APPENDIX B

ENGINE-OUT NO_2 EMISSIONS

Appendix B. Engine-out NO_2 Emissions

1. Emissions Data

Emissions of nitrogen dioxide (NO_2) from diesel engines are not well characterized. Staff has, nevertheless, gathered what it believes to be a sufficient amount of data for the purposes of this rulemaking. The data come primarily from demonstration programs, mining engine certification data, and applications for verification of diesel emission control systems. In total, staff has gathered NO_2 emissions data from 80 distinct engines operated over various emissions test cycles, including a range of engine makes used in different applications. The data set includes 40 on-road engines, 31 off-road engines, and 9 stationary engines. Emission rates of NO_2 were not determined via direct measurement, but rather estimated by subtracting the measured NO from the total measured NOx (both of which were measured using chemiluminescence analyzers). Figure B-1 shows NO_2 emissions in terms of percent of total NOx emissions by mass. Figure B-2 shows the distribution of NO_2 fractions.

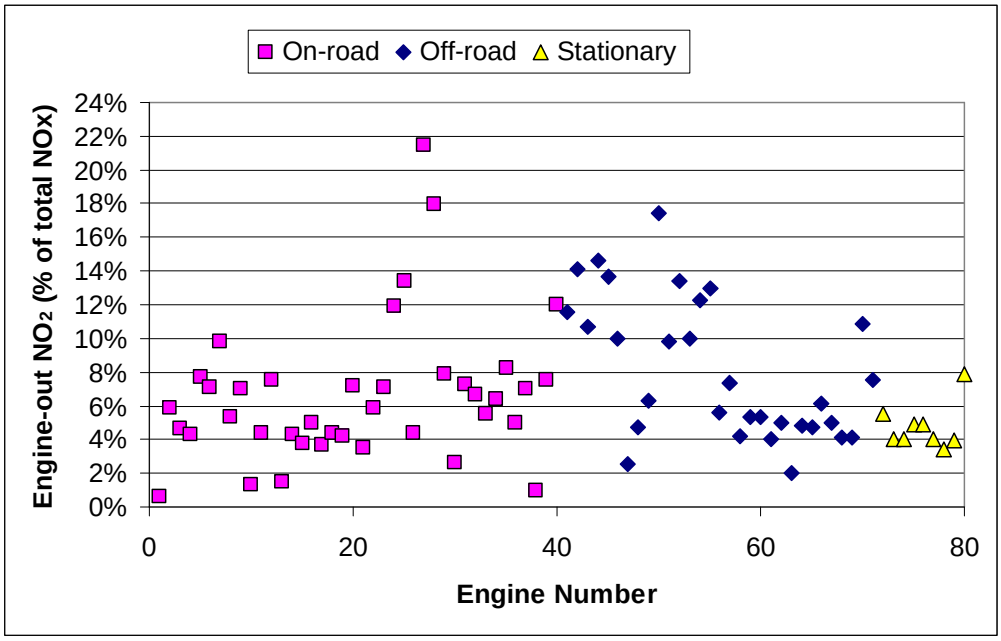

Figure B-1. Engine-out NO_2 data for 80 diesel engines

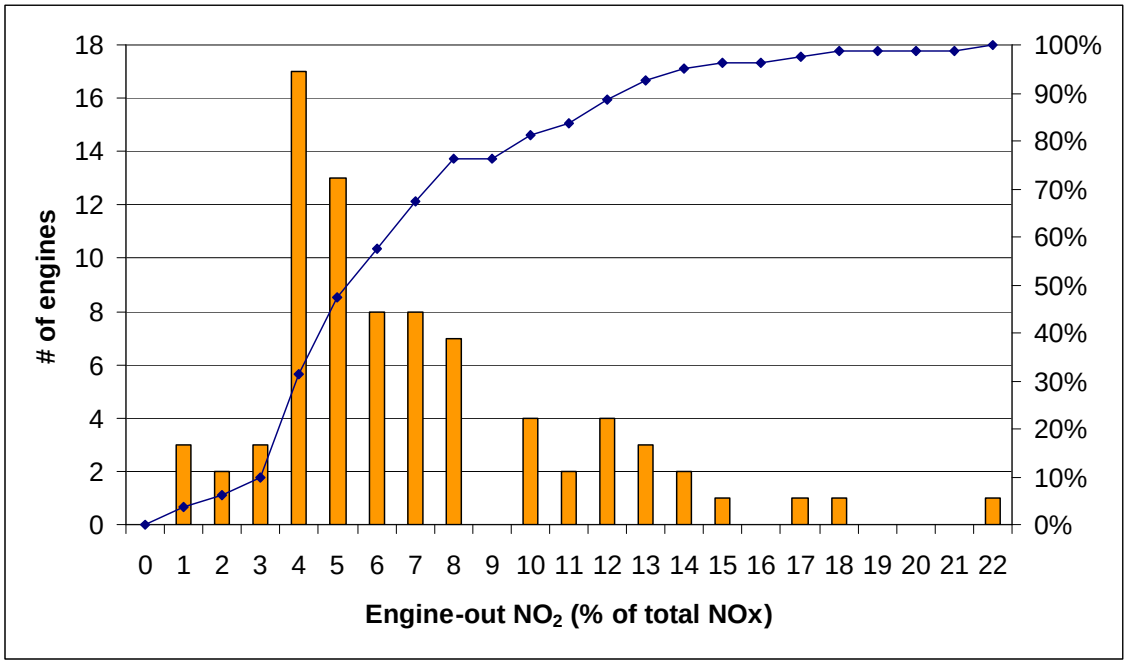

Figure B-2. Population distribution for 80 diesel engines based on engine-out NO_2

The average engine-out NO_2 emission level for all of the engines is 6.9 percent with a standard deviation of 4.1 percent. About 80 percent of the engines have NO_2 emissions less than or equal to 10 percent of total NOx emissions, and two-thirds are between 4 and 8 percent. About 96 percent are less than or equal to 15 percent, which is two standard deviations from the mean (only three engines exceed 15 percent NO_2).

2. Test Engine NO_2 Emissions Limit

While casting the NO_2 limit in terms of a maximum incremental increase helps to isolate the effect of an emission control system on NO_2 emissions, there is still the possibility of obscuring this effect depending on the choice of test engine. If a test engine has unusually high baseline NO_2 emissions, it is conceivable that an emission control system could increase the NO_2 fraction by a smaller increment than if the baseline NO_2 level had been lower, all other variables being equal (such as residence time, temperature, soot loading, etc). With a higher initial concentration of NO_2 (the reaction product) and a lower initial concentration of NO (one of the reactants), a lower overall oxidation rate of NO could result. As a result, testing a single engine with high NO_2 may not reveal the effect of a system on more typical diesel engines.

Staff proposes, therefore, that the test engine's NO_2 emission level serve as one of the criteria by which a given test engine is approved for verification testing. Specifically, staff proposes that the test engine must not have engine-out NO_2 emissions that exceed 15 percent of the total NOx emissions by mass, as measured over the emissions test cycle. Staff arrived at the value 15 percent by adding two standard deviations to the

mean value of 7 percent. Based on the dataset presented here, a cut-off at 15 percent would exclude only a small number of engines with uncharacteristically high NO_2 emissions. If there is a special category of engines with NO_2 emission levels that normally exceed 15 percent, staff proposes that ARB be able to adjust the test engine NO_2 requirement for those engines at its discretion.