ATTACHMENT D

Production Line Testing
Cumulative Sum Procedure

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The staff proposes that compliance of production engines be determined through the Cumulative Sum procedure used by ARB and the U.S. EPA for small off-road engines. This attachment describes the proposed procedure.

The Cumulative Sum procedure replicates the statistical foundation of the federal Selective Enforcement Audit program, while providing greater opportunity for a quick decision, thus minimizing the manufacturer's possible testing burden, particularly for those engine families that consistently meet the emission standards by a wide margin.

The proposed procedure is identical to that which the Board approved in March 1998 for 2000 and later model-year small off-road engines. The maximum number of tests per engine family per year under the proposal would be thirty, but the program offers the prospect of concluding testing earlier if the results are consistent and below the emission standards; this should be compared to the current quality-audit programs for other mobile sources, which require testing one percent of production (other off-road categories) or two percent of production (on-road categories). Overall, staff believes that the Cumulative Sum procedure will minimize the testing burden on manufacturers, and provide greater consistency with the U.S. EPA.

Description:

The emission standards, exhaust sampling and analytical procedures are those described in the Emission Standards and Test Procedures for certification.

At the start of each quarter for the model year, the engine manufacturer would begin randomly selecting engines from each engine family at the end of the assembly line; the engines must be representative of the engine manufacturer's California sales. The manufacturer would submit its procedure for randomly selecting engines to the Executive Officer prior to the start of production for the first year of production.

Required Sample Size Equation: The number N indicates the number of tests required for the model year for an engine family. For newly certified engine families, the manufacturer would calculate the required sample size for the model year according to the equation below, after the first two engines are tested. For carry-over engine families, the manufacturer would combine

the first test of the model year with the last test result from the previous model year and then calculate the required sample size, N, for the model year.

$$N = \left[\frac{(t_{95} \times \sigma)}{(x - STD)}\right]^2 + 1$$

Where:

N = required sample size for the model year.

t_{95} = 95% confidence coefficient. It is dependent on the number of tests completed, n, as specified in Table D-1. It defines one-tail, 95% confidence intervals.

σ = test sample standard deviation calculated from the following equation:

$$\sigma = \sqrt{\frac{\sum (X_i - x)^2}{n - 1}}$$

and where:

X_i = emission test result for an individual engine

x = mean of emission test results of the sample

STD = emission standard

n = The number of tests completed in an engine family

A manufacturer would be required to distribute the testing of the remaining number of engines needed to meet the required sample size N, evenly throughout the remainder of the model year. After each new test, N would be recalculated using updated sample means, sample standard deviations and the appropriate 95% confidence coefficient. A manufacturer would have to continue testing and updating each engine family's sample size calculations until a decision is made to stop testing or the engine family fails.

Regardless of whether the conditions of sample size have been met, the engine manufacturer must perform a minimum of two (2) tests per engine family per quarter of production. The maximum required sample size for an engine family is thirty tests per model year.

Table D-1
Number of Tests (n) & 1-tail Confidence Coefficients (t_{95})

n	t_{95}	n	t_{95}	n	t_{95}
2	6.31	12	1.80	22	1.72
3	2.92	13	1.78	23	1.72
4	2.35	14	1.77	24	1.71
5	2.13	15	1.76	25	1.71
6	2.02	16	1.75	26	1.71
7	1.94	17	1.75	27	1.71
8	1.90	18	1.74	28	1.70
9	1.86	19	1.73	29	1.70
10	1.83	20	1.73	30	1.70
11	1.81	21	1.72	∞	1.645

Cumulative Sum Equation: A manufacturer would also construct the following Cumulative Sum equation for each regulated pollutant for each engine family.

$$C_i = \max[0\ 0R\ (C_{i-1} + X_i - (STD + F))]$$

Where:

C_i = The current Cumulative Sum statistic

C_{i-1} = The previous Cumulative Sum statistic. Prior to any testing, the Cumulative Sum statistic = 0 (i.e. $C_0 = 0$)

X_i = The current emission test result for an individual engine

STD = Emission standard

F = $0.25 \times \sigma$

After each test, manufacturers would update the Cumulative

Sum statistic, C_i, and compare it to the action limit, H, which is the sample standard deviation multiplied by five. Note that the sample standard deviation (and hence, the action limit) would also be recalculated after each test. If $C_i > H$ for two consecutive tests, the engine family would fail.

All results from the previous quarters of the same model year would be included in the on-going analysis, provided that the engine family has not failed (e.g., if three engines of a family were tested in the first quarter, the first test of the second quarter would be considered as the fourth test).