Proposed *3 Bin Moving Average Window (MAW) Method for Chassis Certified Medium Duty Vehicles (MDVs)

By: California Air Resources Board (CARB)

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Proposed *3 Bin MAW Method for chassis certified MDVs as of May 2021. Subject to change before official rulemaking occurs.

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*3 Bin MAW Method: Same method adopted for the Heavy Duty (HD) Omnibus rulemaking except the FCL value is replaced with an alternate value for chassis certified MDVs

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I. 3 Bin MAW Method

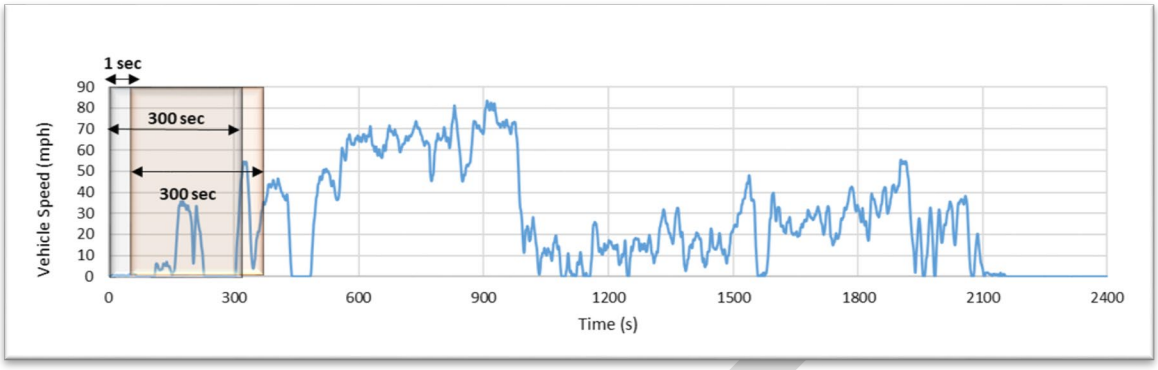

Figure 1: 5 Minute Overlapping Windows

Emissions and vehicle test data are collected on-road using a Portable Emissions Measurement System (PEMS). Data will be analyzed using continuous 5 minute windows that start at every second and will be overlapping. As shown in Figure 1.

	Idle bin	**Low Load bin**	**Med/High Load Bin**	**Otto bin**
Diesel	≤6% Engine Load	>6 and ≤ 20% Engine Load	> 20% Engine Load	
Gasoline				0-100% Engine Load

Table 1: Bins for Diesel and Gasoline

Windows will be binned by engine load percentage. Diesel and gasoline MDVs will have their windows binned as specified in table 1. Emissions for each bin will be calculated using the HD in-use equation which can be found in section II of this handout.

Emissions for each bin is compared to the HD standard that is specific to that bin which can be found in section III of this handout.

Window exclusions and requirements will apply to be considered valid and can be found in section IV.

II. 3 Bin MAW Equations

The following are the equations that were used to apply the 3 bin MAW method to the chassis certified MDV data set that was presented at the ACC II May 2021 workshop.

Calculating Percent Engine Load for Each Window:

$$Percent\ Engine\ Load_{window} = \frac{3{,}600\ sec/hr}{FCL\ \times HPmax} \times \frac{\sum_{t=1}^{300}(\dot{m}_{CO2} \times \Delta t)}{300\ sec}$$

*$FCL\ \approx$ FTP chassis test cycle ($\frac{CO2\ g}{hp-hr}$)

$HPmax$ = Maximum rated horsepower (hp)

$\dot{m}_{CO2}$= mass emission rate of CO2 emitted per second ($\frac{g}{s}$)

Δt = data sampling rate (1 Hz)

*HD uses the Family Certification Level (FCL) which is declared by the manufacturer that is at or above emission test result for all emission-data engines. For chassis certified MDVs, we replaced the FCL with an alternate value that is calculated based on the FTP chassis certification test cycle. The method we used for calculating the alternate FCL value is shown in Section II.

Calculating Emissions for Low Load, Med/High Load, and Otto Bin

$$e_{sos\ a,b} = \frac{\sum_{k=1}^{n_b}\sum_{t=1}^{300}(\dot{m}_a \times \Delta t)}{\sum_{k=1}^{n_b}\sum_{t=1}^{300}(\dot{m}_{CO2} \times \Delta t)} \times FCL$$

$e_{sos\ a,b}$ = emissions ($\frac{g}{hp-hr}$)

a = criteria pollutant (NMHC, CO, NOx, and PM)

b = refers to low load, med/high or Otto Bin

$\dot{m}_a$ = mass emission rate of criteria pollutant emitted per second ($\frac{g}{s}$)

$\dot{m}_{CO2}$= mass emission rate of CO2 emitted per second ($\frac{g}{s}$)

Δt = data sampling rate (1 Hz)

*FCL $\approx$ FTP chassis test cycle ($\frac{CO2\ g}{hp-hr}$)

Calculating Emissions for Idle Bin

$$e_{sos\ a,idle} = \frac{\sum_{k=1}^{n_{idle}}\sum_{t=1}^{300}(\dot{m}_a \times \Delta t)}{\sum_{k=1}^{n_{idle}}\sum_{t=1}^{300}(\Delta t)} \times \frac{3{,}600 sec}{1 hr}$$

$e_{sos\ a,idle}$ = idle emissions for the pollutant ($\frac{g}{hr}$)

a = criteria pollutant

n_{idle} = number of windows in the idle bin

$\dot{m}_a$ = mass emission rate of pollutant emitted per second ($\frac{g}{s}$)

Δt = data sampling rate (1 Hz)

Calculating FCL Alternate Value for Chassis Certified MDVs

To Calculate Work on the FTP Chassis test cycle, the following equation was used:

$$\sum \frac{speed(rpm) \times Torque(lb-ft)}{5252} \times \Delta t \times \frac{hr}{3600\ sec} = hp-hr$$

Speed (rpm) = Engine Speed from FTP OBD data

Torque (lb-ft) = Calculated Load (OBD) × Max Torque at RPM (data from the manufacturer)

Δt = OBD sampling rate (1 Hz)

The CO2 is measured from the FTP chassis test cycle, then divided by the total work (hp-hr) produced on the FTP chassis test cycle.

$$\frac{FTP\ CO2\ g}{hp-hr} \approx FCL$$

III. 3 Bin MAW In-use Standards

Bin	Percent Engine Load	Emission In-use Threshold
Idle	≤ 6% Engine Load	$e_{sos\ a,idle}$≤ CF x idle standard
Low	> 6% and ≤ 20% Engine Load	$e_{sos\ a,Low}$≤ CF x LLC standard
Medium/High	> 20% Engine Load	$e_{sos\ a,MedHigh}$ ≤ CF x FTP/RMC standard
Otto Bin	0-100 % Engine Load	$e_{sos\ a}$ ≤ CF x FTP standard

- The equations for the standards are those adopted by the HD Omnibus rulemaking. The conformity factor (CF) for 2024-2029 model year would be equal to 2.0 and the 2030 subsequent model year CF is equal to 1.5. The CF is from the 15 day changes for the

HD Omnibus rulemaking and is still under review at this time May 2021.

IV. Exemptions and Requirements

The following are exemptions and requirements from Appendix B-1 and B-2 for Proposed Amendments to the Diesel Test Procedures and Otto Test Procedures which were adopted by the HD Omnibus rulemaking. This section also includes the exemptions and requirements in the proposed 15 day changes that are still under review and may change after the time of May 2021.

This section includes some of the exemptions and requirements but may not show all of them in this handout.

Data Collected during any of the following conditions shall be considered Invalid Data:

- Zero drift check or conditioning of the Portable Emissions Measurement System (PEMS) instrumentation
- Atmospheric pressure less than 82.5 kPa
- Ambient air temperature less than 19 deg. F (-7 deg. C)
- Altitudes greater than 5,500 feet above sea-level; or
- Altitudes less than or equal to 5,500 feet above sea level, for temperatures greater than the temperature determined by the following equation at the specified altitude
- Ambient Air Temperature threshold (equation not shown here)
- Vehicle operation during indicated manual active regeneration and automatic active regeneration
- Vehicle operation where the engine is shut-off or keyed off while the engine rpm is equivalent to zero

Valid Test:

The following section includes some of the exemptions and requirements but may not show all of them in this handout.

- Emissions sampling (NMHC, CO, NOx, PM and CO2), exhaust flowrate parameters, and sampling of relevant OBD parameters, and ambient temperature and humidity shall commence prior to starting the engine. The coolant temperature shall not exceed 86 deg. F (30 deg. C) at the start of the test. If the ambient temperature and the coolant temperature exceeds 86 deg. F (30 deg. C) at the start of the test, the test is void and testing shall be rescheduled.

- Vehicle Pass criteria is determined by comparing criteria emission to the In-Use Threshold, defined in section III

- Each bin (idle, low, and medium/high) will be required to accumulate 2,400 valid windows. If the minimum valid window requirements per bin is not met on the first day of testing, continue testing for additional shift-days until the valid window requirement is met for each bin.

V. References:

1. Appendix B-1 Proposed Amendments to the Diesel Test Procedures “CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 2004 AND SUBSEQUENT MODEL HEAVY-DUTY DIESEL ENGINES AND VEHICLES”, Date of Hearing: August 27, 2020
2. Appendix B-2 Proposed Amendments to the Otto-Cycle Test Procedures “CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 2004 AND SUBSEQUENT MODEL HEAVY-DUTY OTTO-CYCLE ENGINES AND VEHICLES”, Date of Hearing: August 27, 2020
3. Proposed 15 Day Changes to Appendix B-1 Diesel Test Procedures “CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 2004 AND SUBSEQUENT MODEL HEAVY-DUTY DIESEL ENGINES AND VEHICLES” (under review)
4. Proposed 15 Day Changes to Appendix B-2 Proposed Amendments to the Otto-Cycle Test Procedures “CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 2004 AND SUBSEQUENT MODEL HEAVY-DUTY OTTO-CYCLE ENGINES AND VEHICLES” (under review)