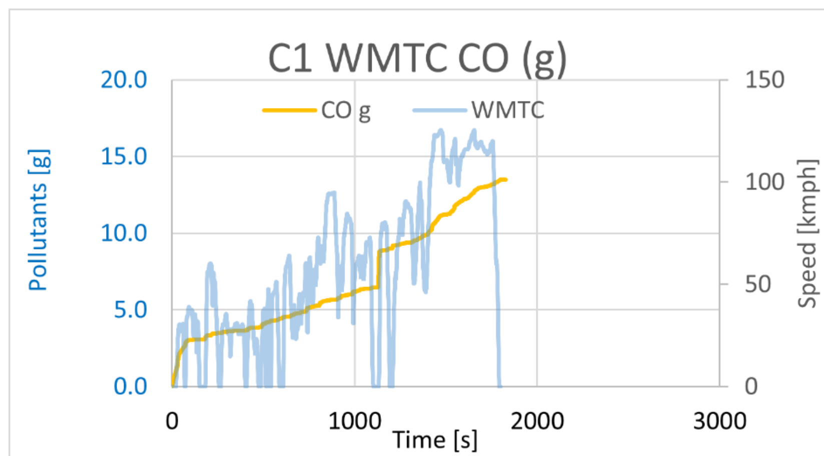
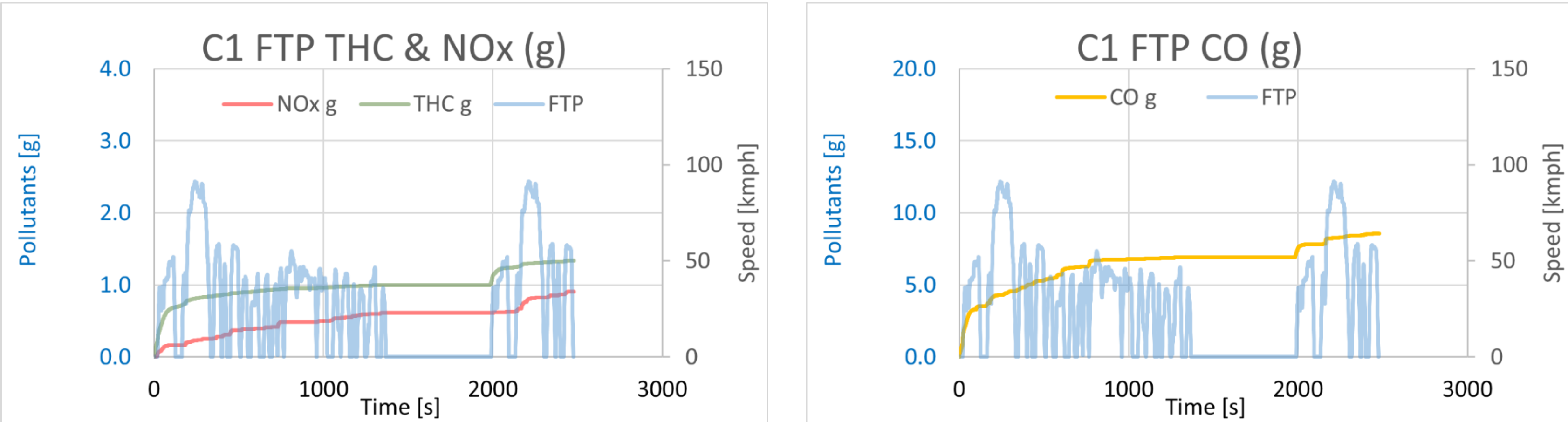


Figure 16. C1 Cumulative FTP Emissions



Instantaneous charts for C2 in Figure 17 and Figure 18 below shows much of the THC and CO coming at the cold start and during the high-speed portions of the WMTC and mostly at the cold start of the FTP whereas NOx seemed to correlate better with hard accelerations in both the WMTC and FTP. Higher peak emissions were generated on the WMTC only for THC in contrast to motorcycle C1.

Figure 17. C2 Instantaneous WMTC Emissions

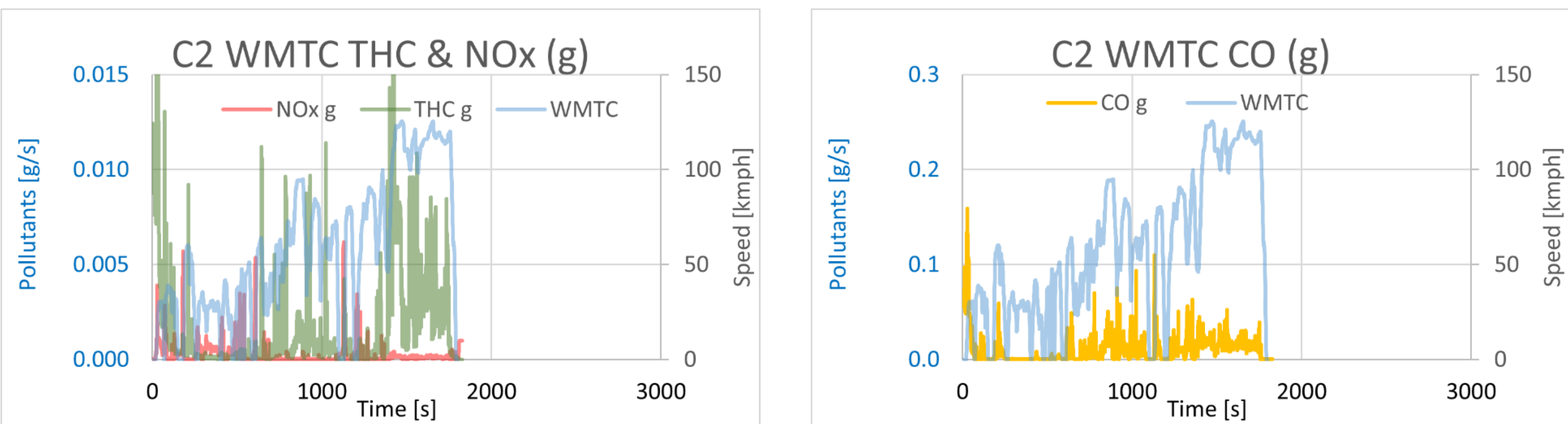
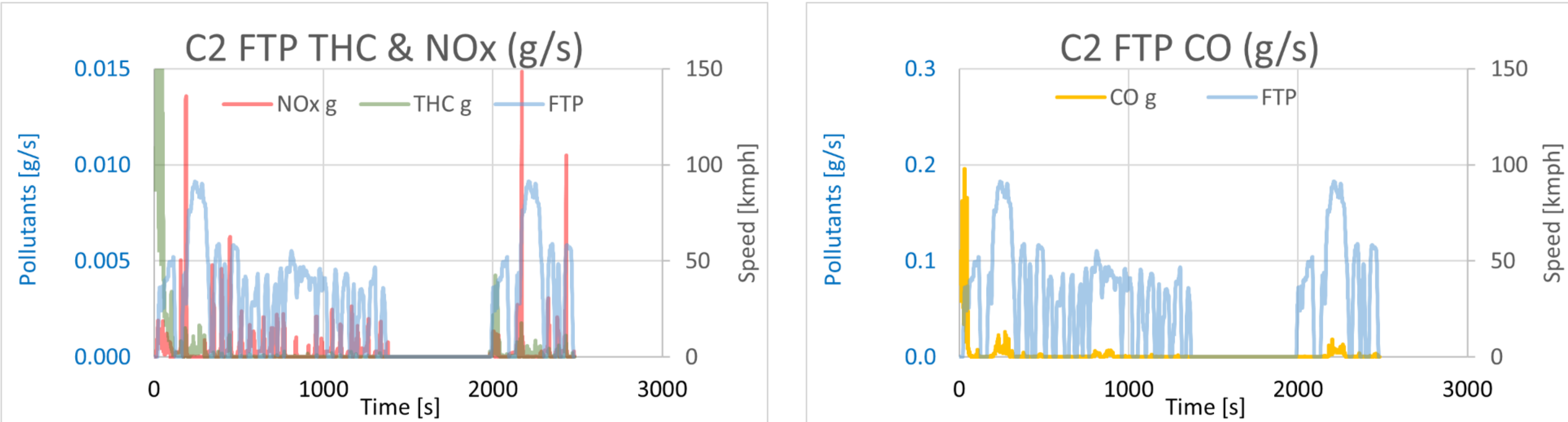


Figure 18. C2 Instantaneous FTP Emissions



Cumulative traces from C2 in Figure 19 and Figure 20 show that most of the emissions for THC and CO occur during the WMTC cold start and high-speed sections, whereas in the FTP these occurred mostly at cold start. This suggests that the emissions controls for this ONMC were optimized for the lower speeds included in the FTP, not the higher speeds on the WMTC. This was true for NOx as well, but to a much lesser degree. Overall, the WMTC generated significantly more THC and CO emissions whereas the FTP generated more NOx than the WMTC even though the levels were very low.

Figure 19. C2 Cumulative WMTC Emissions

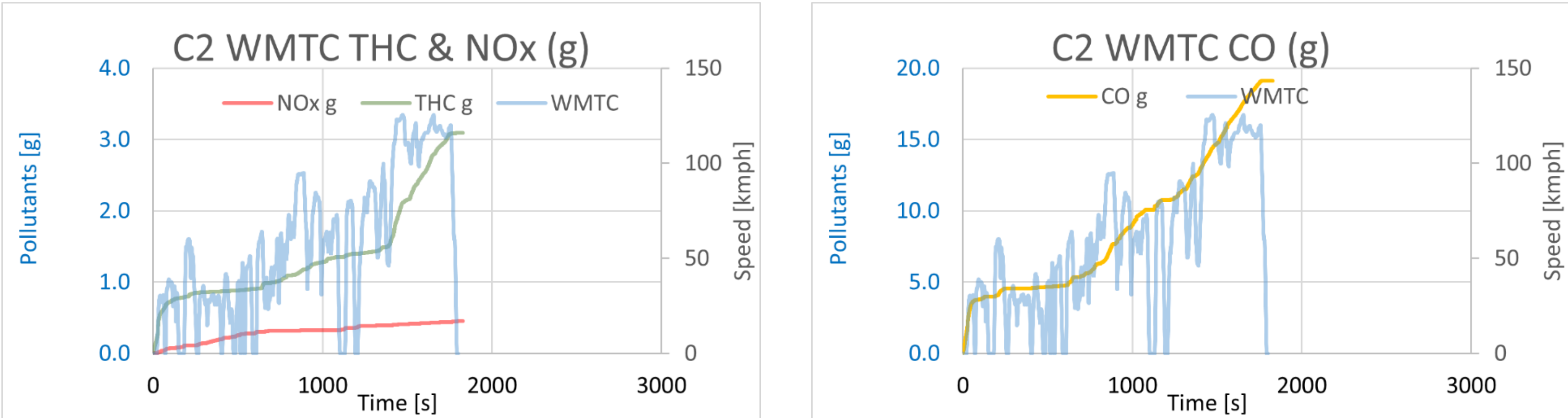
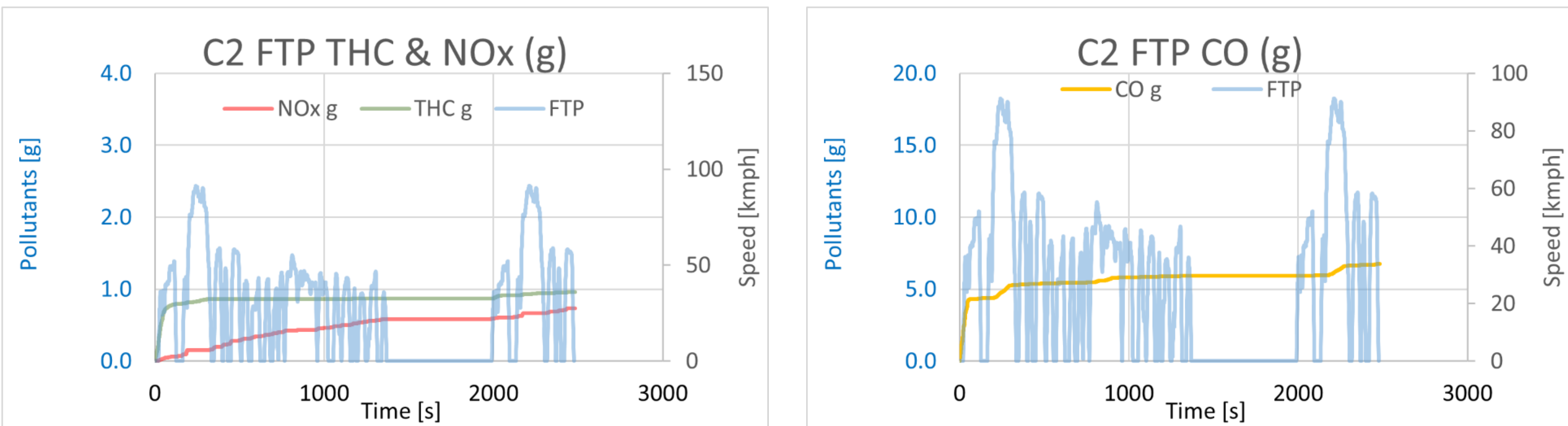


Figure 20. C2 Cumulative FTP Emissions



Instantaneous charts for C3 in Figure 21 and Figure 22 show much of the THC and CO coming at the cold start and during the high-speed portions of the WMTC and mostly at the cold start of the FTP whereas NOx seemed to correlate better with hard accelerations in both the WMTC and FTP. Higher peak emissions were generated on the WMTC for all THC and NOx.

Figure 21. C3 Instantaneous WMTC Emissions

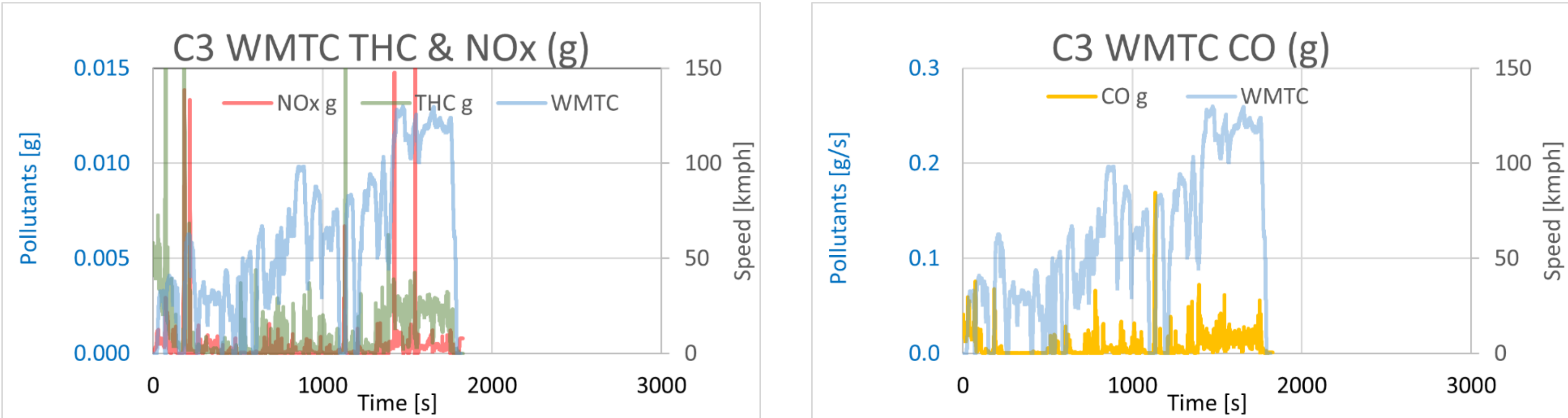
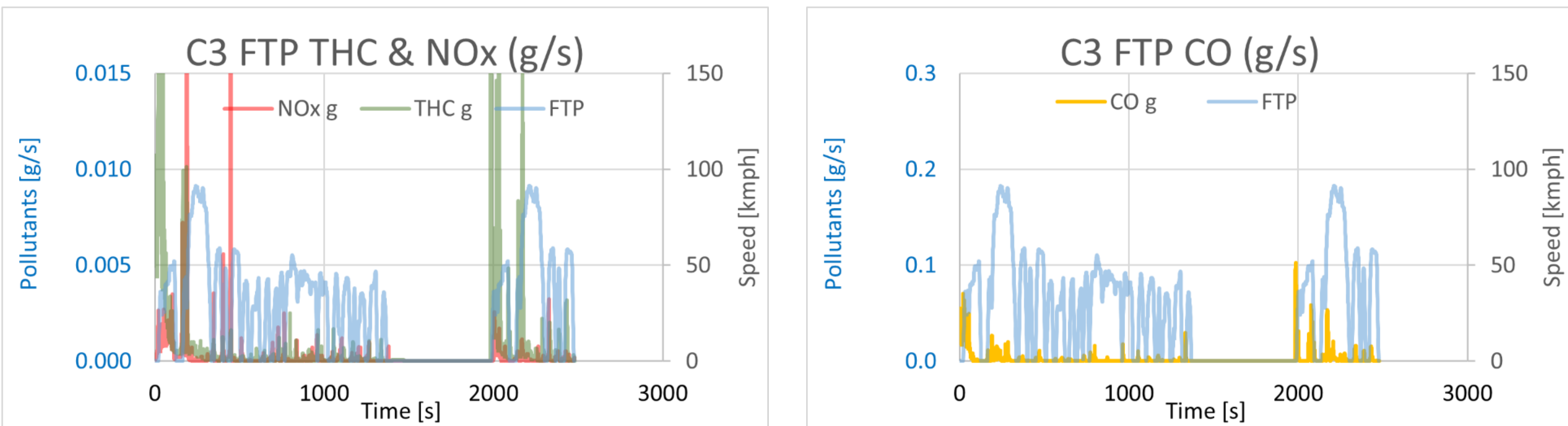


Figure 22. C3 Instantaneous FTP Emissions



Cumulative charts from C3 in Figure 23 and Figure 24 show that most of the emissions for THC and CO occur during the WMTC cold start and high-speed sections, whereas in the FTP these occurred mostly at cold and to a lesser degree hot start. This suggests that the emissions controls for this ONMC were optimized for the lower speeds included in the FTP, not the higher speeds on the WMTC. This was true for NOx as well, but to a much lesser degree.

Overall, the WMTC generated significantly more THC and CO emissions whereas the FTP generated more NOx than the WMTC even though the levels were very low.

Figure 23. C3 Cumulative WMTC Emissions

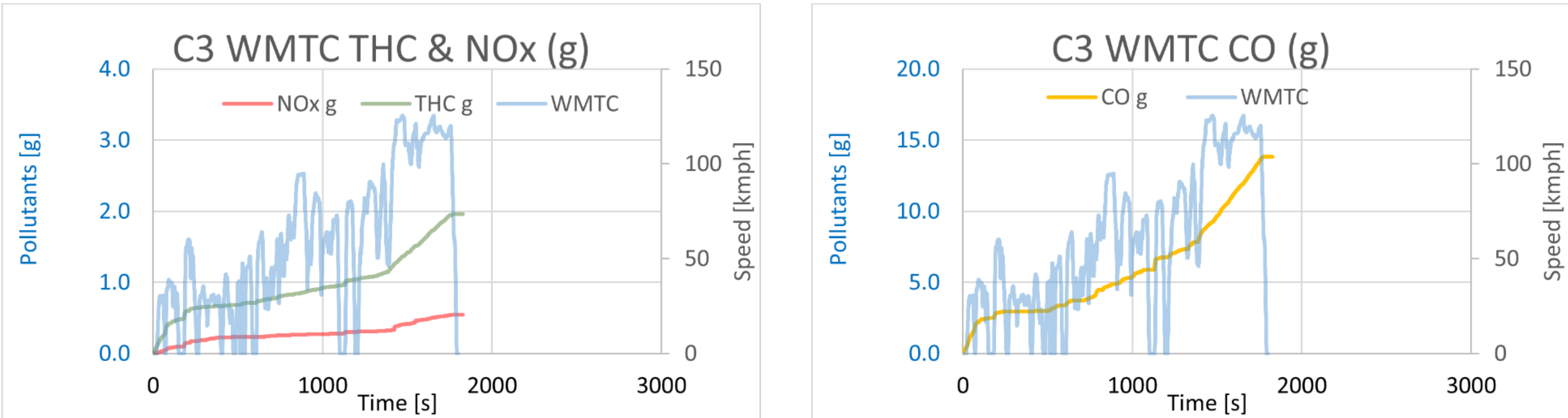
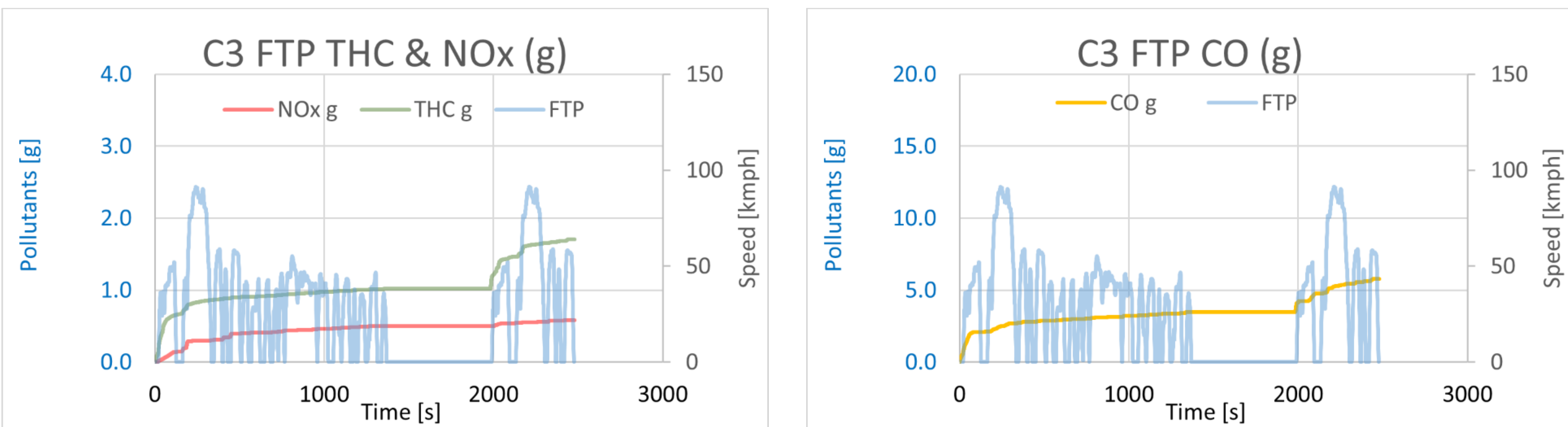


Figure 24. C3 Cumulative FTP Emissions



Instantaneous charts for C4 in Figure 25 and Figure 26 show much of the THC coming at the cold start and during the high-speed portions of the WMTC and mostly at the cold and to a lesser degree hot start of the FTP. Whereas NOx and CO seemed to correlate better with hard accelerations in both the WMTC and FTP. Higher peak emissions were generated on the WMTC for NOx and CO.

Figure 25. C4 Instantaneous WMTC Emissions

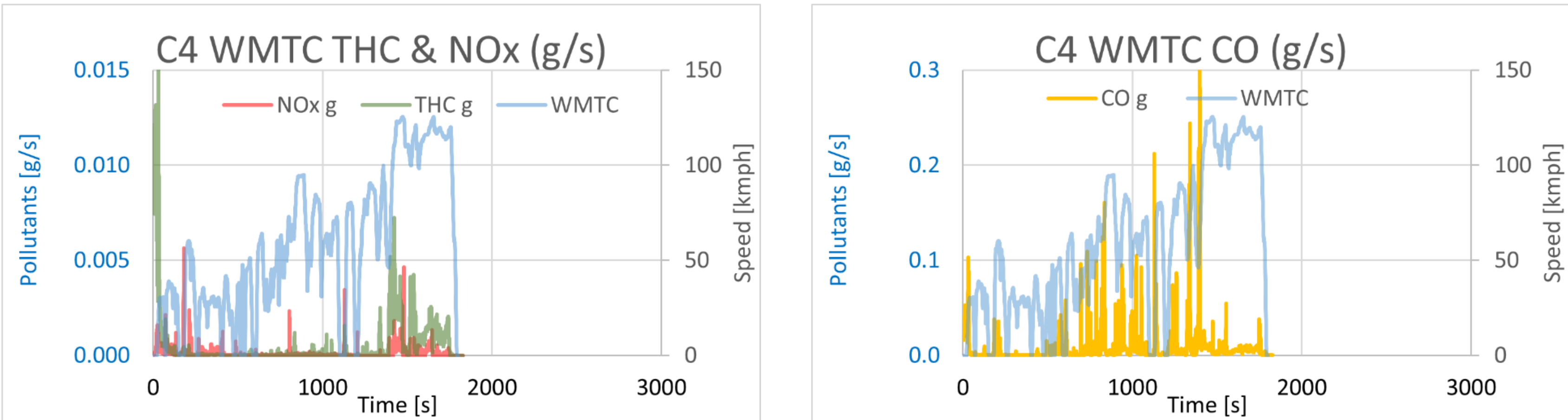
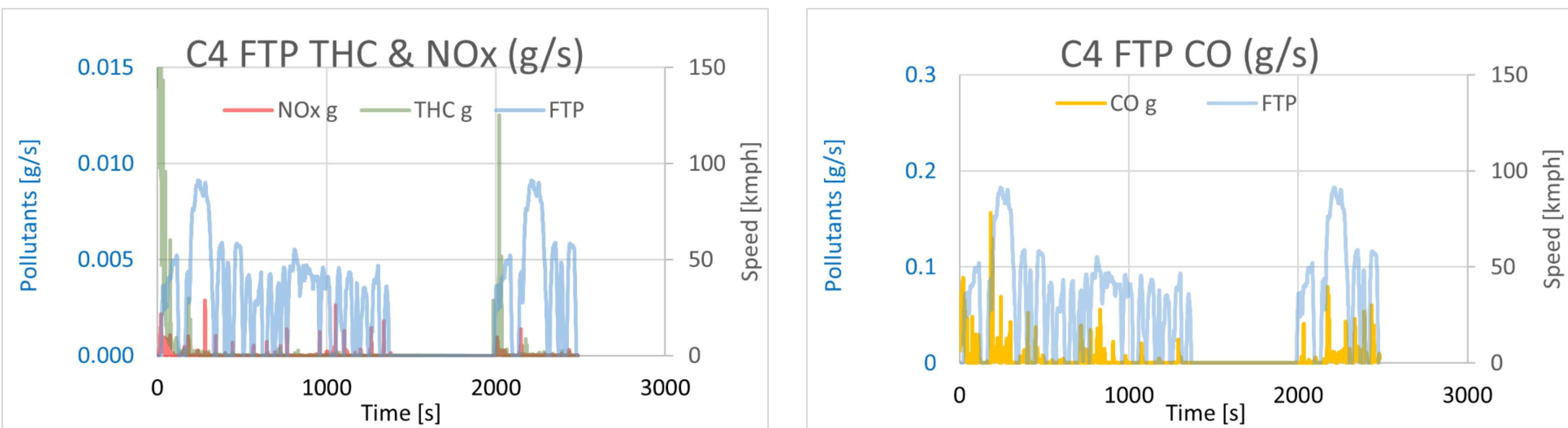


Figure 26. C4 Instantaneous FTP Emissions



Cumulative traces from C4 in Figure 27 and Figure 28 show that most of the emissions for THC and CO occur during the WMTC cold start and high-speed sections, whereas in the FTP THC occurred mostly at cold start. This was true for NOx too but to a much lesser degree. Overall, the WMTC generated significantly more THC and CO emissions whereas the FTP generated more NOx than the WMTC even though the levels were very low.

Figure 27. C4 Cumulative WMTC Emissions

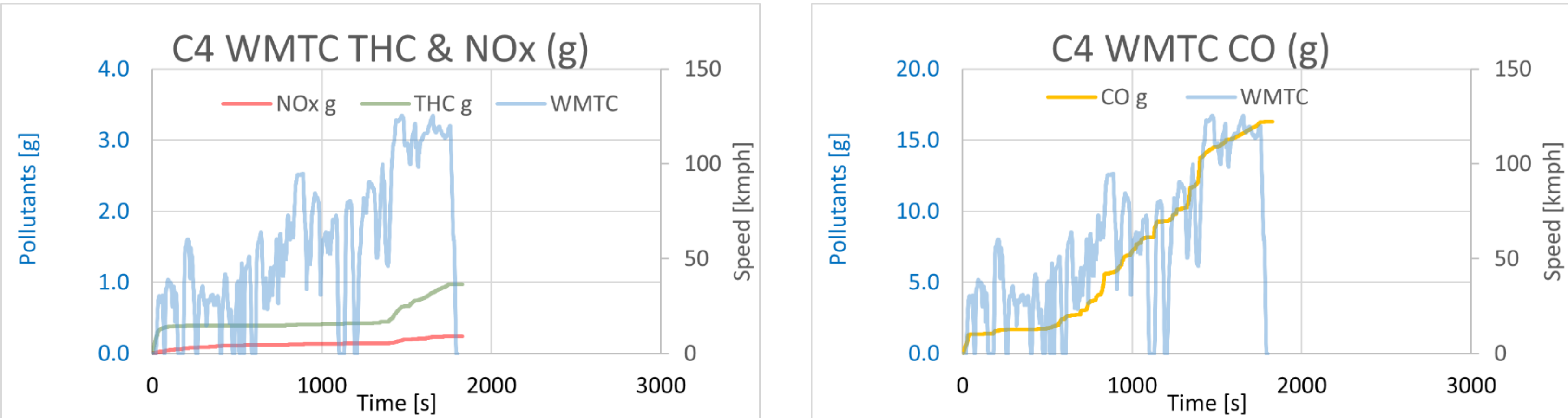
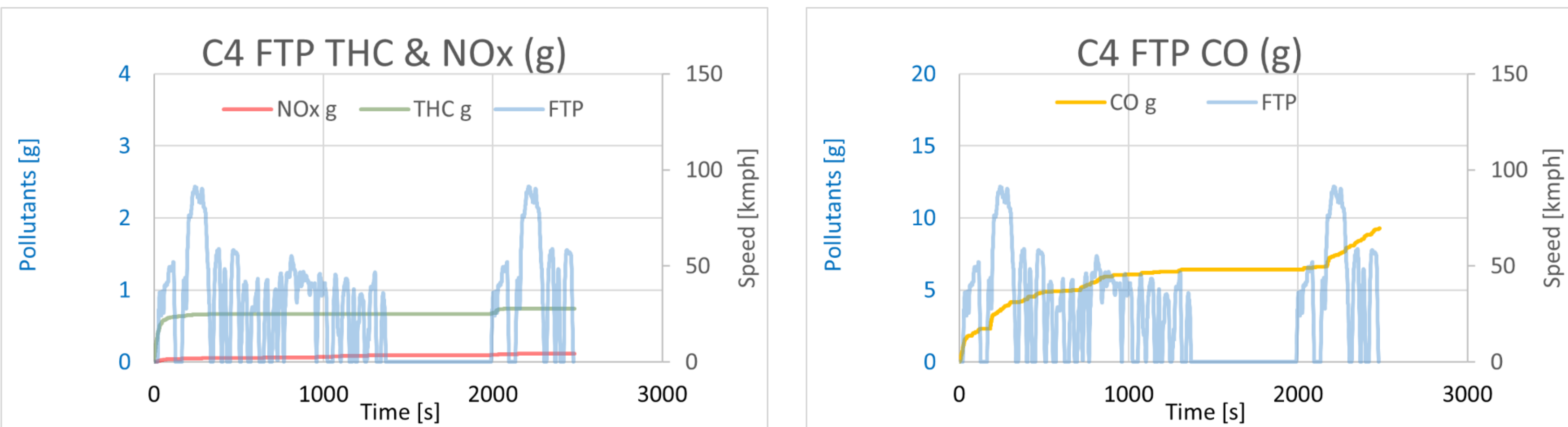


Figure 28. C4 Cumulative FTP Emissions



Motorcycle M1 was tested by a manufacturer in their own lab facility and only cumulative results were readily available as shown in Figure 29 and Figure 30. Cold start appears to be the biggest driver of THC and CO emissions, with emissions being well controlled even during high-speed sections of the WMTC. Overall, the WMTC generated more emissions for CO.

Figure 29. M1 Cumulative WMTC Emissions

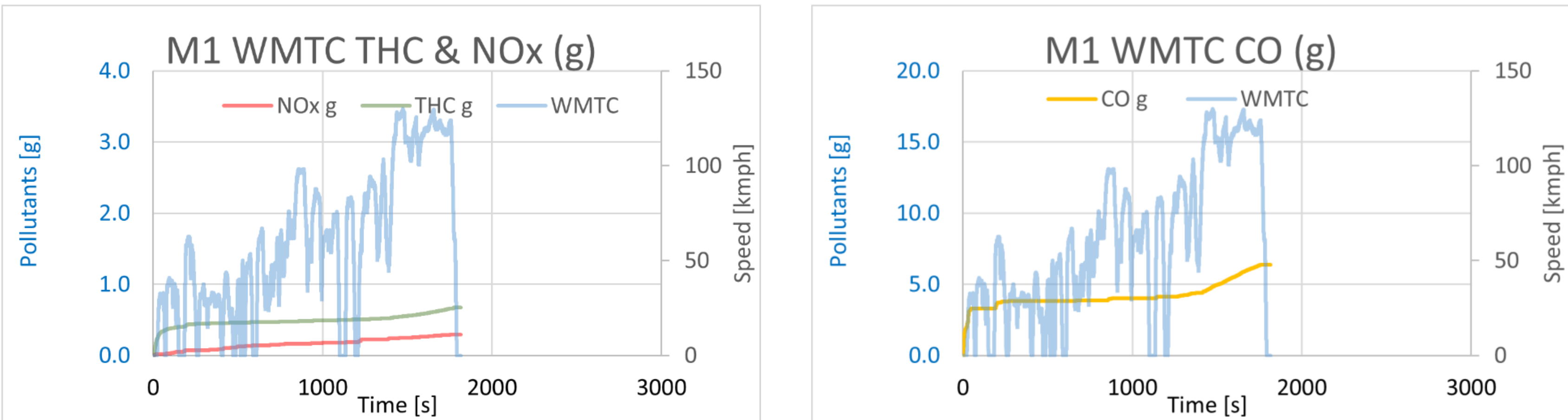


Figure 30. M1 Cumulative FTP Emissions

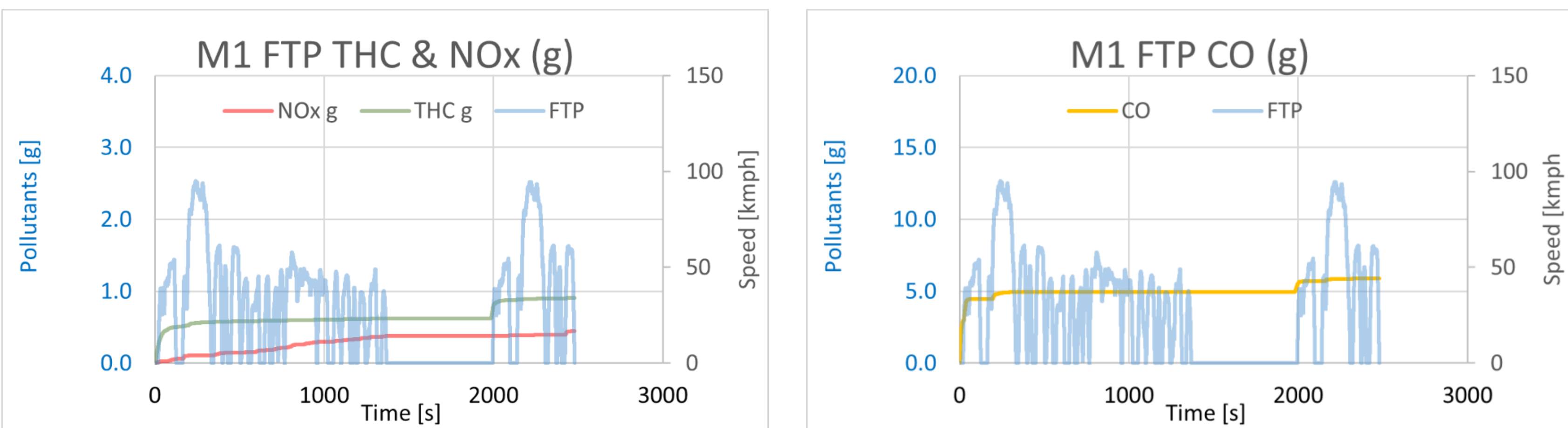


Table 12 shows a numerical comparison of the emissions data generated from all ONMCs for total grams (g), maximum grams per second (g/s) and average g/s. Generally, the EU 5 type-approved motorcycles (C4 and M1) performed much better on THC and NOx. However, this was not true for CO. But it should be noted that all these ONMCs are well below current and proposed CO limits.

Table 12. Summary of Modal Results

		C1			C2			C3			C4			M1*		
		THC	NOx	CO	THC	NOx	CO	THC	NOx	CO	THC	NOx	CO	THC	NOx	CO
WMTC	Total g	1.43	1.71	13.47	3.09	0.45	19.11	1.96	0.54	13.82	0.97	0.24	16.31	0.68	0.29	6.38
	Max g/s	1.7E-02	1.6E-02	8.0E-01	5.4E-02	6.2E-03	1.6E-01	2.9E-02	1.5E-02	1.7E-01	1.6E-02	5.6E-03	3.9E-01	N/A	N/A	N/A
	Avg g/s	7.8E-04	9.4E-04	7.4E-03	1.7E-03	2.6E-04	1.0E-02	1.1E-03	3.1E-04	7.6E-03	5.3E-04	1.3E-04	8.9E-03	N/A	N/A	N/A
FTP	Total g	1.34	0.91	8.55	0.96	0.74	6.75	1.71	0.59	5.77	0.74	0.12	9.29	0.45	0.91	5.90
	Max g/s	3.1E-02	1.4E-02	2.5E-01	3.8E-02	1.5E-02	2.0E-01	4.8E-02	1.6E-02	1.0E-01	2.6E-02	2.9E-03	1.6E-01	N/A	N/A	N/A
	Avg g/s	7.0E-04	4.8E-04	4.5E-03	5.0E-04	3.9E-04	3.6E-03	9.0E-04	3.1E-04	3.0E-03	3.9E-04	6.2E-05	4.9E-03	N/A	N/A	N/A

*Only Cumulative Modal data was collected for M1.

The cumulative emissions in grams were averaged for all of these CARB certified ONMCs (C1 – C3) for THC, NOx and CO in order to compare how much better the EU 5 type-approved motorcycles performed (Table 13). Except for CO emissions on motorcycle C4, these emissions were all significantly lower for the EU 5 motorcycles than the average of the CARB certified motorcycles. As discussed above, all these motorcycles are all well under the current and proposed CO limits.

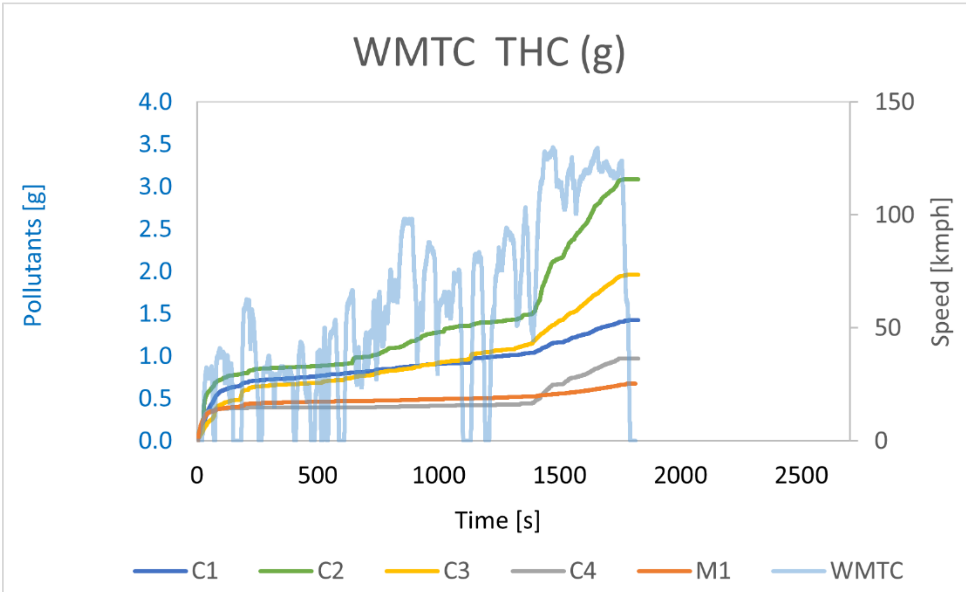
Table 13. Euro 5 Type-approved Motorcycles Compared to Cumulative Emissions of Average CARB Certified

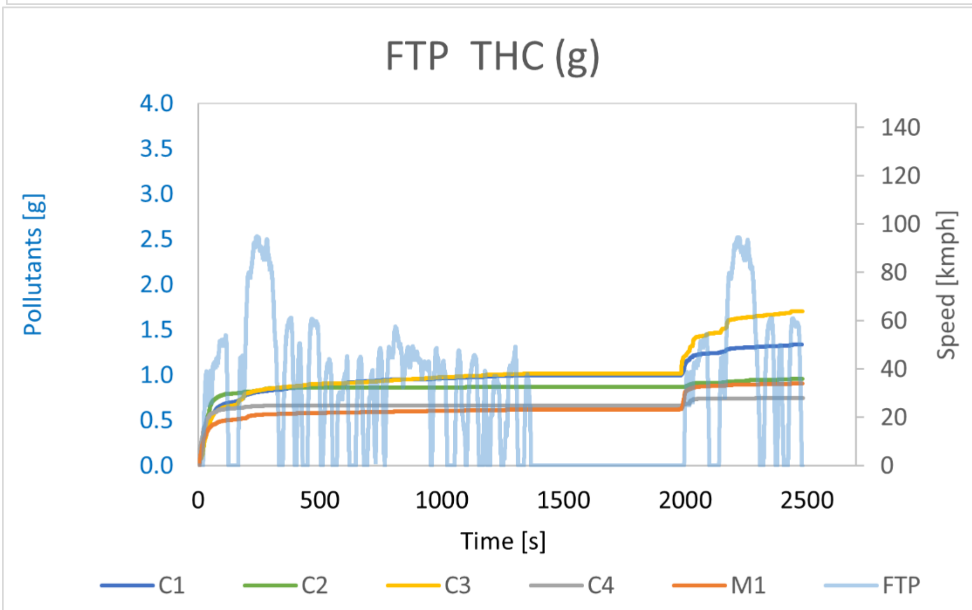
	Average CARB ONMC Emissions (g)			C4 vs. Average CARB ONMC Emissions (g)			M1 vs. Average CARB ONMC Emissions (g)		
	THC	NOx	CO	THC	NOx	CO	THC	NOx	CO
WMTC	2.16	0.90	15.47	-1.19	-0.66	0.84	-1.48	-0.61	-9.09
% Δ	N/A	N/A	N/A	-55.0%	-73.4%	5.4%	-68.7%	-67.3%	-58.8%
FTP	1.33	0.74	7.02	-0.59	-0.63	2.27	-0.43	-0.29	-1.12
% Δ	N/A	N/A	N/A	-44.2%	-84.3%	32.2%	-32.1%	-39.5%	-16.0%

Combined Modals

Combined cumulative trace comparisons are given below in Figure 31 for THC for all ONMCs. Again, it is clear that the EU 5 type-approved motorcycles C4 and M1 perform better on both the FTP and WMTC than the CARB certified motorcycles, although the difference is more apparent on the WMTC. This is likely because the emissions controls for these motorcycles are optimized for that drive cycle.

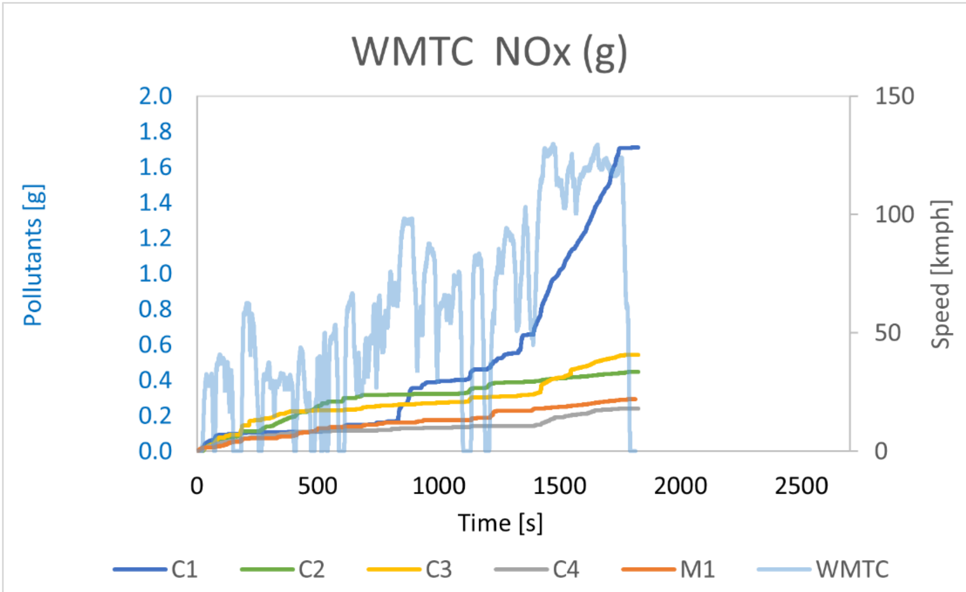
Figure 31. Multi-Motorcycle Direct Emissions Comparison on THC for WMTC and FTP cycles

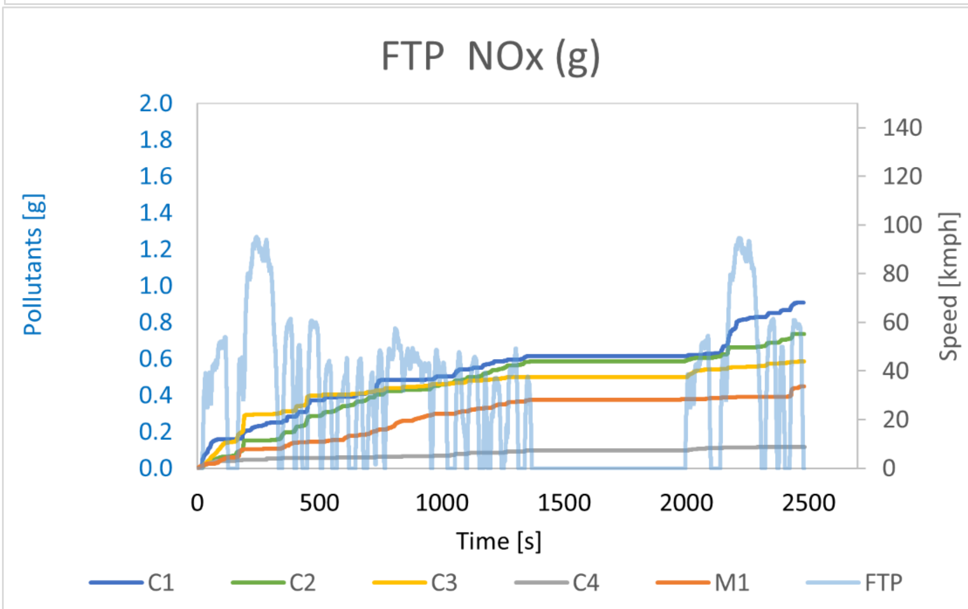




Combined cumulative trace comparisons are given below in Figure 32 for NOx for all ONMCs. Again, it is clear that the EU 5 typed-approved motorcycles C4 and M1 perform better on both drive cycles than the CARB certified motorcycles, although the difference is again more apparent on the WMTC. This is likely because the emission controls for these ONMCs are optimized for that drive cycle.

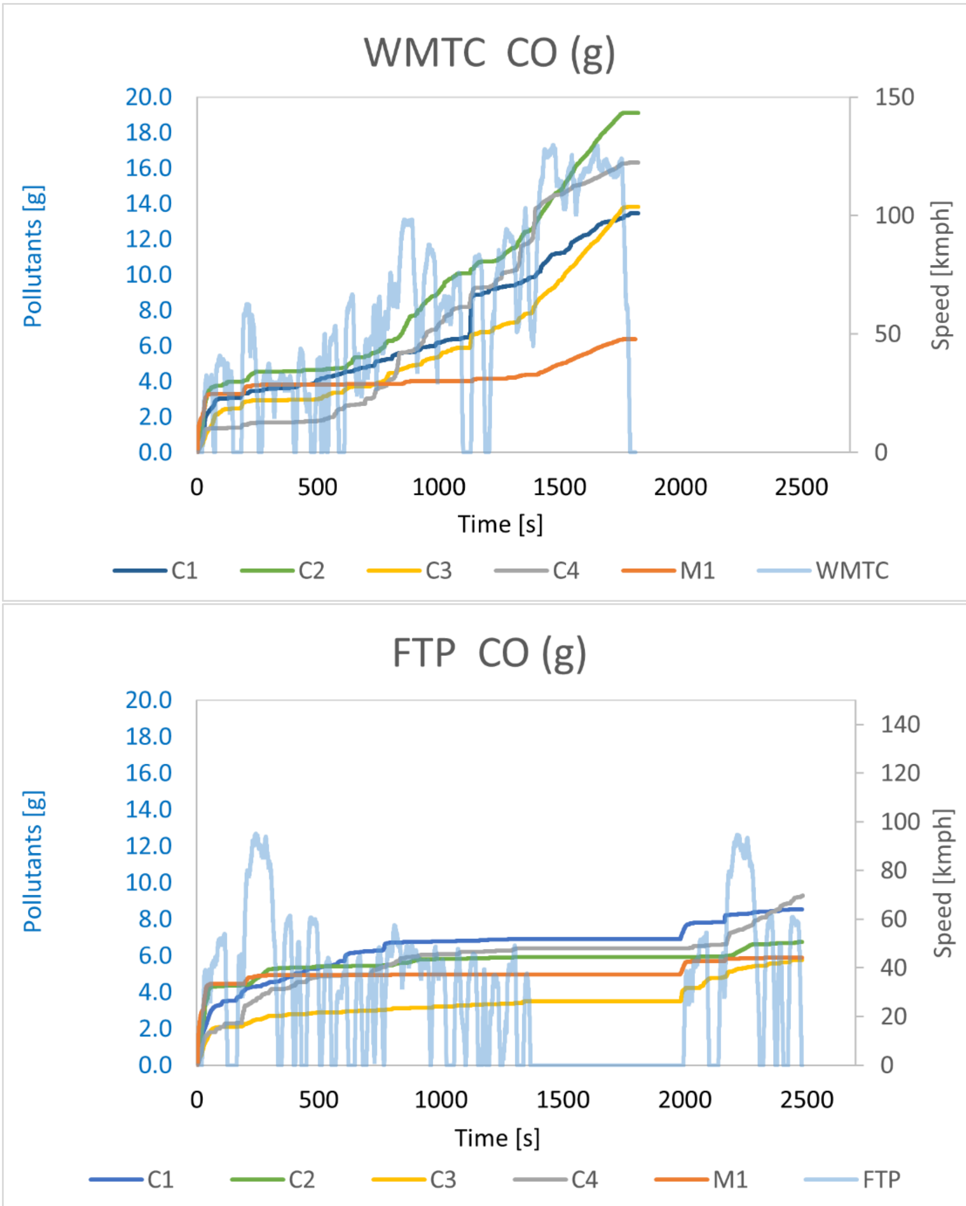
Figure 32. Motorcycle to Motorcycle Comparison on NOx for WMTC and FTP cycles





Combined cumulative trace comparisons are given below in Figure 33 for CO for all motorcycles. Here, the EU 5 type-approved motorcycles performed similar to the CARB certified motorcycles on both drive cycles, with the exception that the M1 was strikingly better on the high-speed portion of the WMTC. This is likely because the THC and NOx standards have been a much bigger challenge to meet, so performance has likely been optimized for controlling those emissions. Also of note was that, with the exception of M1, all of the other ONMCs tested produced the majority of emissions during the high speed section of the WMTC, showing the relative importance of these real world speeds being included in certification testing.

Figure 33. Motorcycle to Motorcycle Comparison on CO for WMTC and FTP cycles



EU5 ONMC Performance Against the Proposed Standard

While we have seen visually in the graphs that the EU5 bikes did very well against the proposed emission limits on all variations of fuel and drive cycles, it is important to show definitively that these bikes did well against the proposed standard of meeting the EU5 emissions limits with LEV III fuel on the WMTC drive cycle. Table 14 show that in most cases, the EU5 bikes were usually well under 50% of the proposed standard.

Table 14. EU5 Type-approved Bike Performance Against the Proposed CARB Standard and Emissions Limits

	HC	NOx	CO	NMHC
C4	41.3%	14.5%	61.5%	52.4%
M1*	37.7%	35.8%	33.2%	47.0%
E6	40.9%	34.1%	48.2%	46.9%

See section Drive Cycles for M1 note.

Conclusion

This study found that over an analysis of data collected from 12 ONMCs with 10 Class III (>280cc), 1 Class 1b (125cc) and 1 Class 1a (49cc), that while both fuel and drive cycles can have an impact on exhaust emissions measured during certification testing, that choice of certification fuels considered has a relatively minor impact on emissions while the difference between the WMTC and FTP drive cycles was significant.

While several different fuels were tested, the one most significant to the Proposal is the switch from EU5 fuel to LEV III fuel in allowing EU5 type approval data to be used in CARB certification testing. Staff found that the impact across the bikes tested on this combination of fuels on the WMTC led to an average change in emissions of any pollutant of less than 10% (NOx), with most pollutants impacted far less. Relative to the proposed EU5 emissions limits, this change in emissions resulted in less than 7% (CO) again with most pollutants impacted far less. It is important to note that these small differences could easily fall into the normal variability between repeated tests on ONMCs using the same fuel and drive cycle. Further, the data showed that bikes built to the EU 5 standard often emit at levels less than half of the EU5 standard, leaving a wide margin to account for this small variability in exhaust emissions in going from the EU 5 test fuel to the CARB LEV III test fuel.

The testing showed that the impact to emissions in going from the FTP to the WMTC drive cycle on average raised some emissions up to 44%. Further, as shown, the WMTC exposes bikes during certification testing to much higher speeds and accelerations more representative of real-world riding. These higher speeds tend to be where a large portion of total emissions occur. This is a strong indication that bikes certified on the WMTC will need to be built to higher standards to meet the same emissions limits as bikes certified on the FTP, making these bikes likely to emit less in the real world.

The testing also demonstrated that many of the bikes built to meet CARB certification standards emitted near or below the much more stringent emissions limits of the EU 5 standard, and generally well below current CARB standards. This is a strong indication as well that aside from there being many EU5 compliant bikes that could meet the standard, many CARB certified bikes may be able to reliably pass the proposed exhaust standard with modest modifications.

Appendix 1

Test Data

The emissions data in this appendix are summaries of all bikes tested in this report for any combination of fuel and drive cycle. In total it represents 58 trials comprised of 193 tests.[8] This information can be distilled in the nomenclature of column on as follows: which ONMC was tested, the drive cycle tested, the fuel used during that run, the number of tests run and the location of the testing. For example, C1-WMTC-T2-4-C would denote an average pollutant measure of 4 tests on test bike C1 on the WMTC with Indolene (T2) test fuel as tested by CARB. For each of these trials, the following is given for each pollutant: average, standard deviation of the sample, constant of variation, and the confidence interval.

[8] CARB. ONMC Exhaust Emissions Analysis Spreadsheet to Support the Proposed Amendments to On-Road Motorcycle (ONMC) Emissions Standards, August 17, 2023.

Vehicle-Drive Cycle-Fuel-Location	# Runs	HC				NOx				HC+NOx				CO				NMHC			
		Avg	Std Dev	CV (%)	CI (%)	Avg	Std Dev	CV (%)	95% CI	Avg	Std Dev	CV (%)	95% CI	Avg	Std Dev	CV (%)	95% CI	Avg	Std Dev	CV (%)	95% CI
C1-WMTC-T2-4-C	4	0.066	0.001	1.5%	0.002	0.068	0.010	14.5%	0.016	0.134	0.010	7.3%	0.016	0.547	0.037	6.8%	0.059	0.059	0.001	1.5%	0.001
C1-WMTC-EU5-3-C	3	0.067	0.018	27.2%	0.045	0.061	0.005	8.8%	0.013	0.127	0.015	12.1%	0.038	0.548	0.042	7.7%	0.105	0.060	0.017	28.0%	0.041
C1-WMTC-LEVIII-4-C	4	0.075	0.007	9.2%	0.011	0.060	0.003	5.6%	0.005	0.135	0.004	3.0%	0.006	0.646	0.090	13.9%	0.143	0.067	0.006	9.7%	0.010
C1-FTP-LEVIII-3-C	3	0.059	0.002	3.1%	0.005	0.043	0.007	16.7%	0.018	0.102	0.008	8.0%	0.020	0.371	0.057	15.3%	0.142	0.051	0.002	3.4%	0.004
C2-WMTC-T2-3-C	3	0.100	0.010	9.9%	0.025	0.016	0.001	6.7%	0.003	0.116	0.009	7.7%	0.022	0.603	0.052	8.6%	0.128	0.085	0.009	10.5%	0.022
C2-WMTC-EU5-5-C	5	0.068	0.007	10.9%	0.009	0.024	0.006	23.4%	0.007	0.091	0.012	13.3%	0.015	0.534	0.114	21.4%	0.142	0.059	0.005	9.2%	0.007
C2-WMTC-LEVIII-3-C	3	0.078	0.009	11.2%	0.022	0.023	0.001	5.1%	0.003	0.101	0.010	9.8%	0.024	0.436	0.018	4.1%	0.044	0.063	0.007	10.9%	0.017
C2-FTP-T2-3-C	3	0.069	0.008	11.6%	0.020	0.028	0.003	9.6%	0.007	0.098	0.010	9.9%	0.024	0.538	0.073	13.5%	0.181	0.053	0.007	12.5%	0.017
C2-FTP-EU5-2-C	2	0.055	0.006	11.6%	0.057	0.032	0.004	12.4%	0.036	0.087	0.002	2.8%	0.021	0.397	0.048	12.0%	0.428	0.045	0.004	9.0%	0.036
C2-FTP-LEVIII-2-C	2	0.047	0.014	30.0%	0.126	0.042	0.000	0.1%	0.000	0.089	0.014	15.7%	0.126	0.270	0.006	2.1%	0.051	0.035	0.009	26.8%	0.085
C3-WMTC-T2-3-C	3	0.072	0.003	4.2%	0.008	0.018	0.003	15.4%	0.007	0.090	0.004	4.8%	0.011	0.474	0.038	8.0%	0.094	0.058	0.003	4.3%	0.006
C3-WMTC-EU5-8-C	8	0.076	0.014	18.7%	0.012	0.022	0.006	26.3%	0.005	0.098	0.016	16.4%	0.014	0.477	0.104	21.8%	0.087	0.065	0.015	23.0%	0.013
C3-WMTC-LEVIII-3-C	3	0.070	0.007	9.6%	0.017	0.025	0.002	7.6%	0.005	0.095	0.009	9.0%	0.021	0.397	0.036	9.1%	0.090	0.055	0.005	9.8%	0.013
C3-FTP-T2-3-C	3	0.077	0.004	5.6%	0.011	0.015	0.006	42.3%	0.016	0.092	0.010	10.7%	0.025	0.670	0.159	23.7%	0.395	0.060	0.006	10.1%	0.015
C3-FTP-EU5-1-C	1	0.057	N/A	N/A	N/A	0.015	N/A	N/A	N/A	0.072	N/A	N/A	N/A	0.440	N/A	N/A	N/A	0.046	N/A	N/A	N/A

Vehicle-Drive Cycle-Fuel-Location	# Runs	HC				NOx				HC+NOx				CO				NMHC			
		Avg	Std Dev	CV (%)	CI (%)	Avg	Std Dev	CV (%)	95% CI	Avg	Std Dev	CV (%)	95% CI	Avg	Std Dev	CV (%)	95% CI	Avg	Std Dev	CV (%)	95% CI
C3-FTP-LEVIII-3-C	3	0.083	0.013	15.3%	0.031	0.022	0.004	19.3%	0.011	0.105	0.013	12.7%	0.033	0.388	0.226	58.1%	0.561	0.067	0.011	15.8%	0.026
C4-WMTC-T2-3-C	3	0.044	0.001	3.1%	0.003	0.008	0.001	7.1%	0.001	0.052	0.002	3.5%	0.005	0.667	0.026	3.9%	0.065	0.038	0.002	4.2%	0.004
C4-WMTC-EU5-3-C	3	0.036	0.002	6.1%	0.005	0.007	0.001	18.3%	0.003	0.043	0.002	4.4%	0.005	0.731	0.105	14.3%	0.260	0.031	0.002	6.4%	0.005
C4-WMTC-LEVIII-4-C	4	0.041	0.007	18.0%	0.012	0.009	0.001	15.5%	0.002	0.050	0.008	16.1%	0.013	0.615	0.052	8.5%	0.083	0.036	0.007	20.6%	0.012
C4-FTP-T2-3-C	3	0.035	0.006	16.5%	0.014	0.007	0.000	3.5%	0.001	0.042	0.006	13.6%	0.014	0.540	0.062	11.5%	0.154	0.031	0.005	17.2%	0.013
C4-FTP-LEVIII-4-C	4	0.031	0.002	7.1%	0.003	0.007	0.001	12.9%	0.001	0.037	0.002	4.6%	0.003	0.480	0.088	18.3%	0.140	0.027	0.002	9.3%	0.004
M1*-WMTC-T2-3-M	3	0.037	0.003	7.7%	0.007	0.013	0.002	18.6%	0.006	0.050	0.004	8.0%	0.010	0.460	0.030	6.4%	0.074	0.032	0.001	4.6%	0.004
M1-WMTC-EU5-3-M	3	0.032	0.001	1.8%	0.001	0.014	0.003	20.1%	0.007	0.046	0.003	6.6%	0.007	0.315	0.030	9.6%	0.075	0.027	0.000	1.3%	0.001
M1*-WMTC-LEVIII-3-M	3	0.038	0.001	3.1%	0.003	0.021	0.010	48.4%	0.026	0.059	0.012	19.5%	0.029	0.332	0.034	10.2%	0.084	0.032	0.002	5.7%	0.005
M1-FTP-T2-3-M	3	0.034	0.002	5.6%	0.005	0.028	0.004	14.7%	0.010	0.062	0.003	4.5%	0.007	0.243	0.025	10.3%	0.062	0.029	0.000	1.6%	0.001
E1-WMTC-T2-5-E	5	0.279	0.026	9.3%	0.032	0.147	0.011	7.5%	0.014	0.426	0.037	8.7%	0.046	1.441	0.170	11.8%	0.211	0.268	0.025	9.3%	0.031
E1-WMTC-T3-2-E	2	0.262	0.001	0.4%	0.009	0.155	0.004	2.6%	0.036	0.417	0.005	1.2%	0.045	1.089	0.044	4.0%	0.395	0.253	0.001	0.4%	0.009
E1-WMTC-LEVIII-3-E	3	0.299	0.005	1.7%	0.012	0.162	0.004	2.5%	0.010	0.461	0.009	2.0%	0.022	1.195	0.024	2.0%	0.060	0.289	0.004	1.4%	0.010
E1-FTP-T2-3-E	3	0.275	0.008	2.9%	0.020	0.076	0.001	1.3%	0.002	0.351	0.009	2.6%	0.022	1.282	0.059	4.6%	0.147	0.263	0.008	3.0%	0.020
E1-FTP-T3-3-E	3	0.224	0.005	2.2%	0.012	0.079	0.002	2.5%	0.005	0.303	0.007	2.3%	0.017	0.756	0.053	7.0%	0.132	0.215	0.005	2.3%	0.012
E1-FTP-LEVIII-3-E	3	0.290	0.022	7.6%	0.055	0.090	0.003	3.3%	0.007	0.380	0.025	6.6%	0.062	0.964	0.073	7.6%	0.181	0.279	0.021	7.5%	0.052

Vehicle-Drive Cycle-Fuel-Location	# Runs	HC				NOx				HC+NOx				CO				NMHC			
		Avg	Std Dev	CV (%)	CI (%)	Avg	Std Dev	CV (%)	95% CI	Avg	Std Dev	CV (%)	95% CI	Avg	Std Dev	CV (%)	95% CI	Avg	Std Dev	CV (%)	95% CI
E2-WMTC-T2-6-E	6	0.054	0.002	3.7%	0.002	0.111	0.009	8.1%	0.009	0.165	0.011	6.7%	0.012	0.258	0.031	12.0%	0.033	0.047	0.002	4.3%	0.002
E2-WMTC-T3-6-E	6	0.049	0.002	4.1%	0.002	0.111	0.008	7.2%	0.008	0.160	0.010	6.3%	0.010	0.218	0.023	10.6%	0.024	0.042	0.002	4.8%	0.002
E2-WMTC-LEVIII-3-E	3	0.052	0.001	1.9%	0.002	0.113	0.005	4.4%	0.012	0.165	0.006	3.6%	0.015	0.241	0.027	11.2%	0.067	0.045	0.001	2.2%	0.002
E2-FTP-T2-6-E	6	0.054	0.003	5.6%	0.003	0.059	0.003	5.1%	0.003	0.113	0.006	5.3%	0.006	0.246	0.033	13.4%	0.035	0.046	0.002	4.3%	0.002
E2-FTP-T3-3-E	3	0.054	0.003	5.6%	0.007	0.070	0.006	8.6%	0.015	0.124	0.009	7.3%	0.022	0.205	0.012	5.9%	0.030	0.044	0.003	6.8%	0.007
E2-FTP-LEVIII-3-E	3	0.053	0.003	5.7%	0.007	0.069	0.001	1.4%	0.002	0.122	0.004	3.3%	0.010	0.218	0.006	2.8%	0.015	0.043	0.002	4.7%	0.005
E3-WMTC-T2-3-E	3	0.097	0.013	13.4%	0.032	0.137	0.005	3.6%	0.012	0.234	0.018	7.7%	0.045	0.753	0.054	7.2%	0.134	0.084	0.013	15.5%	0.032
E3-WMTC-T3-3-E	3	0.083	0.005	6.0%	0.012	0.129	0.001	0.8%	0.002	0.212	0.006	2.8%	0.015	0.784	0.045	5.7%	0.112	0.069	0.004	5.8%	0.010
E3-WMTC-LEVIII-3-E	3	0.098	0.018	18.4%	0.045	0.153	0.006	3.9%	0.015	0.251	0.024	9.6%	0.060	0.799	0.034	4.3%	0.084	0.084	0.017	20.2%	0.042
E3-FTP-T2-3-E	3	0.055	0.002	3.6%	0.005	0.076	0.011	14.5%	0.027	0.131	0.013	9.9%	0.032	0.544	0.026	4.8%	0.065	0.043	0.002	4.7%	0.005
E3-FTP-T3-4-E	4	0.053	0.006	11.3%	0.010	0.083	0.004	4.8%	0.006	0.136	0.010	7.4%	0.016	0.536	0.015	2.8%	0.024	0.040	0.006	15.0%	0.010
E3-FTP-LEVIII-3-E	3	0.052	0.003	5.8%	0.007	0.093	0.009	9.7%	0.022	0.145	0.012	8.3%	0.030	0.513	0.020	3.9%	0.050	0.040	0.002	5.0%	0.005
E4-WMTC-T2-3-E	3	0.086	0.008	9.3%	0.020	0.019	0.002	8.7%	0.004	0.105	0.010	9.2%	0.024	1.545	0.036	2.3%	0.088	0.080	0.008	9.6%	0.019
E4-WMTC-EU5-3-E	3	0.069	0.007	10.5%	0.018	0.016	0.000	2.4%	0.001	0.086	0.008	9.0%	0.019	1.300	0.144	11.1%	0.358	0.065	0.007	10.5%	0.017
E4-WMTC-LEVIII-3-E	3	0.066	0.006	9.0%	0.015	0.018	0.001	6.0%	0.003	0.084	0.007	8.3%	0.017	1.039	0.188	18.1%	0.468	0.061	0.005	8.2%	0.012
E4-FTP-T2-4-E	4	0.038	0.006	14.7%	0.009	0.010	0.001	10.6%	0.002	0.048	0.007	13.8%	0.011	0.355	0.105	29.4%	0.166	0.035	0.005	15.1%	0.008

Vehicle-Drive Cycle-Fuel-Location	# Runs	HC				NOx				HC+NOx				CO				NMHC			
		Avg	Std Dev	CV (%)	CI (%)	Avg	Std Dev	CV (%)	95% CI	Avg	Std Dev	CV (%)	95% CI	Avg	Std Dev	CV (%)	95% CI	Avg	Std Dev	CV (%)	95% CI
E5-WMTC-T2-4-E	4	0.074	0.003	4.7%	0.006	0.053	0.006	11.0%	0.009	0.127	0.009	7.3%	0.015	0.653	0.008	1.3%	0.013	0.069	0.004	5.2%	0.006
E5-WMTC-EU5-2-E	2	0.088	0.001	0.7%	0.005	0.050	0.002	3.6%	0.016	0.138	0.002	1.8%	0.022	0.630	0.007	1.1%	0.060	0.084	0.001	0.8%	0.006
E5-WMTC-LEVIII-3-E	3	0.091	0.003	3.6%	0.008	0.055	0.005	8.5%	0.011	0.145	0.008	5.4%	0.020	0.631	0.032	5.1%	0.081	0.086	0.003	3.6%	0.008
E5-FTP-T2-3-E	3	0.055	0.000	0.1%	0.000	0.044	0.000	1.1%	0.001	0.099	0.001	0.6%	0.001	0.320	0.009	2.8%	0.022	0.051	0.000	0.9%	0.001
E6-WMTC-T2-3-E	3	0.047	0.001	2.2%	0.003	0.020	0.002	9.0%	0.004	0.067	0.003	4.2%	0.007	0.642	0.035	5.5%	0.087	0.038	0.001	1.6%	0.002
E6-WMTC-EU5-3-E	3	0.049	0.003	6.3%	0.008	0.023	0.003	15.4%	0.009	0.072	0.007	9.1%	0.016	0.600	0.034	5.6%	0.083	0.041	0.003	7.1%	0.007
E6-WMTC-LEVIII-2-E	2	0.041	0.011	25.7%	0.094	0.020	0.003	16.8%	0.031	0.061	0.014	22.7%	0.125	0.482	0.022	4.6%	0.198	0.032	0.010	31.2%	0.089
E6-FTP-T2-3-E	3	0.048	0.001	2.1%	0.002	0.008	0.001	7.2%	0.001	0.056	0.002	2.8%	0.004	0.495	0.019	3.9%	0.048	0.038	0.001	3.1%	0.003
E7-WMTC-EU5-3-E	3	0.334	0.036	10.8%	0.090	0.072	0.002	3.5%	0.006	0.405	0.039	9.5%	0.096	0.770	0.081	10.5%	0.200	0.327	0.035	10.8%	0.088
E7-WMTC-LEVIII-4-E	4	0.327	0.016	4.8%	0.025	0.067	0.003	4.6%	0.005	0.394	0.019	4.8%	0.030	0.728	0.103	14.1%	0.163	0.320	0.016	4.9%	0.025
E7-FTP-LEVIII-3-E	3	0.226	0.003	1.4%	0.008	0.072	0.001	1.9%	0.003	0.298	0.004	1.5%	0.011	0.793	0.054	6.8%	0.134	0.220	0.003	1.5%	0.008

See section Drive Cycles for M1 note.

Appendix 2

Test Plan

TO: Mark Fuentes, Division Chief
Mobile Source Laboratory Division

Allen Lyons, Division Chief
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THROUGH: Sharon Lemieux, Chief

In-Use Programs Branch

Thomas Valencia, Chief
Haagen-Smit Laboratory Engineering & Testing Branch

Mang Zhang, Chief
Chemical Analysis & Emissions Research Branch

FROM: Scott Bacon, Manager
Engineering and Regulatory Development Section
Emissions Certification and Compliance Division

DATE: August 13,2019

SUBJECT: ON-ROAD MOTORCYCLE REGULATORY DEVELOPMENT TESTING

PROJECT NUMBER: 2R1904
PROJECT START DATE: September 1, 2019

INTRODUCTION

The Engineering and Regulatory Development Section (ERDS) of the Emissions Certification and Compliance Division (ECCD) is planning to go to the Board with a regulation in late 2020 to reduce emissions from on-road motorcycles. Current California Air Resources Board (CARB) regulatory standards for motorcycles were adopted in 1998 and have not been updated since. Many jurisdictions throughout the world appear to have surpassed California in lowering emissions standards for this category. Therefore, ERDS is working to determine the feasibility of setting lower emissions limits for motorcycles and potentially harmonizing with lower European Union (EU) 5 motorcycle standards. This will require motorcycle testing resources at the Haagen-Smit Laboratory (HSL) to compare emissions between EU 5 and CARB exhaust certification procedures. This test plan details the testing requirements and procedures for the program to be performed at HSL upon test vehicle availability.

OBJECTIVE

The objective of this test plan is to draw exhaust emissions comparisons between EU and CARB motorcycle certification test procedures and quantify certification fuel type impact on motorcycle emissions.

Gaseous and particulate matter (PM) emissions will be measured in a portable motorcycle dynamometer test cell per CARB's current motorcycle exhaust certification procedure and the EU 5 type I exhaust emissions test procedure. For the CARB test procedure, only the specified Code of Federal Regulations (CFR) Indolene test fuel (E0) shall be used. For the EU 5 test procedure, the test fuel specified in that procedure (E5), the CARB LEV III test Cert fuel (E10), and the E0 fuel for CARB's current motorcycle testing will be used.

REFERENCED TEST PROCEDURES

The purpose of this testing is to quantify emissions differences between exhaust certification test procedures and the certification fuels used. These tests are as follows:

1. EU 134/2014, Annex II (Test type I requirements: tailpipe emissions after cold start). This will be referred to throughout simply as the WMTC. https://eur-lex.europa.eu/eli/reg_del/2014/134/oj/eng
2. Federal Test Procedure (FTP), Subparts E and F, Part 86, Title 40, Code of Federal Regulations, as they existed on July 7, 1986. This will simply be referred to throughout as the FTP.

TESTING FACILITY

This testing program will be conducted in HSL's Test Cell 3. The major equipment components for Cell 3 are as follows.

Test Cell Dynamometer

Test Cell 3 is equipped with a 20 inches single roll portable motorcycle dynamometer capable of testing motorcycle up to 1,000 kg.

Test Cell Sampling System

Test Cell 3 is equipped with a 10-inches full-flow dilution tunnel constant volume sampler (CVS) with a nominal flow between 150 and 1,000 standard cubic feet per minute.

Test Cell PM Filter-based Sampling System

Test Cell 3 has three AVL SPC-472 Samplers. Teflon filters can be used to collect PM samples for PM mass analysis.

Test Cell Analytical System

Test Cell 3 is equipped with an analytical bench for measuring Total Hydrocarbon (THC), Carbon Monoxide (CO), Carbon Dioxide (CO_2), Nitric Oxide/Oxides of Nitrogen (NO/NO_x) and methane (CH_4) for each test phase. Cell 3 has the ability to measure real-time modal emission data for THC, CO, CO_2, and NO/NO_x.

Real-time PM Instruments

Multiple real-time PM instruments will be used to measure the diluted exhaust from the CVS dilution tunnel:

1. Particle number: a PMP-compliant SPC system with cut-point of 23 nm for solid particle count measurement will be used.
2. Particle size spectrum: an EEPS (Model 3090, TSI) will be used for real-time PM size distribution measurement.
3. Black carbon (BC): an MSS (Model 483, AVL) will be used to measure real-time BC emissions.

MOTORCYCLES

A total of four class III motorcycles have been selected by ECCD staff to be tested in this program as shown in the Table 1, Appendix A. Three motorcycles have been purchased by ECCD and one EU 5 compliant motorcycle is being loaned from a manufacturer. Note that these motorcycles will also be used in other ongoing test plans as well so some coordination may be needed between these programs.

TEST CYCLE REQUIREMENTS

Gaseous (THC, NMHC, CH_4, CO, NO_X, and CO_2) and PM emissions will be collected for all FTP and WMTC drive cycles performed in the test cell. Weekly tunnel blank (TB) PM will be collected using the FTP (EC1B) test cycle with the 3-filter method. Project engineer will decide which FTP and WMTC tests will conduct modal measurements.

TEST FUELS

This program will use three fuels throughout the testing that will be specified during each procedure. The test fuels used will be:

1. Indolene certification fuel Tier 2 (E0) with the CARB fuel code IC21.
2. LEV III certification fuel (E10) will be used that is available in drums at HSL with the CARB fuel code EC09-1-1.

3. EU 5 (E5) reference fuel as specified in EU 134/2014. CARB fuel code will be assigned and updated after fuel analysis is completed.

MOTORCYCLE DELIVERY AND CHECK-IN

The motorcycles 1 and 3 from Appendix A are currently available for testing. Motorcycle 2 and 4 are expected to be acquired by ECCD staff by August 2019. ECCD staff will ensure these motorcycles have reached 1000 miles. Upon mileage being accumulated, ECCD staff will notify the test engineer, then deliver the motorcycles to HSL laboratory for testing.

EXHAUST TESTING PROCEDURE

All applicable test cell Standard Operation Procedure (SOPs) should be followed and weekly quality assurance (QA) should be performed, verified, and documented prior to conducting motorcycle emission testing. A chain of custody sheet shall be filled out for each motorcycle as it goes through testing. These sheets can be found in Appendix C.

<u>General Test Preparation</u>

1. Verify tire pressures to manufacturer specifications ± 2.2 psi;
2. Conduct a 3-filter FTP (EC1B) TB test weekly in Test Cell 3.

<u>Motorcycle Preparation and Preconditioning for FTP (EC1B):</u>

1. Verify and record motorcycle has minimum mileage accumulation of 3,500 km (2,175 mi) prior to testing.
2. Verify and record driver mass 80 ± 10 kg (176 ± 22 lb).
3. Drain and re-fill tank with Indolene test fuel to 50% capacity.
4. Confirm dynamometer coefficients based on EIM with 40 CFR §86.529.98 and follow shift schedule as specified in 40 CFR §86.528.78.
5. Drive one UDDS cycle to precondition the motorcycle as specified in 40 CFR §86.515.78(a). No emissions collection is necessary.
6. Cold soak the motorcycle 12-36 hours at standard temperature 68°F to 86°F for next day's testing. Remove key from the ignition during soaking.

<u>Testing Sequence for FTP (EC1B):</u>

1. Push the motorcycle to dynamometer.
2. Ensure the connections between the motorcycle tailpipe and sampling equipment are leak-tight.
3. Conduct an FTP (EC1B) test cycle to measure bag emissions and real time PM measurements, and collect PM samples. The filters will be sent to chemistry lab for PM mass analysis.
4. Follow shift schedule as specified in 40 CFR §86.528.78.

5. If three tests have not been completed, cold soak the motorcycle at standard temperature 68°F to 86°F overnight to prepare for next day's testing. Remove key from the ignition during soaking.
6. Repeat steps 1 to 4 until three valid EC1B tests have been conducted.

Motorcycle Preparation and Preconditioning for Type I Test (WMTC):

1. Verify and record motorcycle has minimum mileage accumulation prior to testing of 1,000 km (621 mi).
2. Verify and record driver mass 75 ± 5 kg (165 ± 11 lb). If we do not have a driver meeting these qualifications, contact Project engineer for instructions.
3. Drain and re-fill tank with Indolene test fuel to 50% capacity;
4. Decide sub-classification under L-category for the motorcycle to be tested:
   - EU Class 1: Engine capacity <150 cm3 and Vmax < 100 km/h
   - EU Class 2-1: Engine capacity <150 cm3 and 100 km/h< Vmax < 115 km/h
   - EU Class 2-2: Engine capacity >150 cm3 and Vmax < 115 km/h
   - EU Class 3-1: 130 km/h < Vmax < 140 km/h
   - EU Class 3-2: Engine capacity >1500 cm3 or Vmax > 140 km/h
5. Select WMTC Stage 3 test cycles parts based on the motorcycle sub-classification under L-category:
   - Class 1: Part 1 (reduced speed) + Part 1 (reduced speed)
   - Class 2-1: Part 1 (reduced speed) + Part 2 (reduced speed)
   - Class 2-2: Part 1 + Part 2
   - Class 3-1: Part 1 + Part 2 +Part 3 (reduced speed)
   - Class 3-2: Part 1 + Part 2 +Part 3
7. Set dynamometer coefficients based on EIM (Refer to Appendix 5, Commission Delegated Regulation No 134/2014).
8. The blower outlet shall be at least 0.40 m^2 (4.31 ft^2). Locate the blower bottom outlet 5-20 cm above floor level and blower outlet 30-45 cm in front of motorcycle front wheel.
   8.1. Throughout the test, a variable-speed cooling blower (fan) shall be positioned in front of the motorcycle so as to direct the cooling air onto it in a manner that simulates actual operating conditions. The blower speed shall be such that for motorcycle speeds of:
   - < 10 km/h, the linear velocity of the air at the blower outlet ranges from 0 km/h to a maximum of 5 km/h above the corresponding roller speed;
   - 10 to 50 km/h, the linear velocity of the air at the blower outlet is within ±5 km/h of the corresponding roller speed;
   - > 50 km/h, the linear velocity of the air shall be within ± 10 percent.

8.2. If fan is not capable of conforming to these standards, run the fan as close as possible and note how the fan constraints differed from the testing constraints of 8.1 above.

9. Shift schedule must be determined for each motorcycle and follow the equations as given per Annex II, Section 4.5.5.2 Test Motorcycles with Manual Transmission, Commission Delegated Regulation No 134/2014.
   9.1. An example calculation can be found in Appendix 9 to Annex II.
10. Drive or push the motorcycle to dynamometer.
11. Drive one WMTC cycle as determined in step 3 above with the shift schedule derived in step 6 above to precondition the motorcycle. No emissions collection is necessary.
12. Cold soak the motorcycle at standard temperature 68°F to 86°F for next day's testing for 12-36 hours. Remove key from the ignition during soaking.

<u>Testing Sequence for Type I Test (WMTC):</u>

1. Push the motorcycle to dynamometer.
2. Ensure the connections between the motorcycle tailpipe and sampling equipment are leak-tight.
3. Conduct a WMTC cycle as determined in preconditioning steps above to measure bag emissions and real time PM measurements, and collect PM samples. The filters will be sent to chemistry lab for PM mass analysis.
4. Follow shift schedule as determined during preconditioning steps above.
5. Put transmission in gear 15 s after the engine is started.
6. No simultaneous use of brake and throttle shall be permitted.
7. Turn off cooling fan immediately after the end of sample period.
8. If three tests have not been completed, cold soak the motorcycle at standard temperature 68°F to 86°F overnight to prepare for next day's testing. Remove key from the ignition during soaking.
9. Repeat steps 1 to 7 until three valid WMTC tests have been conducted on the specified test fuel.
10. Upon completing three valid tests on the Indolene test fuel, repeat the entire WMTC preconditioning and testing process again but for both EU 5 and CARB LEV III test fuels until three tests have been completed successfully on each of those fuels.

PM FILTER REQUIREMENT

Filter-based PM samples will be collected to determine PM gravimetric mass. Monthly trip blank Teflon filters will be collected in this program. Weekly FTP tunnel blank tests will be sampled for PM mass with the 3-filter method. It is estimated that a total of 170 Teflon filters will be needed for this project including for samples, tunnel blanks, and trip blanks.

The Project Manager/Engineer and Test Engineer will determine the PM filter numbers required for each week and notify the Aerosol Analysis and Method Evaluation Section (AAMES) staff, two weeks prior to motorcycle testing, about the filter requirement.

The tentative schedule for PM filter collection for motorcycles selected to be tested are shown in Appendix D.

VERIFIABLE DATA

All test cycles including the FTP and WMTC shall strictly meet all regulatory requirements to be considered a valid test. Any specially designed screening test cycles will be considered valid as long as the test equipment meets its normal acceptance procedures. Additionally, motorcycles tested under these special cycles without utilizing a HFID analyzer will also be considered valid. In general, the only special cycles that will be invalidated are those tests where the cycle was not completed in its entirety or when the filter sampler is left on during non-cycle testing. In case of doubt, the Project Manager/Engineer will make the final decision on the validity of the data.

DATA HANDLING AND MANAGEMENT

The Test Engineer will review all test results for completeness and verify that all tests meet applicable EU, CFR and CARB applicable requirements, and that all documentation is complete. In case of test aborts or invalidation of data, the test will be repeated and the reasons for test aborts/invalidation will be documented. After reviewing and approving the data, the Test Engineer will notify the Project Engineer of the status of the test data.

The Project Engineer will have access to all test data and documentation of the test motorcycles at any time during this project. All data will be reviewed by the Project Engineer for completeness and accuracy.

At the end of the project, the Project Manager/Engineer will notify the Laboratory Data Support Branch (LDSB) staff the completion of the project, coordinate with the LDSB staff to complete the final data verification and transfer data into the Motorcycle Emission Database System.

QUALITY CONTROL

Only tests meeting all weekly QA criteria will be used for data analysis. This includes but is not limited to dynamometer speed and load accuracy checks, CVS propane recovery tests, analyzer responses to gas standards, and tests of the accuracy of environmental measurements (barometric pressure, dew point, and temperature).

DATA ANALYSIS/REPORT

The Project Engineer will analyze the data collected in this program and present the final report to upper management within 8 weeks of test completion.

MOTORCYCLE RELEASE

The Test Engineer will notify the Project Manager/Engineer after all scheduled testing has been completed and emissions as well as repair data have been reviewed.

TEST PROJECT PERIOD

The duration of this project is about 4 months and is planned to start in July 2019. However, some of these motorcycles will be tested under other parallel test plans which could cause delay with some of this testing.

PROJECT REPORT AND CONTACTS

Project Engineer: Jason McPhee, Engineering and Regulation Development Section (ERDS), at (916) 323-1104 or jason.mcphee@arb.ca.gov

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Appendices

A. Motorcycle List and Testing Summary

B. Motorcycle Description Sheet

C. Chain of Custody

D. PM Sample Matrix

E. Project Information Sheet

Appendix A

Motorcycle List and Testing Summary

Table 1 Motorcycles List

MC#	Brand	Models	Model Year
1	ONMC make / model information is redacted to retain anonymity of test results		2018-Current
2			2017-Current
3			2018-Current
4			2020

* The EU 5 compliant motorcycle has not yet been identified as it is expected to be on the market in late 2019.

Table 2 of this appendix lists the specific tests and total number of tests that each motorcycle must be run through.

Table 2. Test Matrix Summary

MC#	Tests				
	TYPE I (WMTC)			FTP	Total
	LEV III	Indolene	E5	Indolene	
1	3	3	3	3	12
2	3	3	3	3	12
3	3	3	3	3	12
4	3	3	3	3	12
Total	**12**	**12**	**12**	**12**	48

Appendix B

Motorcycle Description Sheet

Highway Motorcycle and Off-Road Recreational Vehicle Description

Project: **Vehicle No.** **VIN :**
Model Year: **Engine Family:**
Manufacturer: **Evap. Family:**
Division: **Model Code:**_______________ **Fuel Tanks**
Model : **Size** (gal) : . Aux. Tank
Veh. Class: ________ **50% Cap.** (gal): .

MC1A = HMC Class I-A <50 cc
MC1B = HMC Class I-B 50 cc - 169 cc
MC2 = HMC Class II 170 cc - 279 cc
MC3 = HMC Class III 280 cc and over
OFMC = Off-Road Motorcycle
ATV = All Terrain Vehicle
OFUV = Off-Road Utility Vehicle
OFSV = Off-Road Sport Vehicle
SC = Sand Car

Equivalent Inertia Mass (kg):
Road Load Force (N): . **Dyno.Coeff's (SI units):** A ____________ B ____________ C _
Drive Wheels :__________ **Received date :** ____/____/________

1F = One Wheel Drive, Front
2F = Two Wheel Drive, Front
2R = Two Wheel Drive, Rear
1R = One Wheel Drive, Rear
4M = Four Wheel Drive, Mandatory
4O = Four Wheel Drive, Optional

License Number :
Country :
State : __________
Gross Veh. Wt. (kg) :
Source Project : ________________
Tire Size : _______________ **Drive Tire Pressure (Psi):** ______
Miles / Hrs ___MI ___KM ___NA
Project Engineer : ____________________
Zip Code :

Codes

Thermodynamic Cycle: ________

B = Spark Ignited, 4 Stroke
C = Spark Ignited, 2 Stroke
D = Comp Ignited, 4 Stroke
H = Other
E = Comp. Ignited, 2 Stroke
F = Sterling
G = Spark ignited, 5 Stroke

Specifications

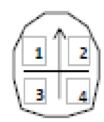
Num. Cylinders : Rated Power (kW) _________
Num. Caburetors : Rated Speed (rpm) _________
Barrels/Carb. : Peak Torque (N-m) _________
Eng. Disp. Vol. (cc) : Peak Torque Speed (rpm) ______

EGR System : ___Yes ___No
Engine Cooling: Air Cooled _____ Water Cooled _____
O2 Sensor Code : _______

N = No O2S
1 = Oxygen Sensor
2 = Dual O2S
3 = Heated O2S
4 = Heated O2S (two)
5 = Heated O2S (three)
6 = Dual Heated O2S
7 = Heated O2S, O2S
8 = Air-Fuel Ratio Sensor
9 = Heated AFS
D = Dual Heated AFS
E = OTHER

Turbo Type :_____ N = None S = Supercharger T = Turbocharger
Air Inject Type : _____ N = Neither A = Air Injection Pump P = Pulse Air
Pre-Catalyst Type : ________ **Main-Catalyst Type :** ________

N = Neither Cat. Nor Thermal Reactor
1 = Oxidation Catalytic Converter
2 = OC (two)
3 = Dual OC
4 = Dual OC (two)
5 = Warm-Up OC
6 = Dual Warm-Up OC
7 = Three-Way Catalytic Converter
8 = TWC (two)
9 = Dual TWC
W = Dual TWC (two)
X = TWC Plus OC
Y = Warm-Up TWC
Z = OTHER



Engine Configuration : _____

L = In Line H = Horizontally opposed R = Rotary C = Single Cylinder
V = V Type S = Stratified Charge T = Transverse P = Other

Certification Code : _____

A = 50 States B = 49 States C = CA Only
D = Other

Evap. Canisters

Canister Type : _____

1 = No Canister on Vehicle
2 = Canister Inaccessible
3 = Closed Bottom Canister
4 = Open Bottom Canister

Canister Location : ____

N = Not Applicable
1 = Vehicle Quadrant Location
2 = Vehicle Quadrant Location
3 = Vehicle Quadrant Location
4 = Vehicle Quadrant Location
M = Multiple Locations

Transmission Type : ______

A = Automatic
A2 = Auto, 2Sp
A3 = Auto, 3Sp
A4 = Auto, 4Sp
A5 = Auto, 5Sp
M = Manual
M3 = Manual, 3Sp
M4 = Manual, 4Sp
M5 = Manual, 5Sp
M6 = Manual, 6Sp
M8 = Manual, 8Sp
AV = Auto, Variable Sp
C4 = Creeper, 4Sp
L3 = Lock Up Auto, 3Sp
L4 = Lock Up Auto, 4Sp
L5 = Lock Up Auto, 5Sp
SM = Semi-manual
SA = Semi-Auto
S2 = Semi-Auto, 2Sp
S3 = Semi-Auto, 3Sp
S4 = Semi-Auto, 4Sp
S5 = Semi-Auto, 5Sp
NA = N/A or Unidentified
OT = Other

Comments

Extra parts? Yes No

ABS:	Yes	No
Stability Control:	Yes	No
Traction Control:	Yes	No

Exhaust: **Single** **Dual**

Fuel Injection Type : ______

1 = None
4 = Sequential MFI
7 = Direct Diesel Injection
2 = Throttle Body Fuel Injection
5 = Direct Gasoline Injection
3 = Multi-port Fuel Injection
6 = Indirect Diesel Injection

OBD Type : ________

A = No OBD B = Yes, Non-mandated C = Yes OBD I D = Yes, OBD II

Multi-Fuel Capability : ______

S = Dedicated B = Bi-Fuel F = Flexible Fuel K = Dual X = Hybrid Electric

Date : Check out
Mi/Hrs Check out

ARB Signature: Check-in ____________ **ARB Signature:** Check-Out ____________

Driver Signature: Check-in ____________ **Driver Signature:** Check-Out ____________

Appendix C

Chain of Custody

Project Engineer: Jason McPhee **Backups: Shishan Hu**

Test Engineer: Tuyen Dinh **Backup: Thomas Desimone**

Persons performing task shall sign, date, and fill-in time when task is completed.

Certification Exhaust Test (WMTC, LEV III Fuel)				
Motorcycle #:				
	Initial	**Date**	**Completed Time**	**Odometer**
Weekly 3-filter (EC1) Tunnel Blank				
Accumulate miles to 621 mi if necessary using commercial fuel				
Drain and re-fill tank with CARB LEV III fuel to 50% capacity				
Adjust Tire Pressure to Mfr.'s ± 2.2 psi				
Record driver mass Target is 75 ± 5 kg (165 ± 11 lb).				
Perform one WMTC cycle as preconditioning				
Drain and re-fill tank with CARB LEV III fuel to 50% capacity				
Cold Soak 68°F to 86°F for 12-36 hours				
Conduct WMTC test 1				

Cold Soak 68°F to 86°F for 12-36 hours				
Conduct WMTC test 2				
Add 1 gallon CARB LEV III fuel				
Cold Soak 68°F to 86°F for 12-36 hours				
Conduct WMTC test 3				
Repeat WMTC Test if Necessary (3 valid tests)				
Perform one WMTC cycle as preconditioning (Skip this if a WMTC test is conducted on the same day)				
Cold Soak 68°F to 86°F for 12-36 hours				
Conduct WMTC test (makeup)				

Chain of Custody

Engineer: Jason McPhee **Backups: Shishan Hu**

Test Engineer: Tuyen Dinh **Backup: Thomas Desimone**

Persons performing task shall sign, date, and fill-in time when task is completed.

Certification Exhaust Test (WMTC, E5 Fuel)				
Motorcycle #:				
Drain and re-fill tank with E5 fuel to 50% capacity				
Adjust Tire Pressure to Mfr.'s ± 2.2 psi				
Record driver mass Target is 75 ± 5 kg (165 ± 11 lb).				
Perform one WMTC cycle as preconditioning				
Drain and re-fill tank with E5 fuel to 50% capacity				
Cold Soak 68°F to 86°F for 12-36 hours				
Conduct WMTC test 1				
Cold Soak 68°F to 86°F for 12-36 hours				
Conduct WMTC test 2				

Add 1 gallon E5 fuel				
Cold Soak 68°F to 86°F for 12-36 hours				
Conduct WMTC test 3				
Repeat WMTC Test if Necessary (3 valid tests)				
Perform one WMTC cycle as preconditioning (Skip this if a WMTC test is conducted on the same day)				
Cold Soak 68°F to 86°F for 12-36 hours				
Conduct WMTC test (makeup)				

Chain of Custody

Project Engineer: Jason McPhee **Backups: Shishan Hu**

Test Engineer: Tuyen Dinh **Backup: Thomas Desimone**

Persons performing task shall sign, date, and fill-in time when task is completed.

Certification Exhaust Test (WMTC, Indolene Fuel)				
Motorcycle #:				
Weekly 3-filter (EC1) Tunnel Blank				
Drain and re-fill tank with Indolene fuel to 50% capacity				
Adjust Tire Pressure to Mfr.'s ± 2.2 psi				
Record driver mass Target is 75 ± 5 kg (165 ± 11 lb).				
Perform one WMTC cycle as preconditioning				
Drain and re-fill tank with Indolene fuel to 50% capacity				
Cold Soak 68°F to 86°F for 12-36 hours				
Conduct WMTC test 1				
Cold Soak 68°F to 86°F for 12-36 hours				
Conduct WMTC test 2				

Add 1 gallon Indolene fuel				
Cold Soak 68°F to 86°F for 12-36 hours				
Conduct WMTC test 3				
Repeat WMTC Test if Necessary (3 valid tests)				
Perform one WMTC cycle as preconditioning (Skip this if a WMTC test is conducted on the same day)				
Cold Soak 68°F to 86°F for 12-36 hours				
Conduct WMTC test (makeup)				

Chain of Custody

Project Engineer: Jason McPhee **Backups: Shishan Hu**

Test Engineer: Tuyen Dinh **Backup: Thomas Desimone**

Persons performing task shall sign, date, and fill-in time when task is completed.

Certification Exhaust Test (FTP, Indolene Fuel)				
Motorcycle #:				
Weekly 3-filter (EC1) Tunnel Blank				
Adjust Tire Pressure to Mfr.'s ± 2.2 psi				
Drain and re-fill tank with Indolene fuel to 50% capacity				
Record driver mass Target is 80 ± 10 kg (176 ± 22 lb).				
Perform one UDDS cycle as preconditioning (J-prep)				
Cold Soak 68°F to 86°F 12-36 hours				
Conduct EC1B test 1				
Cold Soak 68°F to 86°F (6-36 hours for MC1 8-36 hours for MC2 12-36 hours for MC3)				
Conduct EC1B test 2				
Add 1 gallon Indolene fuel				
Cold Soak 68°F to 86°F 12-36 hours				

Conduct EC1B test 3				
Repeat EC1B Test if Necessary (3 valid tests)				
Cold Soak 68°F to 86°F 12-36 hours				
Conduct EC1B test (makeup)				

Appendix D

PM Sample Matrix

Weekly Estimate		PM Sample (Teflon Filter)
Monday	Tunnel Blank (weekly)	3
Tuesday	Motorcycle 1 (FTP or WMTC)	3
	Motorcycle 2 (FTP or WMTC)	3
Wednesday	Motorcycle 1 (FTP or WMTC)	3
	Motorcycle 2 (FTP or WMTC)	3
Thursday	Motorcycle 1 (FTP or WMTC)	3
	Motorcycle 2 (FTP or WMTC)	3
Friday	Motorcycle 3 (FTP or WMTC)	3
	Motorcycle 4 (FTP or WMTC)	3
	Trip Blank (monthly)	1
	(Makeup Tests)	(6)
	Total =	**34**

Note:

(1) It is planned to conduct two cold start tests for two motorcycles per day. If more motorcycles are available to be tested at the same week, test engineer will coordinate with AAMES for filter preparing.

Appendix E

Project Information Sheet

PROJECT INFORMATION FORM	
INITIAL PROJECT INFORMATION (must be filled out when project ID is issued)	
PROJECT ID: (No more than 8 characters)	(to be assigned by LTSS)
PROJECT ABSTRACT: (Short paragraph describing the objective of this project)	To draw exhaust emissions comparisons between EU and CARB motorcycle certification test procedures and quantify certification fuel type impact on motorcycle emissions.
Project Engineer:	Jason McPhee
Test Engineer:	Tuyen Dinh
Project Estimated Start Date:	29-Jul-19
Project Estimated End Date:	6-Mar-20
Estimated Number of Vehicles at End of Project:	4
Primary Test Cell Used for Testing:	3
Estimated Total # of Tests for Project:	48
Estimated # of Tests per Vehicle:	12
Is Final Report Planned: (Y/N):	Y
Estimated Test Time per Vehicle (days):	16
More than one manufacturer? Y/N	Y
Type of Testing	☐ Engine ☐ Vehicle ☑ Motorcycle ☐ Other :________
Type of Project	☑ Research ☐ Surveillance ☐ Crosscheck ☐ Screening ☐ Title 13 ☐ Confirmatory ☐ Compliance/In-Use ☐ After Market Part Evalution ☐ Other: ________

Appendix 3

Test Plan Amendment 1

TEST PLAN AMENDMENT SUMMARY

On-Road Motorcycle Regulatory Development Testing

Project No. 2R1904 – Amendment #1

Prepared by the

Engineering and Regulatory Development Section

September 4th, 2019

This is the first amendment to Project No. 2R1904. The test plan section changes were made in Exhaust Testing Procedure. The purpose of this amendment is to add canister loading during motorcycle soaking to reduce emission testing variance.

In the section EXHAUST TESTING PROCEDURE, under Motorcycle Preparation and Preconditioning for FTP (EC1B), add:

7. "During soaking, load the motorcycle's canister at 15 grams of butane per hour until 2 grams breakthrough is achieved".

In the section EXHAUST TESTING PROCEDURE, under Motorcycle Preparation and Preconditioning for Type I Test (WMTC): add:

13. "During soaking, load the motorcycle's canister at 15 grams of 50% butane per hour until 2 grams breakthrough is achieved".

Appendix 4

Test Plan Addendum 1

TEST PLAN ADDENDUM #1 SUMMARY

On-Road Motorcycle Regulatory Development Testing

Project No. 2R1904 – Addendum #1

Prepared by the

Engineering and Regulatory Development Section

April 1st, 2021

This is the first addendum to Project No. 2R1904. The test plan section changes were made in Exhaust Testing Procedure. The purpose of this amendment is to measure canister purge rates during preconditioning drive cycles in order to better understand canister capacity.

In the section TESTING FACILITY, add:

"Purge Flow Meter

J-Tec VF563 series blow-by flow meter for use in measuring canister purge flow during prep cycles."

In the section EXHAUST TESTING PROCEDURE, under Motorcycle Preparation and Preconditioning for FTP (EC1B), insert:

5. "Connect the purge flow meter to the carbon canister purge port."
6. "Drive one UDDS cycle to precondition the motorcycle as specified in 40 CFR §86.515.78(a). No emissions collection is necessary. Measure and record second by second flow rates during the drive cycle."
7. "Remove flow meter from the carbon canister purge port."

In the section EXHAUST TESTING PROCEDURE, under Motorcycle Preparation and Preconditioning for Type I Test (WMTC): insert:

11. “Connect the flow meter to the carbon canister purge port.”

12. “Drive one WMTC cycle as determined in step 3 above with the shift schedule derived in step 6 above to precondition the motorcycle. No emissions collection is necessary. Measure and record second by second flow rates during the drive cycle.”

13. “Remove flow meter from the carbon canister purge port.”

In the section PROJECT REPORT AND CONTACTS, add:

“Test Engineer: Travis Wong, Evaporative & Motorcycle Testing Section, at (626) 350-6517 or travis.wong@arb.ca.gov.”