Appendix E3

State of California
Air Resources Board

Proposed Amendments to On-Road Motorcycle (ONMC) Emission Standards and Test Procedures

Carbon Canister Purge Test Results

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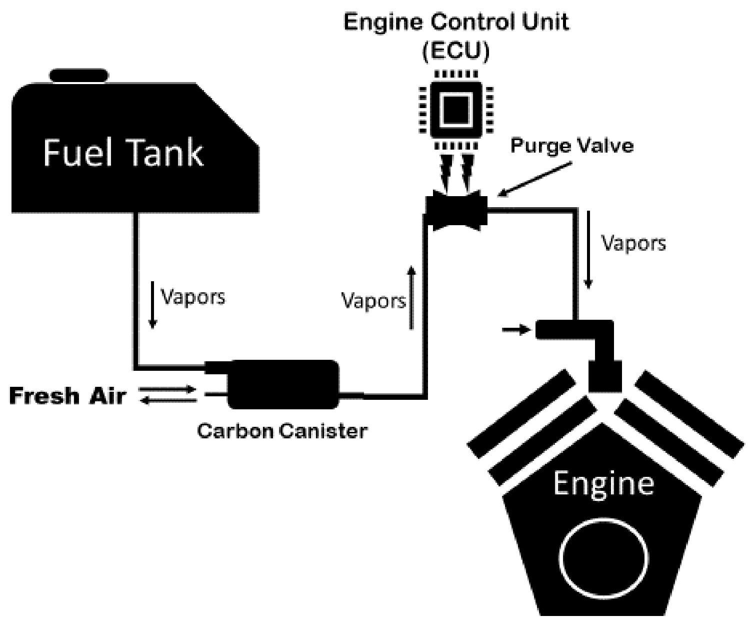
Contents

1 Introduction

Evaporation of gasoline from a motorcycle fuel system during vehicle operation and storage is a source of reactive organic gas that can combine with nitrogen oxides and sunlight to produce ground level ozone. These evaporative emissions can be controlled using a canister filled with activated carbon material which captures hydrocarbon molecules that would otherwise be vented from the fuel tank to the atmosphere. Captured hydrocarbon molecules can be removed from the carbon material by drawing fresh air through the carbon canister, which is referred to as carbon canister purge. The primary mechanism for carbon canister purge on a motor vehicle is to draw fresh air through the carbon canister and into the engine intake during vehicle operation, where the hydrocarbon molecules from the carbon canister are mixed with fuel and burned in the engine's combustion chamber (Figure 1).

Figure 1. *Typical Carbon Canister Configuration*



This report examines the carbon canister purge characteristics of on-road motorcycles (ONMC) under different test drive cycles. The carbon canister is only purged under certain engine operating conditions defined by the motorcycle manufacturer and controlled by the engine control unit (ECU). The size of a motorcycle's carbon canister and its ability to purge captured vapors back into the engine are important for controlling evaporative emissions when the motorcycle is at rest. In an ideal scenario, the carbon canister should be as free as possible of stored hydrocarbons when the motorcycle enters a rest phase (e.g., overnight). This maximizes the ability of the carbon canister to capture evaporative emissions during vehicle storage. The total purge volume during a test drive cycle is a measurement of the air flow through the carbon canister into the engine. Generally, during operation, the more time spent with the purge valve open and air flowing through the carbon canister into the engine the more capacity the canister will have to collect and retain diurnal emissions. The desorption rate of fuel vapors from the carbon in the canister is dependent on the concentration gradient between the hydrocarbons in the air and in the carbon media. As the concentration of hydrocarbon vapors decrease in the air, the ability of the carbon media to release hydrocarbons also decreases. Thus, there will always be hydrocarbon vapors that cannot be purged, and the true working capacity of the carbon canister is less than the canister volume.

The California Air Resources Board (CARB) has not promulgated a standard or requirement for the carbon canister purge rate for motorcycles. CARB has been regulating emissions from on-road motorcycles (ONMC) since 1978. The current ONMC emission standards were last updated in 1998. Since then, more stringent exhaust emissions standards have been developed by other global jurisdictions, most notably the European Union (EU). The stringent exhaust standards set by the EU have required the motorcycle industry to develop motorcycles with lower exhaust emissions than what is currently required in California. While current CARB ONMC evaporative standards are on par with most other state and federal jurisdictions, other vehicle categories regulated by CARB are subject to lower evaporative emissions limits. For example, in 2013 CARB adopted more stringent evaporative emissions limits with a more robust 3-day evaporative testing method for the Off Highway Recreational Vehicle (OHRV) category. This category includes off-highway motorcycles that are closely related to ONMCs. Currently, ONMCs only require a 2-hour evaporative emission test for certification, but the upcoming proposed regulation will match the 3-day test of OHRVs. With California not enacting new emissions standards for ONMCs since 1998, the allowable emissions rate per mile for motorcycles is significantly higher than other vehicle categories that are subject to more current and stringent regulatory standards. In support of a new regulation, the collection of emissions testing data from late model ONMCs is imperative to comparing how the new regulation will improve air quality over the current standards.

The testing for this report was conducted by CARB in support of the proposed amendments to ONMC Emission Standards and Test Procedures intended to go to the Board for consideration in late 2023.[1] This testing was performed at CARB's Haagen Smit Laboratory and began in 2021.

2 Experimental Description

The initial objective of testing was to compare exhaust and evaporative emissions measured when following the current EU and CARB motorcycle certification test procedures, with particular focus on the different dynamometer drive cycles and certification fuel types. During this testing, staff installed a flow meter that could be used to measure carbon canister purge during each dynamometer drive cycle. The flow meter was connected to the purge port of the carbon canister and measured the volume of fresh air that was drawn into the canister to strip off stored hydrocarbon molecules from the carbon material and draw them into the engine to be used for combustion. Using the flow meter on the remaining test runs, staff proceeded to collect data from the ONMCs. Data was collected during emissions testing and prep cycles as stated in the test plan given in Appendix A: Test Plan. The original test plan was amended with the changes shown in Appendix B: Test Plan Amendment Summary. The specific amendment for purge flow testing is given in Appendix C: Test Plan Addendum #1 Summary.

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

This test incorporates three different drive cycles (Section 2.4): the Federal Test Procedure (FTP), the World harmonized Motorcycle Testing Cycle (WMTC), and the US06. The US06 is not normally used by CARB for regulatory or compliance testing of motorcycles but was included in this test plan to aid in developing an accurate statewide motorcycles emissions estimate. The US06 drive cycle includes higher speeds and more aggressive acceleration events than found in the FTP. All tested ONMCs had a minimum of three runs on the FTP and WMTC drive cycles, while the US06 was run a minimum of twice per ONMC tested.

2.1 Carbon Canister

The purpose of a carbon canister is to collect excess vapors from the fuel system, that otherwise would enter the environment, and recycle them back into the engine for combustion. The design, size, and location vary by ONMC, but all carbon canisters function in a similar way. The carbon canister includes a volume of activated carbon called the carbon bed. This very porous activated carbon has a high surface area allowing for high efficiency in absorption and desorption of gases and liquids. The carbon canister can be configured with single or multiple chambers. These chambers are held in place with a series of springs and spacers. In addition, filters are used to keep the carbon in place, and prevent contaminates from entering the canister. Various ports for different operating mechanisms are included. These ports can consist of a tank port to collect excess vapors from the tank, a vent port to draw air in from the atmosphere, a purge port to purge the vapors back into the engine for combustion, and a drain port if the canister happens to accumulate liquid that cannot be efficiently removed through normal purge operation.

All ONMCs used for this test were equipped with factory OEM carbon canisters. CARB staff followed the U.S. EPA light-duty test procedure 40 CFR 86.132-96 to determine carbon canister butane working capacity. This involves first purging the canister with fresh air and then loading the canister with a 50/50 mix of butane and nitrogen until there is a 2 g breakthrough. This loading procedure ensures that the canister is effectively full of vapors. After the carbon canister loading procedure, the motorcycle was operated on a dynamometer following one of the three prescribed driving cycles. Starting with a full carbon canister before each test demonstrates the effectiveness of the motorcycle's ability to purge the canister during the drive cycle.

2.2 Test Equipment

The J-Tec VF563AA series blow-by flow meter shown in Figure 2 was used during testing to measure purge flow from the carbon canister. The meter was installed in-line on the hose between the purge port on the carbon canister and the engine. This flow meter was recommended by a leading carbon material manufacturer since it provides accurate and repeatable measurement in the target flow ranges while introducing minimal pressure drop in the carbon canister system. Specifications for the flow meter are given in Appendix D: Flow Meter Specifications.

Figure 2. *J-Tec VF563AA Flow Meter.*

2.3 On-road Motorcycles Tested

Four motorcycles representative of Class III ONMCs (greater than 279cc) were selected by CARB staff to be tested. The motorcycles used for testing are labeled in this report as A through D (to maintain anonymity), as shown in Table 1**.** Motorcycles A, B, and C are California-specification motorcycles that were purchased new by CARB. These motorcycles are designed and certified to meet applicable CARB exhaust and evaporative standards. Motorcycle D was designed for EU Type Approval (Euro 5) and was loaned to CARB by the manufacturer[2] for testing. Euro 5 evaporative emissions standards and test procedures are very similar to those used by CARB. However, Euro 5 exhaust emissions standards are much more stringent than the corresponding CARB standards. None of the test vehicles were previously owned by the public, avoiding potential unknown variables in testing due to abuse, poor maintenance, or tampering of emissions control systems. The motorcycles used for testing in this report were also used in Appendix E1 “Exhaust Emissions Test Results”. The method for making the tested motorcycle’s brand anonymous varied between the two reports. To clarify the naming convention between reports, Motorcycles A, B, C, and D in this report correspond to motorcycles C1, C2, C3, and C4 in the exhaust emissions report. All motorcycles were tested at CARB’s Haagen-Smit Laboratory in El Monte, California.

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

Table 1. *Test vehicle descriptions.*

Description	Motorcycle A	Motorcycle B	Motorcycle C	Motorcycle D
Model Year	2018	2019	2019	2020
Odometer at time of test [km]	1632	2171	1270	1048
Engine Displacement [cc]	>900	>700	>1500	>600
Engine Configuration	Inline 4	Inline 3	V-2	Inline 3
Valves per Cylinder / Configuration	4-DOHC VVT	4-DOHC	4-DOHC	4-DOHC
Bore x Stroke [mm x mm]	76 x 55.1	78.0 x 59.1	100 x 111.1	78 x 53.4
Bore to Stroke Ratio	1.38	1.32	0.90	1.46
Compression Ratio	13.2:1	11.5:1	10.0:1	12.54:1
Number of Spark Plugs	4	3	2	3
Cooling System	liquid	liquid	air/oil	liquid
Emission Control Systems	SFI, PAIR, TWC, H2OS	SFI, PAIR, TWC, H02S	SFI, 2TWC, 2HO2S	SFI, PAIR, TWC(2), HO2S
Approx. Maximum Power [kW at rpm]	150 @ 13200	80 @ 9980	65 @ 5020	95 @ 11750
Approx. Maximum Torque [Nm at rpm]	120 @ 10800	80 @ 8460	145 @ 3000	80 @ 9350
Approx. Power Density [kW/L]	150	95	40	120
Transmission	6-speed constant mesh, Wet, multi-plate type	6-speed; multiplate assist and slipper clutch	6-speed-manual	6-speed-manual
Equivalent Inertia Mass [kg]	290	290	400	280
Fuel Tank Size (L)	16	14	13.2	17.4
Carbon Canister Size (mL)	390	220	380	260
Shift Schedule (FTP, US06)	Manufacturer Prescribed	Manufacturer Prescribed	Manufacturer Prescribed	CFR

2.4 Drive cycles

Three drive-cycles were included in this testing:

(1) Federal Test Procedure (FTP) – FTP is CARB's current ONMC certification drive cycle and is based on the Urban Dynamometer Driving Schedule (UDDS) with additional modifications. The FTP drive cycle was originally developed to be representative of the driving characteristics of passenger cars.
(2) World harmonized Motorcycle Test Cycle (WMTC) – The WMTC is the current test cycle used in Europe for certifying motorcycles and was developed to be representative of the driving characteristics of ONMCs.
(3) US06 – The US06 was developed as a supplement to the FTP to include high speed aggressive driving.

The key differences between the various drive-cycles used for this testing are listed in Table 2. It shows the variation in max and average speeds, distance, and the start conditions that are incorporated in the drive-cycles.

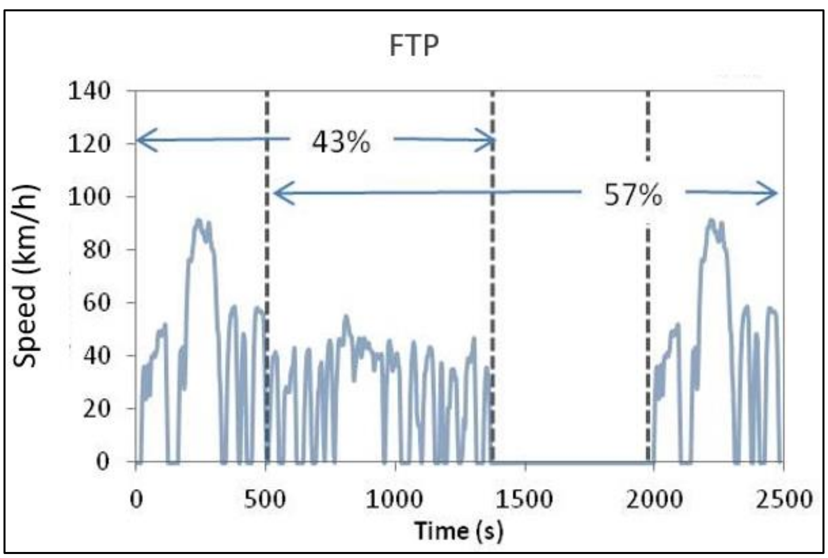
Table 2. *Key drive cycle parameters. For WMTC: P1, P2, P3 represent the parts of the drive cycle.*

Drive Cycle	Total Time (s)	Max Speed (km/h)	Average Speed (km/h)	Distance (km)	% Time Accelerating	% Time Cruising	Cold Start? (Y/N)	Hot Start? (Y/N)
FTP	1369	91	34	18	37%	18%	Y	Y
WMTC	1800	125	58	29	P1:31%, P2:39%, P3:30%	P1:21%, P2:24%, P3:45%	Y	N
US06	596	129	77	13	36%	26%	N/A[3]	N/A

2.4.1 FTP Drive Cycle

The FTP drive cycle (Figure 3) is the current ONMC certification drive cycle. The FTP is based on the UDDS drive cycle. It consists of the UDDS drive cycle with the first 505 seconds of the UDDS repeated at the end. The FTP begins with a cold engine start and incorporates a 10-minute engine-off hot soak followed by hot engine start at 2000 seconds. Emissions are collected in 3 phases and weighted such that the combined results of phases 1 and 2 contribute to 43% of the total while combined results of phases 2 and 3 contribute 57%. Measuring purge flow rate and volume is not required or typically conducted during emissions testing. Therefore, the carbon canister purge flow rate was monitored throughout the entire drive cycle and was not weighted by the drive cycle phases. The maximum speeds achieved during the FTP is most representative of city-speed riding.

Figure 3. *FTP drive cycle.*



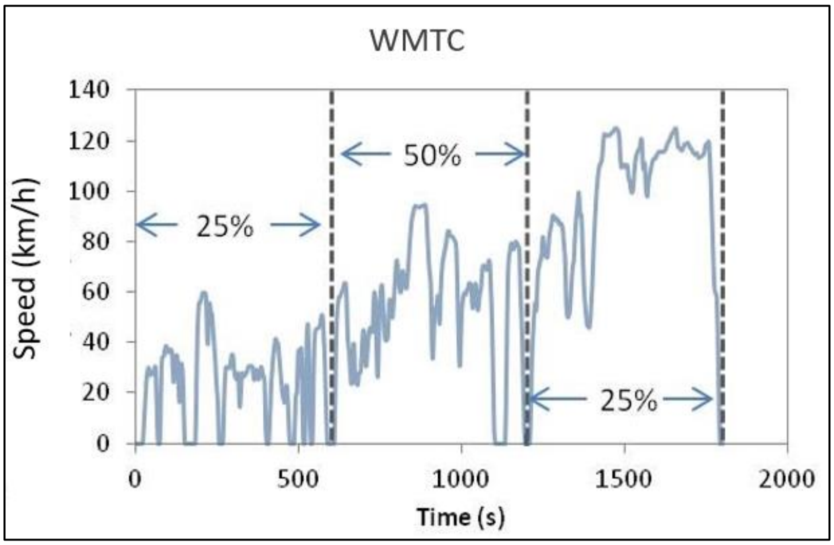
2.4.2 WMTC Drive Cycle

The WMTC drive cycle (Figure 4) is currently used for EU Type Approval. Unlike the FTP, the WMTC is designed specifically for motorcycles and their typical riding practices. Emissions are

[3] To be consistent with FTP and WMTC drive cycle testing, all US06 drive cycle testing included in this report was conducted with a cold engine start.

collected in 3 phases; phase 1 is weighted 25%, phase 2 is weighted 50%, and phase 3 is weighted 25%. The WMTC begins with a cold engine start, but there is no engine off or hot start requirement. WMTC includes several classes and sub-classes with different top speeds and acceleration rates to accommodate a wide variety of motorcycles. Based on the class and top speed of the motorcycles used in this test program, WMTC version 3-2 was used for all testing conducted for this report. The WMTC covers a wide variety of motorcycle operation ranging from low-speed urban operation to higher speeds typically associated with highway riding. Compared to the FTP, the WMTC is more representative of actual ONMC riding.

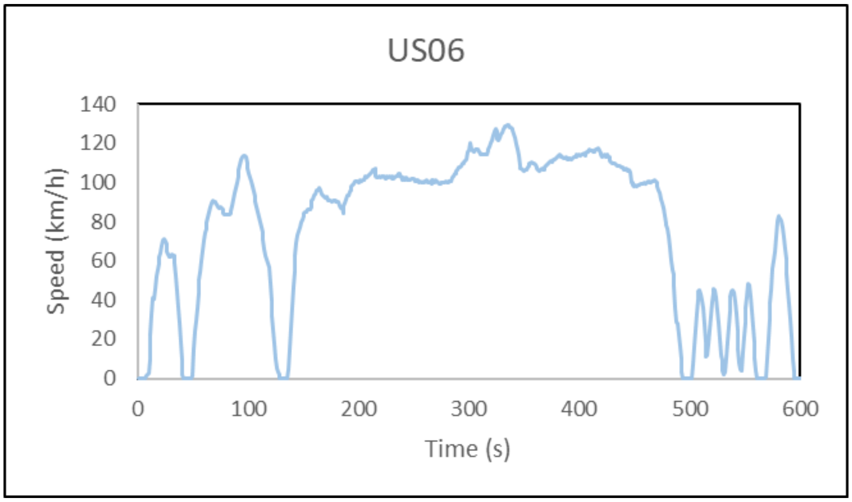
Figure 4. *WMTC drive cycle.*



2.4.3 US06 Drive Cycle

The US06 drive cycle (Figure 5) was developed by the U.S. EPA as a supplemental drive cycle to the FTP and is not currently used in ONMC certification testing. Emissions are only collected in one phase. The US06 adds a higher speed and more aggressive driving profile to the FTP and is being evaluated as part of this testing for future motorcycle emissions inventory development consideration.

Figure 5. *US06 Drive Cycle.*



2.4.4 FTP+US06

As mentioned above, the US06 drive cycle was developed as a supplemental drive cycle to the FTP. While the testing conducted for this report did not run the FTP and US06 together as a single drive cycle, a summation of the results from the two drive cycles can be considered to evaluate the use of these drive cycles together.

3 Results

3.1 Purge Volume

The total purge volume is the volume of fresh air the test motorcycles were able to draw into the carbon canister to remove stored hydrocarbons and deliver the hydrocarbons into the engine to be combusted during a given drive-cycle. Total purge volume statistics over all runs for each drive cycle and motorcycle are shown in Table 3. A summary table of average purge volume observed for each test motorcycle over each drive cycle is shown in Table 4.

Graphical results of the average total purge volume for each drive cycle and motorcycle are shown in Figure 6. While engine size and configuration varied among the Class III motorcycles tested, motorcycles A, B, and C had greater average purge volume across all drive cycles than motorcycle D -- motorcycle D was the only test motorcycle that conformed to stricter Euro 5 exhaust standards. When a motorcycle purges the carbon canister, the purged fuel vapors enrich the air/fuel mixture which can lead to increased exhaust emissions.

Distributions of the average total purge volumes across all test motorcycles for each drive cycle are shown in Figure 7. The FTP showed the lowest overall total purge volume when compared to the other drive cycles. The FTP was originally designed for passenger cars, not motorcycles, and can therefore be misrepresentative of real-world driving conditions. The WMTC drive cycle was specifically designed to mimic real world riding conditions. This is clearly demonstrated when comparing the total purge volume between the WMTC and the FTP drive cycles.

For standalone drive cycles, both the WMTC and the US06 yielded similar average total purge volumes. However, the US06 drive cycle was not designed to be a stand-alone test. The high purge volumes during the US06 drive cycles likely result from the higher test speed and more aggressive riding style. As with the FTP, the US06 drive cycle is not tailored to typical motorcycle riding conditions, so this is not an accurate representation of how a motorcycle would be operated in the real-world.

When the US06 is considered in combination with the FTP as a supplemental drive cycle (FTP+US06), the total purge volumes were greater than the FTP, WMTC, and US06 (alone). While this combination drive cycle provides more opportunities for the motorcycle to have its purge valve open, it is not representative of real-world riding for the reasons discussed above.

Table 3. *Drive cycle statistics of total purge volume (L) for all motorcycles.*

Motorcycle	Drive Cycle	# of Runs	Minimum	Maximum	Average	Standard Deviation
A	FTP	4	105.19	106.21	105.61	0.46
	WMTC	6	139.51	164.34	151.39	10.64
	US06	3	114.40	144.00	127.28	15.17
B	FTP	3	27.58	32.69	29.56	2.74
	WMTC	7	119.54	125.28	121.74	2.27
	US06	3	151.41	159.55	154.63	4.33
C	FTP	5	66.51	77.45	70.30	4.44
	WMTC	8	170.58	181.93	177.96	4.51
	US06	2	127.39	133.18	130.28	4.10
D	FTP	3	18.69	25.85	22.30	3.58
	WMTC	4	41.36	48.36	44.47	2.89
	US06	2	53.69	59.86	56.78	4.36

Table 4. *Average total purge volume (L) over all runs during each drive cycle and motorcycle.*

Motorcycle	FTP	WMTC	US06	FTP+US06
A	105.61	151.39	127.28	232.89
B	29.56	121.74	154.63	184.19
C	70.30	177.96	130.28	200.58
D	22.30	44.47	56.78	79.08

Figure 6. *Average total carbon canister purge volume (L) over all runs for each motorcycle and drive cycle.*

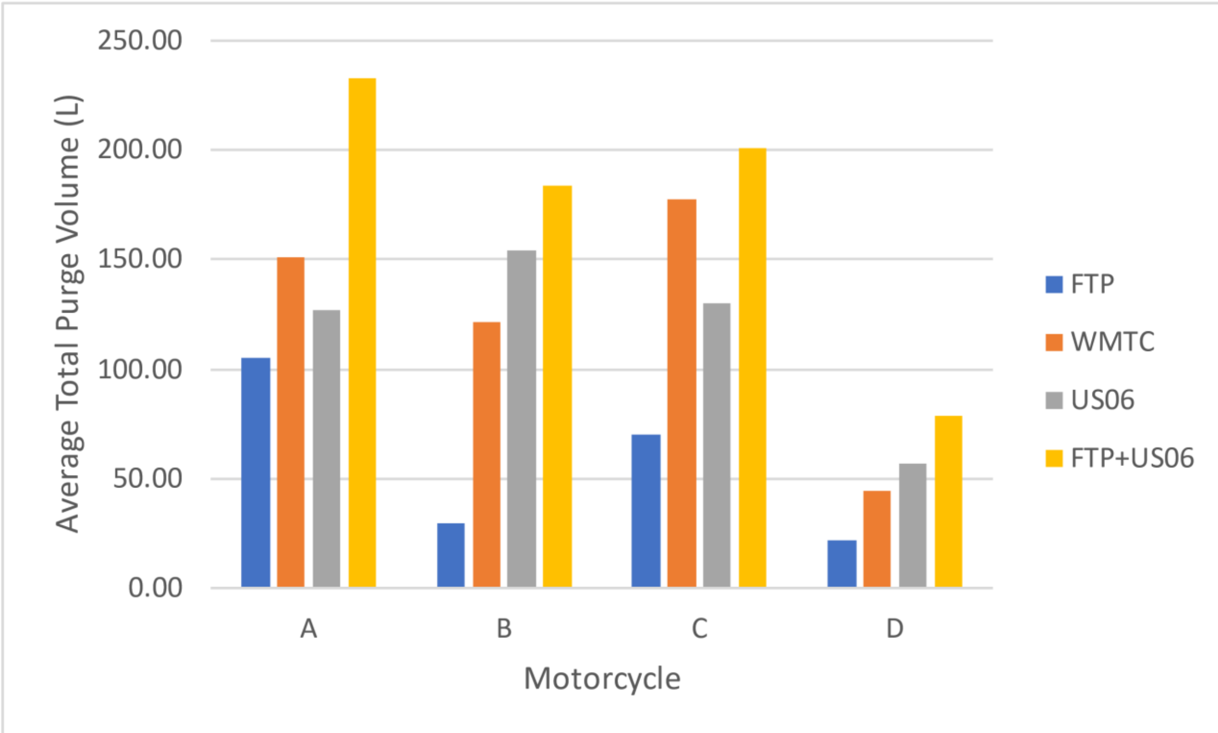
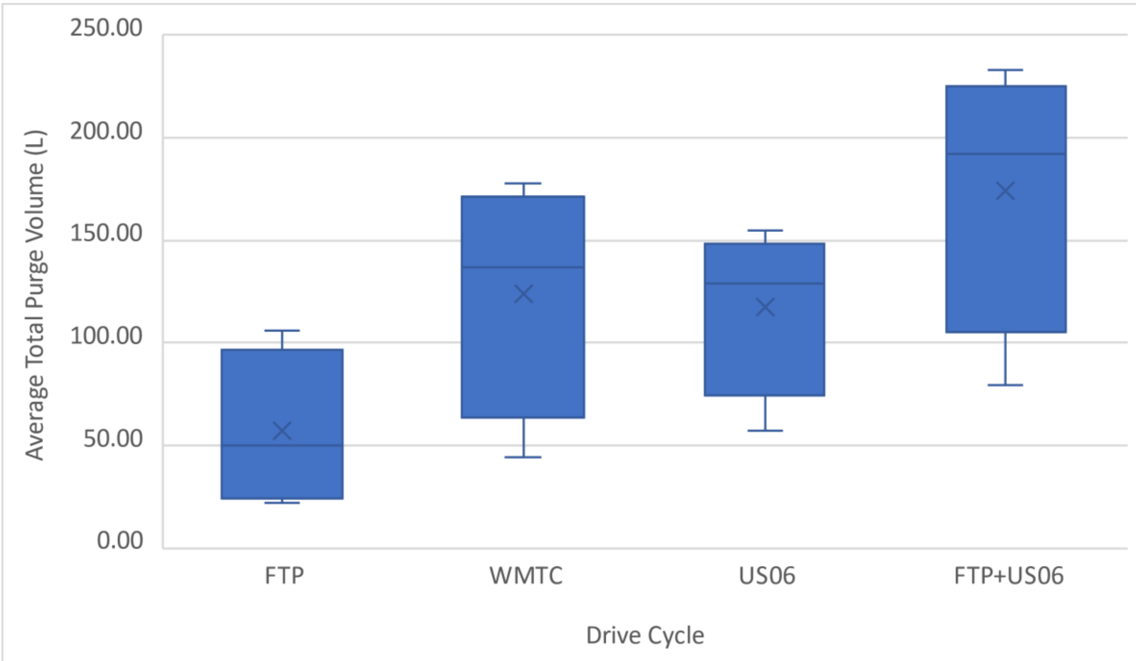


Figure 7. *Distribution of average total purge volume (L) over all runs for all motorcycles within each drive cycle.*



3.2 Bed Volumes

The number of bed volumes exchanged is a direct function of total purge volume and the size of the carbon canister installed on the motorcycle. A larger canister will require a greater volume of purge air to achieve the same number of bed volumes purged as a smaller canister. To determine the number of bed volumes exchanged over a drive cycle, total purge volume is divided by the volume of the carbon canister. This is an important metric because it allows the analysis of the volume of vapor purge that is occurring in relation to the size of the carbon canister. The vehicle preconditioning test procedure defined in 40 CFR § 86.132-96(h)(1)(i-iv) purges a canister for 300 bed volumes to clean or reset the state of the canister. Thus, for this report, we consider a purge volume equivalent to 300 bed volumes to have fully purged the canister. In the following figures we highlight the 300 bed volumes limit with a red line.

Statistics for the total number of bed volumes exchanged for all motorcycles tested are shown in Table 5. Results for average number of bed volumes purged over all runs for each drive cycle (Table 6) are closely related to the results of average total purge volume. No motorcycles had a fully purged canister (>300 bed volumes) after all four drive cycles (Figure 8). Three motorcycles (A, B, and C) were able to fully purge their carbon canisters on three out of the four drive cycles. Motorcycle D was only able to achieve full purge on one of the drive cycles (FTP + US06). As mentioned above, motorcycle D is compliant with stricter EU exhaust emission regulations. The observed low number of bed volumes exchanged over each drive cycle for motorcycle D is likely a result of both low total purge volume and canister size.

Similar to the results described in section 3.1, the FTP showed the lowest average number of bed volumes exchanged during testing while the FTP+US06 had the highest average observed number of bed volumes exchanged. Again, the WMTC and US06 performed similarly and generally yielded fully purged carbon canisters at the end of the tests. The FTP+US06 was the only drive cycle to consistently purge the carbon canisters on all motorcycles over the 300-bed volume threshold. However, as discussed previously, the FTP, US06, and FTP+US06 are not representative of real-world riding conditions.

Table 5. *Drive cycle statistics for the total number of bed volumes exchanged for all motorcycles.*

Motorcycle	Drive Cycle	# of Runs	Minimum	Maximum	Average	Standard Deviation
A	FTP	4	269.72	272.34	270.87	1.13
	WMTC	6	357.72	421.40	388.17	27.28
	US06	3	301.04	379.81	335.23	40.40
B	FTP	3	125.35	148.58	134.38	12.44
	WMTC	7	543.36	569.46	553.35	10.34
	US06	3	688.21	725.38	702.90	19.77
C	FTP	5	175.02	203.81	185.00	11.69
	WMTC	8	448.88	478.75	468.31	11.87
	US06	2	335.23	350.48	342.86	10.79
D	FTP	3	71.87	99.44	85.76	13.79
	WMTC	4	159.09	185.99	171.04	11.12
	US06	2	244.06	272.11	258.09	19.83

Table 6*. Average total number of bed volumes exchanged over all runs during each drive cycle for each test motorcycle.*

Motorcycl e	Carbon Canister Size (mL)	FTP	WMTC	US06	FTP+US06
A	390	270.87	388.17	335.23	606.10
B	220	134.38	553.35	702.90	837.28
C	380	185.00	468.31	342.86	527.85
D	260	85.76	171.04	258.09	343.85

Figure 8. *Number of average bed volumes exchanged over all runs for each drive cycle and each motorcycle A, B, C and D. The red line indicates the 300-bed volume threshold for a fully purged canister.*

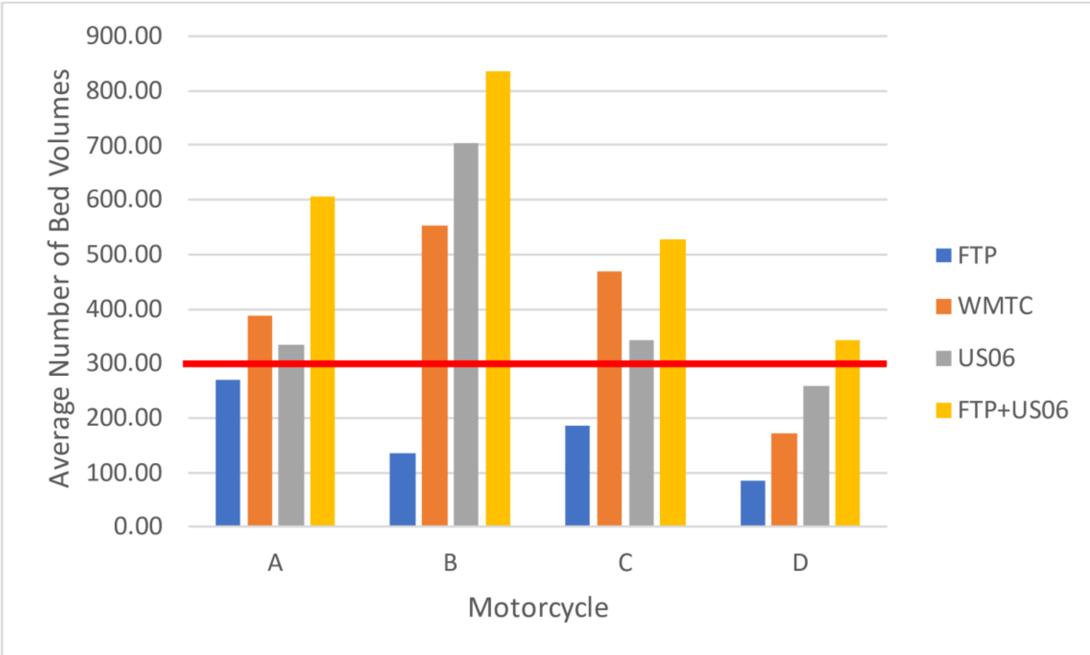
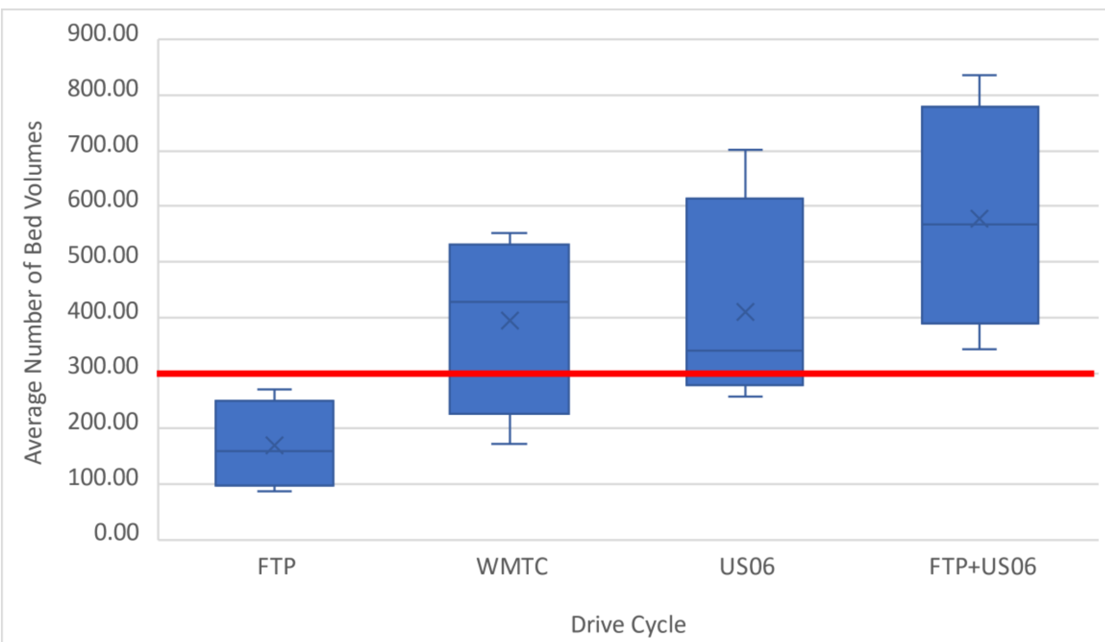


Figure 9. *Distribution of average bed volumes exchanged over all runs for all motorcycles within each drive cycle. The red line indicates the 300-bed volume threshold for a fully purged canister.*



3.3 Purge Valve Operation

The percentage of time the purge valve is open during a drive cycle is directly related to the ability of a motorcycle to purge its carbon canister. If the percentage is high, there is more opportunity for purging vapors from the carbon canister into the engine. The motorcycle's ECU controls when and under what conditions the purge valve should be open. Although having more opportunities to purge is beneficial to creating capacity in the carbon canister for diurnal emissions, purging introduces an unknown concentration of hydrocarbons into the engine which can have a downstream effect on tailpipe emissions.

Table 7 shows the statistics for the percentage of time when the purge valve is open for all motorcycles tested during the various drive cycles. The average percentage of time the purge valve is open for each drive cycle and each motorcycle is detailed in Table 8. Motorcycle D has, on average, the purge valve open for a significantly shorter percent of the time during each drive cycle than the rest of the motorcycles tested. However, Motorcycle D is the only EU5 spec motorcycle tested, and this difference in purge valve operation could potentially be attributed to having to meet a more stringent tailpipe emission standard verses the non EU5 motorcycles. Other factors could include a more conservative purge strategy engineered into the motorcycle by the manufacturer. While those assumptions cannot be verified with these results, future testing explore differences between motorcycles tuned for EU5 specifications versus CARB or U.S. EPA specifications.

As seen in both Figure 10 and Figure 11, the FTP drive cycle has the lowest average percentage of time with the purge valve open during the drive cycle. This may be a result of the lower speeds and milder nature of the FTP, which offers less opportunities for the purge valve to be open. The difference is particularly apparent when compared to the WMTC and US06 drive cycles. The FTP may have demonstrated significantly lower total purge volumes and bed volumes exchanged due to the relatively smaller amount of purge valve open time.

Table 7. *Drive cycle statistics for the percentage of time when the purge valve is open for all motorcycles.*

Motorcycle	Drive Cycle	# of Runs	Minimum	Maximum	Average	Standard Deviation
A	FTP	4	40.68%	41.40%	41.00%	0.32%
	WMTC	6	56.92%	61.14%	58.77%	1.37%
	US06	3	59.65%	76.68%	67.66%	8.56%
B	FTP	3	16.09%	17.21%	16.53%	0.59%
	WMTC	7	41.86%	44.86%	42.90%	0.95%
	US06	3	72.19%	73.41%	72.90%	0.63%
C	FTP	5	47.26%	49.17%	48.47%	0.77%
	WMTC	8	61.89%	64.58%	63.25%	1.00%
	US06	2	61.12%	61.33%	61.22%	0.15%
D	FTP	3	9.59%	13.35%	12.03%	2.12%
	WMTC	4	16.97%	21.50%	18.59%	1.99%
	US06	2	30.54%	36.83%	33.68%	4.45%

***Table 8**. Average percentage of time the purge valve is open during each drive cycle for each test motorcycle.*

Motorcycle	FTP	WMTC	US06	FTP+US06
A	41.00%	58.77%	67.66%	51.36%
B	16.53%	42.90%	72.90%	38.43%
C	48.47%	63.25%	61.22%	53.42%
D	12.03%	18.59%	33.68%	20.44%

***Figure 10.** Average percentage of total drive cycle time that the purge valve is open over all runs for each drive cycle and each motorcycle A, B, C and D.*

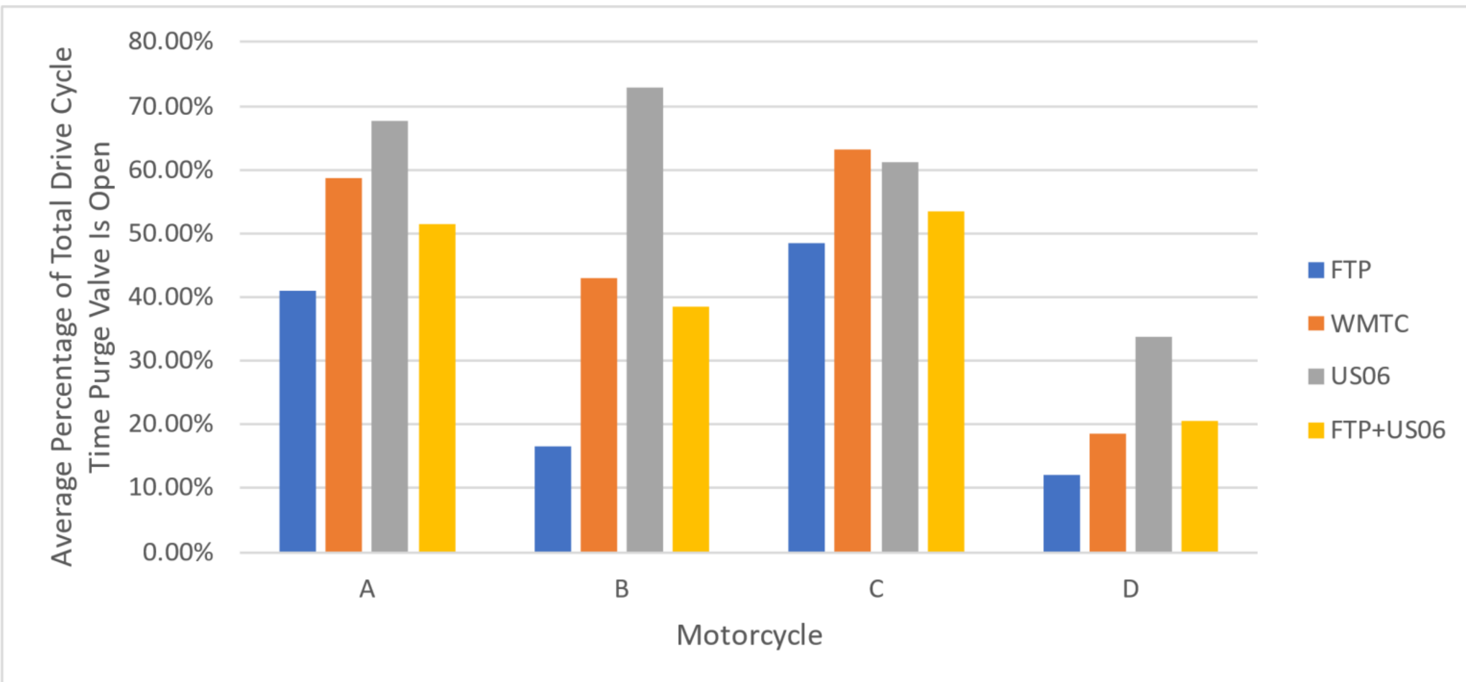
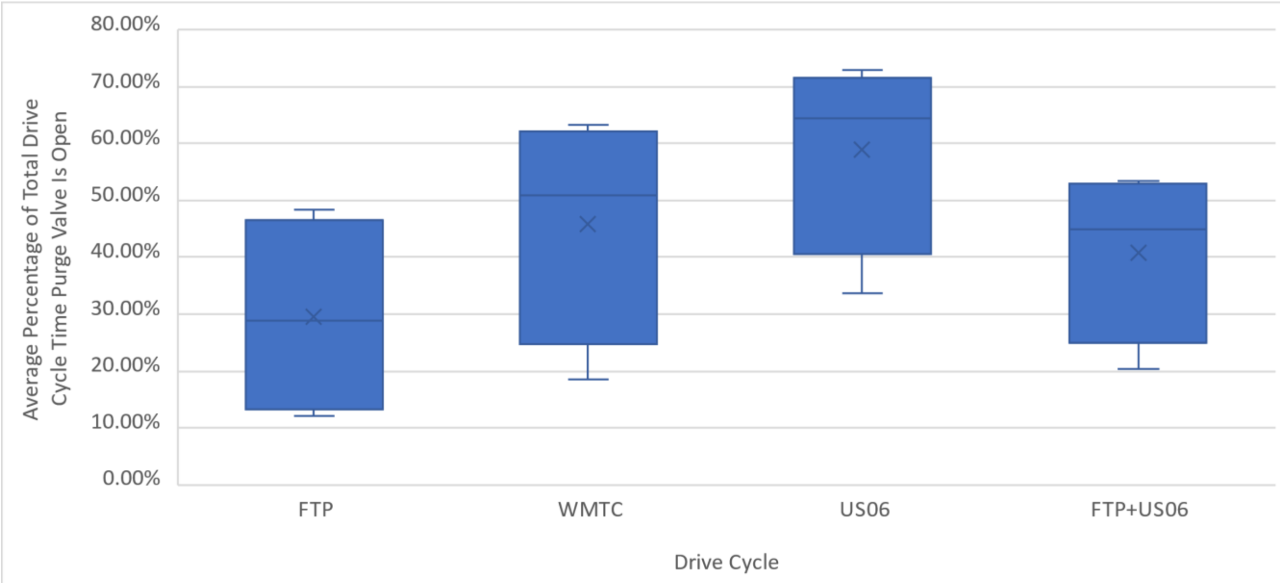


Figure 11. *Distribution of average percentage of total drive cycle time that the purge valve is open over all runs for all motorcycles within each drive cycle.*



3.4 Purge Flow Rate

The average purge flow rate describes the volume and speed of vapors that are being purged from the canister while the purge valve is open. Table 9 shows the statistics for the average flow rate while purging over each run for all motorcycles tested, while Table 10 compares averages between motorcycles and drive cycles.

Even if the purge valve is open for a significant time during a drive cycle, if the average purge flow rate is low there is generally lower total purge volume and thus less bed volumes being exchanges. Generally, this scenario would reduce the overall working capacity to capture diurnal emissions. However, this may not always be true as slower flow rates can yield a greater exchange of vapors from the carbon media into the purging air[4]. According to a study done by the Manufactures of Emission Controls Association (MECA)[4], a flow rate of 5 L/min had a less than 5% increase in canister working capacity compared to a 10 L/min flow rate. This is similar to the ranges of flow rates seen during testing as indicated in Table 9 and Table 10. Thus, we do not expect that the differences in flow rates during our testing had a significant impact on the canister working capacity.

As shown in Figure 12, all motorcycles had generally similar purge flow rates across all drive cycles. Motorcycle D did not demonstrate significantly lower average purge flow rate compared to the other three motorcycles tested as seen in Sections 3.1, 3.2, and 3.3. As detailed in Table 10 and shown in Figure 13, the FTP had the lowest purge flow rate, and when coupled with the lowest percentage of time with the purge valve open, it is clear that FTP has overall lower purge than the other drive cycles. Similar to previous results, the WMTC and FTP+US06 drive cycles have similar

[4] Manufacturers of Emission Controls Association (MECA), Evaluation of Motorcycle Evaporative Canisters. July 15, 2021.

average purge flow rates. The highest average flow rate overall was observed during the stand-alone US06 test. Once again, since US06 is a supplemental test designed to be run in conjunction with the FTP, its performance in these tests shows the contrast of an aggressive high speed drive cycle versus the milder city-oriented FTP.

Table 9. *Drive cycle statistics for the average flow rate (L/min) while purging over each run for all motorcycles.*

Motorcycle	Drive Cycle	# of Runs	Minimum	Maximum	Average	Standard Deviation
A	FTP	4	8.13	8.35	8.24	0.10
	WMTC	6	8.07	9.36	8.58	0.51
	US06	3	9.32	9.65	9.48	0.17
B	FTP	3	5.48	6.08	5.71	0.32
	WMTC	7	9.31	9.61	9.46	0.12
	US06	3	10.42	10.94	10.68	0.26
C	FTP	5	4.34	5.24	4.65	0.37
	WMTC	8	9.04	9.79	9.38	0.24
	US06	2	10.49	10.93	10.71	0.31
D	FTP	3	5.36	6.28	5.96	0.52
	WMTC	4	7.51	8.11	7.89	0.26
	US06	2	8.18	8.85	8.52	0.47

Table 10*. Average of the average flow rate (L/min) while purging during each drive cycle for each test motorcycle.*

Motorcycle	FTP	WMTC	US06	FTP+US06
A	8.24	8.58	9.48	8.87
B	5.71	9.46	10.68	9.37
C	4.65	9.38	10.71	7.35
D	5.96	7.89	8.52	7.59

Figure 12. *Average flow rate while purging (L/min) over all runs for each drive cycle and each motorcycle A, B, C and D.*

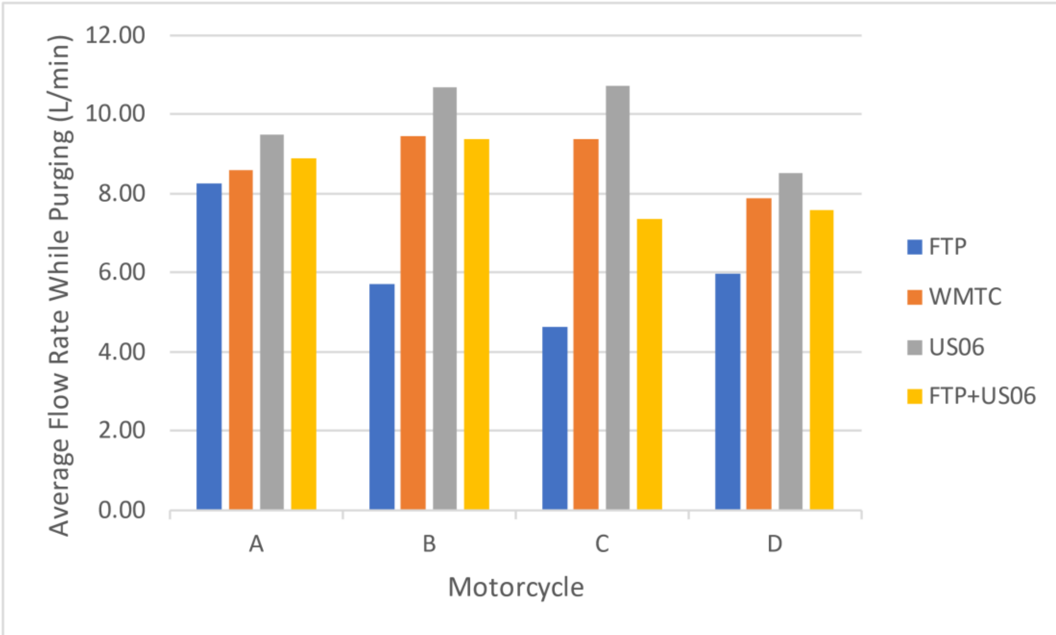
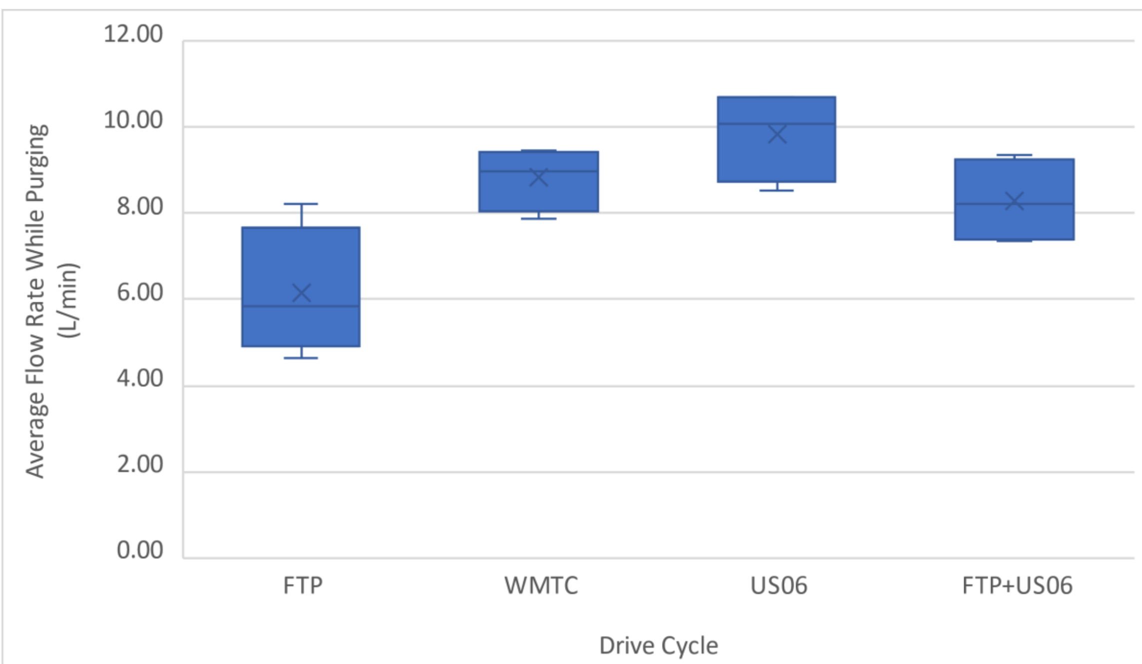


Figure 13. *Distribution of average flow rate while purging (L/min) over all runs for all motorcycles within each drive cycle.*



3.5 Analysis of WMTC Purge by Parts

This testing has demonstrated that the WMTC, as a standalone drive cycle, provides higher purge volume, bed volume exchange, purge time and purge flow rates across the motorcycles tested when compared to the other tested drive cycles. Because all motorcycles tested are classified as class III, the motorcycles were tested using the full version of the WMTC (version 3-2). For smaller displacement motorcycles with lower top speeds, there are slower speed variations of the WMTC drive cycle. While no small displacement motorcycles were used during this testing, by using existing data and focusing on the first and second parts of the WMTC drive cycle, we can consider the potential carbon canister purge characteristics of motorcycles that do not run the full WMTC drive cycle.

Table 11 shows the parameters of the WMTC broken down into each part of the drive cycle. While the duration for all three parts is equivalent (600 s), the distance and max speeds increase steadily from Part 1 through Part 3.

Table 11. *WMTC drive cycle specifications per each part.*

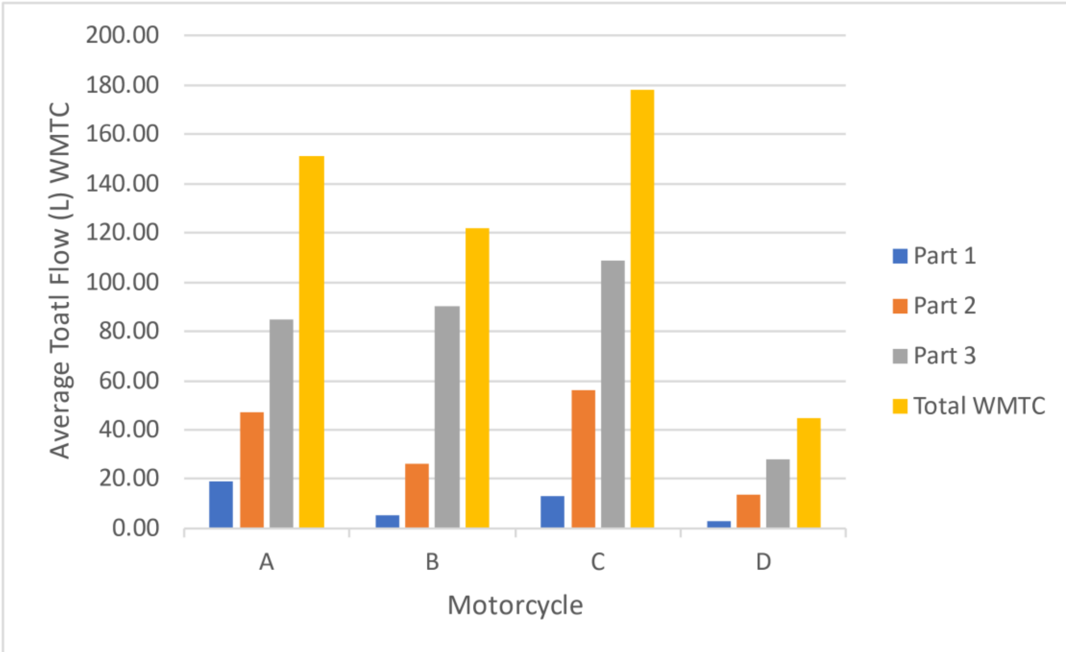
WMTC	Part 1	Part 2	Part 3
Duration	600 s	600 s	600 s
Distance	2.5 mi (4065 m)	5.7 mi (9111 m)	9.8 mi (15736 m)
Max Speed	37 mph (60 km/h)	59 mph (95 km/h)	78 mph (125 km/h)

Table 12 shows the average total purge volume from the carbon canister for each part of the WMTC drive cycle for each test motorcycle. These data demonstrate how each part of the WMTC drive cycle contributes to the total amount of flow seen over the whole test. As seen in the data, the highest fraction of average total purge volume (56-74%) is achieved during Part 3 of the WMTC drive cycle. This is visually demonstrated in Figure 14. Part 3 accounts for more than half of all purge volume during the WMTC drive cycle for all motorcycles tested. Generally, depending on their top speed, lower displacement motorcycles (class I and class II) are only required to run Parts 1 and 2 of the WMTC drive cycle. Based on the data presented, only running Parts 1 and 2 of the WMTC drive cycle would yield significantly lower total average purge volumes (26-54%) compared to the full WMTC drive cycle.

Table 12. *Average Total Purge Volume (L) during each phase of the WMTC drive cycle. Percentage of total average purge volume for each part of the drive cycle is noted in parenthesis rounded to the nearest whole number.*

Motorcycle	Displacement	Part 1	Part 2	Part 3	Total WMTC
A	>900 cc	19.33 (13%)	47.01 (31%)	85.09 (56%)	151.39
B	>700 cc	5.29 (4%)	26.43 (22%)	90.02 (74%)	121.74
C	>1500 cc	13.28 (7%)	55.85 (31%)	109.01 (61%)	177.96
D	>600 cc	3.12 (7%)	13.57 (31%)	27.77 (62%)	44.47

Figure 14. *Average Total Purge Volume (L) per part for each motorcycle of the WMTC*



4 Limitations

4.1 Shift Schedules

How a rider shifts through gears during a test drive cycle can influence the test results. This paper report does not investigate potential variations due to shifting. For completeness, it is important to note the shifting strategy used. The WMTC has a prescribed shift schedule. The FTP and US06 drive cycles allow for either a prescribed shift schedule as given in the code of federal regulations, or the manufacturer may submit results obtained with their recommended shift schedule. The selection of shift schedules is described in Table 1.

4.2 Carbon Canister Aging

This testing was not conducted on carbon canisters that were aged to full useful life. Each canister involved in testing had been exposed to gasoline vapors for at least 1000 miles of normal vehicle operation. However, no specific canister aging protocols were conducted as part of this test program. The performance of carbon canisters may change over time and with use due to environmental factors such as vibration, exposure to moisture, and repeated load/purge cycles.

4.3 Hydrocarbon Mass Purged (Purge Efficiency)

Pre- and post-drive cycle weights of the carbon canister were not determined as part of this test project. Thus, the mass of hydrocarbon purged from the canister during each drive cycle and the corresponding working capacity of the carbon canister after the test run could not be exactly determined. While hydrocarbon mass purged is generally proportional to purge volume, the specific relationship varies depending on several factors including canister design, purge flow rate, and carbon characteristics[4].

4.4 Motorcycle Class

This report only considered Class III motorcycles, defined as motorcycles with engine displacements equal to or greater than 280cc. Motorcycles with smaller engine displacements may have different purge behavior for each drive cycle. Furthermore, the WMTC and FTP cycles defined for smaller displacement motorcycles with lower top speeds include lower speeds and, in some cases, shorter durations than the full versions of the WMTC and FTP that were used in this test program. If further testing is conducted on smaller displacement motorcycles, slower speed variations of the FTP and WMTC could be tested.

4.5 On-Board Data Collection

CARB staff were unable to collect real time data from the motorcycle's engine control unit (ECU) during testing and were therefore unable to analyze what specific engine conditions were associated with purge valve operation. If further testing is conducted, it would be beneficial to collect ECU data and correlate the purge valve operation to engine operating conditions and drive cycle parameters.

5 Conclusions

The testing detailed in this report evaluated the effects of drive cycle on carbon canister purge volume, the total number of bed volumes exchanged per drive cycle, purge valve on-off percentage, and purge flow rates. The ability of a motorcycle to purge the carbon canister during regular operation impacts the canisters working capacity for collecting diurnal emissions. Results of this test program demonstrated that for four, Class III motorcycles both the WMTC and the US06 drive cycles yield similar total purge volumes and both drive cycles generally fully purge the carbon canister by the end of the drive cycle. The FTP drive cycle was not fully able to purge the carbon canister for any of the four motorcycles tested. While the US06 is not considered a stand-alone test, when combined with the FTP, the FTP+US06 yields the highest total purge volume and exceeds the 300-bed volume exchange threshold for all motorcycles needed to achieve maximum working capacity for the carbon canister for all motorcycles tested. However, the combination of FTP+US06 yielded on average lower percent times with the purge valve open during testing and lower flow rates than the WMTC and stand-alone US06.

The FTP, US06, and combined FTP+US06 were developed for passenger cars and are not representative of actual real-world motorcycle riding conditions – the WMTC was developed specifically on motorcycles for this purpose. Finally, the WMTC is an international standard, already being used for regulatory compliance in the EU. Given the overall positive purging results, accurate representation of real-world motorcycle riding conditions, and global adoption, the WTMC is well suited for use as the drive cycle for future CARB ONMC evaporative emissions testing procedures.

Appendix A: Test Plan

TO: Mark Fuentes, Division Chief
Mobile Source Laboratory Division

Allen Lyons, Division Chief
Emissions Certification and Compliance Division

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:

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.

General Test Preparation

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

Motorcycle Preparation and Preconditioning for FTP (EC1B):

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.

Testing Sequence for FTP (EC1B):

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.

<u>Motorcycle Preparation and Preconditioning for Type I Test (WMTC):</u>

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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Test Engineer: Tuyen Dinh, In-Use Inventory Testing Section (IUITS), at (626) 450-6180 or tuyen.dinh@arb.ca.gov.

Backup Test Engineer: Thomas Desimone, IUITS, at (626) 350-6580 or tdesimon@arb.ca.gov

Chemistry Staff: Ying You, Aerosol Analysis and Methods Evaluation Section, at (626) 459-4391 or ying.you@arb.ca.gov.

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	Redacted	Redacted	2018-Current
2	Redacted	Redacted	2017-Current
3	Redacted	Redacted	2018-Current
4	Redacted	Redacted	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
1R = One Wheel Drive, Rear
2F = Two Wheel Drive, Front
4M = Four Wheel Drive, Mandatory
2R = Two Wheel Drive, Rear
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

EGR System : ___Yes ___No

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

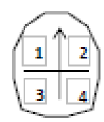
Air Inject Type : _____ N = Neither A = Air Injection Pump P = Pulse Air

Pre-Catalyst Type : ________

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

Main-Catalyst Type : ________

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

Transmission Type : ______

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

Fuel Injection Type : ______

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

Specifications

Num. Cylinders : ☐☐
Num. Caburetors : ☐
Barrels/Carb. : ☐
Eng. Disp. Vol. (cc) : ☐☐☐☐

Rated Power (kW) ________
Rated Speed (rpm) ________
Peak Torque (N-m) ________
Peak Torque Speed (rpm) ______

Engine Cooling: Air Cooled _____ Water Cooled _____

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

Comments

____
____
____
____
____

Extra parts? Yes No

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

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

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**

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

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**

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

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**

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

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 ☐ Survelliance ☐ Crosscheck ☐ Screening ☐ Title 13 ☐ Confirmatory ☐ Compliance/In-Use ☐ After Market Part Evalution ☐ Other: ________________

Appendix B: Test Plan Amendment Summary

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 C: Test Plan Addendum #1 Summary

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.”

Appendix D: Flow Meter Specifications

J-TEC

Visit us online: j-tecassociates.com

VF563 Series Blow-By Flow Meters

The J-TEC in-line flow meters provide all the advantages of vortex shedding technology, in a design that is perfect for rugged applications with minimal space requirements. The VF563 Series is the best value for your low-pressure gaseous flow applications. This device is the meter of choice especially for the measurement of blow-by gases in engine testing applications. Other vortex flow meters lack crucial sensitivity because they can only detect vortices created by large, restrictive obstructions. This diminishes important low-end performance. The J-TEC design incorporates a small strut, which offers minimal flow restriction, for high accuracy over an extended range. Each meter is individually calibrated to NIST traceable standards. J-TEC flow meters have no moving parts, so they are rugged and trouble-free.

Benefits include: Minimal effect on engine performance during measurement, low pressure drop, drift-free performance, excellent at low flows (down to 0.14 ACFM), easy maintenance, 40:1 turndown ratio, continuous flow readings, high accuracy, excellent repeatability.

SPECIFICATIONS

Operating (gas) temperature:	0° to 200°F (-18° to 93°C)
Operating pressure:	-5 to 30 PSIG (-0.34 to 2.1 BARg)
Accuracy:	± 2% full scale
Repeatability:	± 0.5% of reading
Input power:	+12 to +24 VDC at 35 mA
Outputs:	0 to 5 VDC, Frequency or Optional Handheld Display
Construction:	Anodized aluminum
Ambient temperature limits:	-20° to 150°F (-28° to 66°C)
Response Time-Analog/Freq:	100 milliseconds

FLOW RANGES

Model	VF563AA	VF563A	VF563B	VF563J	VF563K	VF563C	VF563F	VF563G
Line Size in. (mm)	3/8 (9.5)	1/2 (12.7)	5/8 (15.9)	3/4 (19.05)	1 (25.4)	1-3/8 (34.9)	2 (50.8)	4 (101.6)
Range ACFM	0.14 to 5	0.25 to 10	0.40 to 16	0.7 to 26	1 to 47	2 to 80	5 to 200	20 to 600
Range CFH	8.4 to 300	15 to 600	24 to 960	42 to 1560	60 to 2820	120 to 4800	300 to 12000	1200 to 36000
Range m3/Hr	0.24 to 8	0.42 to 16	1 to 27	1.1 to 44	1.6 to 79	3 to 135	8 to 339	34 to 1019
Range LPM	4 to 141	7 to 283	11.3 to 453	20 to 736	28 to 1330	57 to 2265	141 to 5662	566 to 16987

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2/2017