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16. Abstract The objective of this document is to present the preliminary findings of the study examining the effects of using PuriNOx on the emissions, performance, and operations of TxDOT's diesel vehicles and equipment. This document briefly summarizes the available literature regarding emulsified diesel fuels, presents the preliminary findings of the effects on performance and operations, discusses other areas of concern, and summarizes the analysis still to be performed. All of the project's principle tasks are still ongoing, and have not yielded sufficient data to make any assessments or recommendations.			
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Emulsified Diesel Emission Testing, Performance Evaluation, and Operational Assessment

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1. Introduction

The Texas Department of Transportation (TxDOT) is currently using an emulsified diesel fuel in its on-road and non-road diesel equipment in eight of Texas's non-attainment counties. The specific fuel being used is manufactured by Lubrizol and called PuriNOx. The summer grade of PuriNOx consists of 20% water, 77% diesel fuel, and 3% additive package. The winter grade of PuriNOx includes some methanol to improve cold weather performance.

A simultaneous study is being performed to examine the effects of using PuriNOx on the emissions, performance, and operations of TxDOT's diesel vehicles and equipment. The research team consists of researchers from three areas within The University of Texas at Austin plus Eastern Research Group (Austin) and Southwest Research Institute (San Antonio). The project began with a review of the available literature regarding emulsified diesel fuels. This review is briefly summarized in Section 2. The project can be divided into three categories: 1) assessment of the effects on performance (including emissions and fuel economy), 2) examination of the effects on TxDOT operations and maintenance, and 3) other areas of concern. The current status of each of these is discussed in Section 3. A brief summary of the analyses to be performed is included in Section 4. All of the project's principle tasks are still ongoing, and have not yet yielded sufficient data to make any assessments or recommendations.

2. Summary of Literature Review

As a liquid, summer-grade PuriNOx does not appear to pose health or safety risks that are greater than conventional diesel fuel. The methanol in winter-grade PuriNOx does pose some additional risks. The Material Safety Data Sheets for diesel fuel and for summer-grade PuriNOx note that exposure to high concentrations of the vapors from the liquid fuels "may cause headaches, dizziness, fatigue, nausea, vomiting, drowsiness, stupor, other central nervous system effects leading to visual impairment, respiratory failure, unconsciousness and death". Although the symptoms are the same, we recommend additional study of the thresholds of exposure to the fuel vapors that may lead to health risks. A TxDOT supported study of the health risks associated with exposure to the exhaust gases from equipment fueled with PuriNOx is on-going, but prior studies indicate that the exhaust poses a significant risk.

The available literature on emulsified diesel fuels presents a lot of conflicting data. It is obvious that the results from using emulsified diesel fuels depend upon the engine, the test cycle, the baseline diesel fuel used for comparison, whether or not the baseline diesel fuel was blended to make the emulsion, and the properties of the diesel fuel in the emulsion. Emissions comparisons between emulsified and conventional diesel fuels—either using engine dyno tests or vehicle tests—are complicated by the torque loss due to the water in the emulsion.

However, some things are known with relative certainty. Emulsified diesel fuel always provides emissions benefits in terms of the oxides of nitrogen (NOx) and particulate matter (PM) when tested over any cycle. The magnitude of the advantage depends upon the engine, the operating conditions, the properties of the baseline diesel fuel, and the properties of the diesel fuel that is blended into the emulsion. The NOx benefit is typically 15–20% but even better for some tests and not so strong for others. The PM benefit is typically 40–50% but, again, even better for some tests and not so strong for others. The PM advantage should be especially engine dependent, and may not be as strong for modern engines that have extremely high injection pressures. However, from the perspective of the State Implementation Plan, Texas is predominately interested in NOx. The NOx benefit of emulsions is not nearly as strong as their effect on PM. Some data suggest that the NOx benefit is most pronounced at low speeds and loads while other data shows the opposite. Thus, data are required for the various engines in the

TxDOT fleet—under operating conditions that simulate their actual use—to assess the NOx emissions benefits of PuriNOx.

It is also known that emulsions offer a benefit in terms of thermal efficiency. However, although diesel fuel consumption decreases, overall fuel consumption increases, and PuriNOx is more expensive than diesel fuel at the present time. This means that the NOx benefit, once quantified for the TxDOT fleet, must be weighed against the increased operating cost. The effects of the torque loss on operations must also be weighed in decisions whether to adopt emulsified diesel fuels.

The available data indicates that emulsified diesel fuels provide benefits in terms of lubricity, injector deposits, and piston ring and cylinder liner wear. However, concern remains over the durability of fuel injectors, and possibly fuel pumps, especially for engines that use very high fuel injection pressures. Additional study of this issue is recommended.

3. The Current Project

As noted above, the present project may be divided into three categories: 1) assessment of the effects on performance (including emissions and fuel economy), 2) examination of the effects on TxDOT operations and maintenance, and 3) other areas of concern. The current status of each of these is discussed in the following subsections.

3.1 Emissions, Fuel Economy, and Performance Testing

Three categories of diesel equipment are being subjected to performance assessments: dump trucks, engines used in off-highway equipment, and small diesel engines, as discussed below.

3.1.1 Single Axle and Tandem Axle Dump Trucks

The US Environmental Protection Agency (EPA) has a standard method for measuring the emissions and fuel economy of on-road heavy duty engines. The EPA chose to test the engines independent of the vehicle because, in general, one can purchase a truck and select from a variety of engines—from a variety of engine manufacturers—at the time of purchase. Thus, the engine becomes EPA certified rather than the entire vehicle, as is done for light-duty vehicles. However, there is no assurance that the standardized "cycle" over which EPA tests heavy-duty engines adequately reflects the way TxDOT operates its equipment. Therefore, the first task was to develop TxDOT-specific driving cycles for both single axle and tandem axle dump trucks.

Eastern Research Group (ERG) developed the required driving cycles by, first, logging data on TxDOT dump trucks as they were being used in normal service and, then, using standard techniques to extract representative "microtrips" from the logged data. Each microtrip starts with an idle followed by acceleration, cruise, and deceleration back to idle. Representative microtrips were then combined into a driving cycle that is about 20 minutes in duration. This resulted in the TxDOT Single Axle 6-Yard Dump Truck Cycle and the TxDOT Tandem Axle 10-Yard Dump Truck Cycle. Both cycles are specifications of vehicle speed as a function of time, on a second-by-second basis.

Southwest Research Institute (SwRI) will test four single axle dump trucks and four tandem axle dump trucks selected from the TxDOT fleet. The dump trucks to be tested are listed below:

Single Axle Dump Trucks

- 1997 International with a T444E engine (electronic injection)
- 1999 GMC TC7H042 with a CAT 3126B (electronic injection)
- 1993 International 4900 with an International 7.6T-I6 (mechanical injection)
- 1996–97 Ford 5.9L (mechanical injection)

Tandem Axle Dump Trucks

- 2000 Volvo WG64F with a Cummins ISM (electronic injection)
- 2000 International 2574 with a Cat C10 (electronic injection)
- 1990 Cummins L10-300 (mechanical injection)
- 1996 CAT 3176 (electronic injection)

Each of the eight dump trucks will be tested on a heavy-duty chassis dynamometer at SwRI. The four tandem axle dump trucks will be tested first, beginning October 28th. The measurements will include both emissions and fuel economy, for PuriNOx compared to #2D on-road diesel fuel. The PuriNOx to be used was blended from the #2D diesel that will be used for comparison. For all the dump trucks, the emissions to be measured will include NOx, PM, hydrocarbons (HC), and carbon monoxide (CO). One of the dump trucks will be subjected to additional emissions testing, including nitrates, sulfates, the soluble organic fraction (SOF) of the PM, and hydrocarbon "speciation". Speciation provides a detailed breakdown of the hydrocarbon emissions, including species that EPA has identified as "exhaust toxics", such as formaldehyde, and species that are on the California Air Resources Board (CARB) list of Toxic Air Contaminants.

3.1.2 Diesel Engines Used in Off-Road Equipment

The first task was to select a type of off-road equipment from the TxDOT fleet that is important from the air quality perspective. From the TxDOT equipment records for the

past year, it was determined that approximately 26% of the diesel fuel used in TxDOT's off-road equipment in Texas's 12 non-attainment counties was consumed by Gradalls. Therefore, we decided to test two Gradall engines and generate a TxDOT-specific Telescoping Boom Excavator Cycle. However, representatives from the Association of General Contractors (AGC) noted that they do not use telescoping boom excavators but, instead, use loaders.

ERG generated both a TxDOT Telescoping Boom Excavator Cycle from data that was logged on a Gradall and an AGC Wheeled Loader Cycle from data that was logged on a wheeled loader. Because the engines in these pieces of equipment perform work without associated miles, these cycles are specifications of engine torque and rpm each second for microtrips that represent both driving and stationary work. These tests will be performed on an engine dynamometer rather than a chassis dyno. Engines from the off-road equipment will be extracted and then mounted on an engine dynamometer at SwRI. The following engines will be tested:

- 2001 Cummins ISB-190 (electronic)—EPA is doing additional tests on this engine
- 1997 Cummins 6BTA5.9 (mechanical)

As with the on-road vehicles, the off-road heavy-duty engines are to be tested for emissions and fuel consumption. Again, emissions will include NOx, PM, HCs, and CO. The ISB-190 will be subjected to additional tests for nitrates, sulfates, SOF, and speciation. The EPA has already paid for an extensive speciation for this same engine operating on diesel fuel over one of EPA's non-road cycles. Three fuels will be compared for the off-road engines: PuriNOx, #2D on-road diesel fuel, and #2D off-road diesel fuel. TxDOT always uses on-road diesel fuel, even for their off-road equipment. However, in some regions of Texas some of the TxDOT contractors use off-road diesel fuel. The PuriNOx to be used for these tests was blended from the #2D on-road diesel fuel that will also be used in pure form as one of the three fuels. The full load torque curves for both engines using all three fuels will be measured. The SwRI began testing the ISB-190 engine October 15th.

3.1.3 Small Diesel Engines

TxDOT uses a variety of small diesel engines for their traffic alerting signals, herbicide sprayers, etc. Therefore, in addition to the heavy equipment testing at SwRI, a 10 hp diesel engine, used in herbicide sprayers, is undergoing testing at UT. Steady-state emissions and fuel consumption will be evaluated over a range of engine speeds and loads with both winter and summer grades of PuriNOx, and compared with operation on #2D on-road diesel fuel. The full load torque curves for these three fuels will also be compared. The engine has been installed in the engine test cell. It has been attached to an engine dynamometer and instrumented to measure speed, torque output, fuel consumption, and emissions. Baseline performance testing is currently being conducted on #2D diesel fuel.

3.2 Effects on Operations and Maintenance

The effects of using PuriNOx on TxDOT's operations and maintenance will be evaluated via:

- interviews of TxDOT PuriNOx users in the Houston district,
- double-blind operator interviews after completion of staged activities ("Roadeo"),
- data logged during the "Roadeo",
- interviews with maintenance personnel in the Houston district, and
- interviews with agencies and organizations that have verified, tested or are currently using PuriNOx.
- Each of these aspects of the study is briefly discussed below.

3.2.1 Houston Operator Interviews

The objectives of surveying PuriNOx users in Houston are to determine what the performance effects or issues associated with the use of PuriNOx fueled vehicles/equipment are, and in which kinds of vehicles/equipment, if any, the use of PuriNOx is deemed problematic. The initial round of operator surveys was conducted at four sites in West Harris, North Harris, Montgomery, and Fort Bend during late August and early September. CTR personnel, with extensive experience in heavy equipment operations, surveyed 44 drivers/operators. The response was almost uniformly negative,

although the intensity of the responses varied depending on the criteria tested. For example, 93% of the respondents stated a reduction in the power of their vehicles/equipment. Furthermore, statistical analysis shows at a 99% confidence level that the mean response of the population would be 4.33 on a scale of 1 to 5 (with 1 being disagree and 5 being agree with the statement that the power of the vehicle/equipment reduced due to the use of PuriNOx). In addition, the drivers/operators raised the following specific concerns about using PuriNOx:

- a 10 to 15% loss of power,
- acceleration problems, particularly that operators felt unsafe when required to merge onto the freeway,
- different required shift points,
- slower hydraulic movement,
- difficulty starting vehicles/equipment in the morning,
- excessive pollution if vehicles/equipment are started only once a week,
- maximum speed which can be reached is 55 miles/hour, which impacts traffic,
- uses more fuel,
- dies when idling (e.g., when stopping at traffic lights),
- smells bad, and
- noisy.

A second round of surveys will be conducted in late November to test whether these negative perceptions decrease once the operators become more familiar and gained more experience with PuriNOx.

3.2.2 "Roadeo"

A representative of Ramos Oil Company, the vendor for PuriNOx in Northern California and a PuriNOx user, claimed that drivers/operators do not object to the use of PuriNOx until they are told that it contains water. The objective of the double-blind operator assessment is thus to determine if drivers/operators, who have never been exposed

to the PuriNOx fuel, can perceive a difference in field performance when neither the operators nor the surveyors know what fuel is being used.

To generate the double-blind assessment of operator perceptions regarding the use of PuriNOx relative to conventional diesel fuels, a "Roadeo" has been scheduled for November 13–14 at three Houston sites. Volunteer TxDOT drivers/operators from outside the Houston districts in which PuriNOx is currently used, will be asked to perform specific tasks with a given type of equipment. The research team, together with the Houston district, has designed a series of "Roadeo" events, which aims to assess the concerns raised by the Houston PuriNOx users. The following equipment has been selected for this analysis:

- 2001 telescoping cranes/bucket trucks (Telelect with Cummins ISB engines)
- 2002 telescoping boom excavators (Gradalls with Cummins ISB-190 engines)
- 1995 loaders (FiatAllis with FiatAllis 8045T engines)
- 1999 single axle 6-yard dump trucks (GMC with Caterpillar 3126B engines)
- 1998 tandem axle 10-yard dump trucks (International with Caterpillar C10 engines)
- 1993 forklifts (Caterpillar with Caterpillar XD3P engines)

Three pieces of equipment of each type will be tested, some of which will be fueled with PuriNOx, and others with diesel fuel. To ensure a complete double-blind test in which neither the operators nor the UT researchers will know which fuel is being used in which vehicle/equipment, Houston TxDOT employees will fuel the vehicles/equipment in advance. Each operator will perform the specific event with all three pieces of identical equipment. Upon completing the specific event, the driver/operator will be asked to rank the performance of the various vehicles/equipment in terms of certain performance criteria, including power, acceleration, idling, required shift points, hydraulic movements, engine noise, etc. To ensure that the events are undertaken in a safe manner and in an effort to control the test, TxDOT observers with no previous PuriNOx exposure will be asked to accompany the drivers/operators during the events. The observers will be tasked to note any events that might bias or influence the results obtained, for example, slow traffic and any unusual driver behavior, such as frustration.

As a quantitative check on these perceptions, the equipment will be data logged to objectively assess the differences in performance. The research team and Project Director are finalizing the logistical arrangements to obtain equipment, operators, and observers, as well as defining the explicit tasks for each type of equipment.

3.2.3 Houston Maintenance Personnel Interviews

The objectives of these interviews are to assess changes made to PuriNOx-fueled vehicles/equipment and to assess additional maintenance requirements. The approach involves surveying mechanics and technicians in the Houston District overseeing outsourcing of work orders, and the mechanics at each of the surveyed sites when available. The first round of these surveys was completed in August and September. Four mechanics were surveyed. The maintenance personnel raised the following concerns:

- the increase in maintenance expenditure (e.g., fuel filters) required to switch to PuriNOx,
- clogging of fuel injectors,
- a need to start the vehicles/equipment at least twice each week when not used, and
- ether/starting fluid is required when the vehicle has not been started for a week.

According to one of the mechanics, a number of operators have asked for their equipment to be re-powered, but apart from an adjustment to the fuel injection of an air compressor so that it would idle on PuriNOx, no changes have been made to any vehicle/equipment. The International T444E bucket trucks were, however, converted back to diesel because they could not perform their operations safely with the PuriNOx torque loss. These 5 trucks were underpowered when using diesel fuel, and the torque loss with PuriNOx resulted in inability to cruise at more than 45 mph or to climb grades. Similarly, one Dragline (with a DDC Series 71 2-stroke engine) and one Moog bridge inspection truck (with a Caterpillar engine) were converted back to diesel due to poor performance. Furthermore, the bridge inspection truck is sometimes used outside of the Houston District, where it cannot obtain PuriNOx. In addition, specific concerns were expressed about the use of PuriNOx in the single cylinder diesels used in herbicide sprayers and traffic alerting

signals. These engines are not used very often. For some, restarting was extremely difficult and the engines were unstable once started. Two traffic alerting signal engines and 3 of the older herbicide sprayer engines were converted back to diesel. Finally, 41 vehicles with the 6.5 liter GM diesel engine were never converted because they use an optical sensor to detect water contamination of the fuel, and these sensors are not compatible with PuriNOx. A total of 383 pieces of equipment/vehicles are operating on PuriNOx in the Houston District.

3.2.4 Additional PuriNOx User Interviews

During the first two months of this project, a number of agencies, companies, and institutions were identified that either verified emissions reductions associated with PuriNOx (e.g., the California Air Resources Board), tested (e.g., the City of Houston) or are currently using PuriNOx (e.g., the Port of Houston). In addition, engine manufacturers looking into the use of PuriNOx in their engines (e.g., Cummins, Inc) and diesel emulsified vendors (e.g., Ramos Oil Company) were identified. Personnel (representatives) from these agencies, companies, and institutions are currently being interviewed to learn from their experiences with PuriNOx and to determine their impressions concerning its use in their equipment. The goal is to document their experiences concerning:

- equipment adaptability,
- fuel economy,
- operational concerns (including power/efficiency loss),
- fuel separation,
- fuel tank corrosion,
- maintenance,
- emissions,
- health effects, and
- cost effectiveness.

The UT Center for Transportation Research is conducting the interviews. Approximately 30 companies and institutions have been identified. The researchers have

conducted a number of these interviews already and are in the process of identifying specific contacts in the remaining cases. Some of the interview findings are highlighted below.

Verification

The California Air Resources Board (CARB) verified that Lubrizol's emulsified diesel fuel (PuriNOx) reduces emissions. Lubrizol funded a test conducted by SwRI in accordance with the CARB protocol on one Detroit Diesel Company engine. The test protocol was submitted to the CARB and based on the test results, a verification letter was provided to Lubrizol. Similarly, Lubrizol provided the British Columbia Ministry of Finance with the emissions test results demonstrated in three studies undertaken by SwRI (the Detroit Diesel engine test results referred to before), Environment Canada and the Millbrook testing facility in England. Based upon the submitted test results, an initial three-year tax exemption is available to PuriNOx users in British Columbia under the General Alternatives Fuels Program. Currently, no one is marketing or using PuriNOx in British Columbia.

PuriNOx Users

Two PuriNOx users have been interviewed, namely Ramos Oil Company, Inc., and the Port of Houston.

Ramos Oil has been using the summer PuriNOx blend for 1-1/2 years in 14 trucks and trailers, ranging from 18-wheeler delivery trucks to smaller package and vacuum trucks. The Port of Houston (POH), on the other hand, tested PuriNOx in various types of equipment and found that, in some instances, performance was affected to the extent that it prevented the use of PuriNOx. The POH has been using PuriNOx successfully for approximately two years in two yard cranes and six yard truck tractors. In both these cases, the representatives regarded their overall experience with PuriNOx to be very positive. Both reported a reduction in fuel economy. The POH reported a 20% increase in fuel usage and Ramos Oil reported a 15% increase in fuel usage. Both representatives also downplayed operator complaints. POH operators complained about power loss only after they became aware of the fact that PuriNOx resulted in a power loss or after they became aware of the fact that there is water in the fuel (Ramos Oil). Both users have never

experienced a case of fuel separation and claim no problems with corrosion and no increased maintenance costs.

PuriNOx Testers

In addition, a number of agencies and companies have tested or are testing PuriNOx fuel in their vehicles/equipment. The research team interviewed a number of operators from agencies and companies that tested PuriNOx, but for various reasons decided not to switch to PuriNOx, including Massachusetts Turnkey Project, Golden Gate Ferries, Teichert Construction, and the City of Houston. Some of the reasons stated for deciding not to switch to PuriNOx include:

- higher fuel costs,
- engine manufacturer's reluctance to endorse the use of diesel emulsified fuels and the associated warranty implications,
- effects on certain engine types,
- infrastructure and logistical implications associated with using another fuel type resulting in one storage tank for gasoline, one tank for diesel, and one tank for PuriNOx,
- fuel separation concerns in vehicles that are not used regularly; and
- equal or superior emissions benefits associated with alternative abatement strategies, such as exhaust aftertreatment technologies.

The City of Sacramento is currently testing (as of October 3, 2002), the summer PuriNOx blend in 20 of their vehicles: 10 side loader refuge trucks and 10 wheel loaders used for picking up garden waste. A final determination as to whether to switch to PuriNOx will be made after conducting the test.

3.3 Other Areas of Concern

In addition to examinations of emissions, fuel economy, performance, operations, and maintenance, other concerns about PuriNOx are also being addressed in this research project. These include: 1) tank corrosion, 2) separation, 3) fuel filters, and 4) durability and safety issues. These aspects of the project are discussed below.

3.3.1 Fuel Storage and Tank Corrosion

PuriNOx fuel is being evaluated for its corrosion potential relative to #2D diesel. These tests have begun at UT, and can be summarized as follows:

- Exposing specimens (strips) cut from 1018 carbon steel (a material used in the manufacture of fuel tanks) to:
  - Winter-grade PuriNOx,
  - Summer-grade PuriNOx, and
  - Standard diesel fuel.
- The fuels are stagnant (not agitated) and the variables are:
  - Time of exposure (times up to one week), and
  - Surface condition of steel (polished and as-received).
- Evaluations will be made based on:
  - Weight loss,
  - Visual examination, and
  - Microscopic examination.
- Evaluations will be used to:
  - Determine the extent of uniform corrosion relative to the standard diesel fuel, and
  - Identify localized forms of corrosion, such as pitting, relative to the standard diesel fuel.

The tests are proceeding. It is, however, too early to make any assessments regarding the relative corrosiveness of the fuels. In addition, it is difficult to thoroughly assess corrosion in a study that is only six months in duration, so a more extensive follow-on study is recommended.

3.3.2 Fuel Separation

Over a period of time, the water and diesel fuel in the emulsion can become layered, with diesel fuel diffusing to the top and water diffusing toward the bottom. Obviously, this

will cause performance problems such as hard starting or complete inability to start the engine. To prevent separation, the stationary storage tanks are recirculated periodically and the equipment is started at least twice per week, even when the equipment is not used. Concerns, however, remain about separation and how various factors might affect it.

The characteristics of the diesel/water separation behavior of the fuel are being studied at UT. Beakers and test tubes containing summer and winter blends of PuriNOx are being stored at three temperatures: 35˚F, 73˚F, and 130˚F. The separation can be observed visually and measurements of specific gravity at three different depths within the beakers are being performed to quantify the degree of separation. After only one week, a visible separation was observable in unagitated samples. Measurements of specific gravity also detected that separation was taking place. The separation was significantly faster at 130˚F than at the lower temperatures. After three weeks, the separation was quite pronounced. At the 130˚F temperature a thick viscous component had settled to the bottom of the containers after three weeks. Test tubes containing PuriNOx will be agitated after different settling times to determine how long the PuriNOx can be left unagitated and still be re-mixed to form a homogenous fuel.

3.3.3 Fuel Filter Tests

Some diesel fuel filters are not compatible with PuriNOx. Lubrizol maintains a list of replacement filters that are compatible. To increase our understanding of this problem, UT will examine the effects of PuriNOx on filters that are known to be incompatible and some that are compatible.

Fuel filters will be soaked in PuriNOx to examine whether this leads to any observable deterioration of the filter materials. Several filters that are considered PuriNOx compatible and several that are considered not to be compatible will be examined. After approximately 3 months of soaking, the filters will be sectioned and examined for deterioration and any accumulation of separated fuel. The filters have been ordered and UT is awaiting their delivery.

3.3.4 Durability and Safety Issues

Two areas of concern are outside the scope of the present project: 1) durability of fuel injectors and fuel pumps, and 2) a potential fire hazard associated with the flash point of winter-grade PuriNOx. Follow-on studies of these issues are recommended.

4. Analyses to Be Performed

The data to be obtained from the tasks discussed in Section 3 will allow assessment of the effects of PuriNOx on performance (emissions, fuel consumption, torque/horsepower loss), maintenance, and operations of TxDOT equipment. In turn, these will contribute data required for an economic analysis and recommendations.

The economic analysis to be performed will involve a cost/benefit analysis. The additional costs associated with PuriNOx compared to conventional diesel fuel include higher fuel prices, additional maintenance, additional infrastructure requirements (e.g. fuel storage tanks), lower fuel economy, etc. The benefit of using PuriNOx is lower emissions of NOx and PM. As indicated earlier, only the NOx benefit is important from the ozone non-attainment perspective. In the proposed economic analysis the cost to achieve, the NOx emissions reductions (dollars-per-ton) will be quantified given available data and compared to the costs of alternative abatement strategies.

Obviously, it is too early in the project to draw any conclusions or make any recommendations.