Final Report

Humidity and Temperature Effects on On-road and Off-road Emissions and Ozone Formation (HARC Project H8B)

Prepared for

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1. INTRODUCTION

The effect of ambient humidity and temperature on the performance and emissions from internal combustion engines, including spark-ignition (SI) engines (gasoline, LPG and natural gas engines) and compression ignition (CI) or diesel engines, has been known for many years. The historical data indicate that higher humidity results in lower NOx emissions. Likewise, higher temperatures have historically been associated with higher emissions except during the cold start for light-duty vehicles when emission control devices and other engine controls may not function properly. Once the engine has warmed up though, higher temperatures result in higher NOx emissions.

The effect of humidity and temperature has been included in nearly all emission measurement methods calculations whether tested in the laboratory or in the field. The codified humidity and temperature corrections for NOx emissions from gasoline and diesel fueled engines are described in the U.S. Code of Federal Regulations (CFR) 86-345-79 and reprised in the International Standard ISO 8178-1 used to correct the available field measurements of commercial marine engines.

Emission inventories, however, have not accounted for humidity and temperature adjustments except for light-duty on-road vehicle emissions estimates in MOBILE6, and that adjustment primarily includes the effect of ambient conditions on air conditioning loads on the engine. The effect of temperature and humidity has not been included in the emission models, MOBILE6 for heavy-duty vehicles and NONROAD for off-road equipment, or for locomotive or commercial marine engine emissions even though the emission data used in the development of emission factors have been adjusted for temperature and humidity using the official adjustment equations in the CFR.

The technical approach of this work was to define the effect of ambient conditions on NOx emissions for on-road vehicles and off-road engines or equipment. This effect was then used to adjust the emission estimates for the Houston-Galveston nonattainment area (HGA) on the portion of the emission inventory consistent with the engine technology by the hourly and spatial ambient temperature and humidity conditions.

While the emissions adjustments described in this work may be considered significant, with a daily 5 to 10% change in NOx emissions for heavy-duty on-road vehicles and off-road equipment, the overall change in emissions was not large in absolute terms compared with all sources in the region. Likewise, the change in the predicted ozone is small both in the year 2000 base case and the 2007 future year projections.

Section 2 describes the review, development, and use of the ambient humidity and temperature emission adjustments used in this work. This section refers to the literature review and engineering analysis performed by Southwest Research Institute provided as complete reports in Appendices A and B. Section 3 describes the effect the adjustments have on predicted ambient ozone levels in 2007 and ozone model performance in 2000.

4. CONCLUSIONS

Texas has led the way in improved air quality evaluation and modeling by developing several innovative techniques and evaluations. One of the more important considerations is to accurately estimate emissions temporally and spatially. This is important not just to improve the predicted air quality but also to focus control strategies on the most effective and cost-effective emission sources. Heavy-duty vehicles and off-road equipment have become increasingly important emission sources categories because light-duty vehicles and stationary source emissions have experienced more control efforts. This work developed methods to incorporate ambient humidity and temperature effects (spatially and temporally) on the estimated NOx emissions from on-road heavy-duty vehicles and off-road engines for the Houston-Galveston nonattainment area (HGA).

The conclusion reached in this work is that humidity and temperature corrections to the NOx emissions rates from internal combustion engines should be included in the modeled emission inventory. ENVIRON provided TCEQ as part of this work a new software tool called CNTRLHR to use in adjusting the modeled emission inventory by hour of day. The adjustment described in this work did not significantly change ozone model performance for the year 2000 base case for HGA. The effects of the adjustment on future year 2007 modeled ozone levels were less than modeled for 2000 because the baseline mobile source NOx emissions are less in 2007.

The effect of ambient humidity and temperature corrections has been included in all reported emission measurements used in developing emission models and estimates. The historical data and scientific understanding indicates that higher humidity results resulting in lower NOx emissions from internal combustion engines used in on-road vehicles and off-road equipment, and higher temperature increases NOx emissions from engines without aftertreatment devices and after those with aftertreatment devices have reached their operating temperature. Except for light-duty on-road vehicle emissions estimates, EPA has not included these ambient condition adjustments to NOx emission rates of on-road heavy-duty vehicles and off-road equipment.

The NOx adjustments for the ambient conditions were applied to the emission inventory of the HGA for on-road heavy-duty and off-road equipment. Because the modeling in this work was performed for a relatively humid area, overall NOx emission decreases were predicted, more significant decreases in night and early morning and less significant decreases and some increases in midday. Though HGA is a region generally considered very humid, the NOx emission reductions were less than 10% of affected sources, and the overall change emissions was less significant when considering all sources in the region. A drier region that reaches similar or higher daily temperature may be predicted to have higher NOx emissions than models currently predict.

The results of the CAMx ozone modeling for HGA revealed several conclusions for the base year case of 2000 and the future attainment year of 2007. The ambient humidity and temperature adjustments caused both increases and decreases in maximum 1-hour ozone levels for year 2000 depending upon day and location. Ozone increases occurred in areas where ozone levels were VOC-limited. The adjustment did not significantly change ozone model performance for the year 2000 base case. Because the effect of the adjustments on model performance was small the ozone modeling should no be used to decide whether or not the adjustment is “correct”.

The 2007 ozone modeling shows both increases and decreases in maximum 1-hour ozone levels due to the NOx adjustment, as for 2000. The increases in daily maximum ozone in 2007 were smaller than in 2000, indicating a shift toward more NOx-limited conditions in 2007 relative to 2000.