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Implementation Of Retrofit Program For Diesel Equipment During The Construction Phase The I-95 New Haven Harbor Crossing Improvement Program In Southern Connecticut

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Guido Schattanek
Parsons Brinckerhoff Inc., One Penn Plaza, New York, NY 10119

Donna Weaver
Connecticut Department of Transportation, 2800 Berlin Turnpike, Newington, CT 06131

ABSTRACT

The Connecticut Department of Transportation (DOT) implemented a diesel vehicle emission control program during the construction phase of the I-95 New Haven Harbor Crossing Improvement Program (I-95 NHHC) in Southern Connecticut. The I-95 NHHC project includes the reconstruction of Interstate I-95 from Exit 46 in New Haven to Exit 54 in Branford, and the replacement of the Pearl Harbor Memorial Bridge. Construction of the 7.2-mile corridor started in 2002 and is expected to take more than twelve years to complete.

The I-95 NHHC diesel vehicle emissions control program required that diesel powered construction equipment either retrofit the engine with emission control devises, and/or use clean fuels.

This paper focuses on the results of the program after over 70 pieces of diesel powered construction equipment have been retrofitted with oxidation catalysts during the first three years of construction. It includes: a summary of the development of the emission control specifications and estimated emission reductions and cost; a description of the information process to contractors, the inspection-verification process, and the tracking procedures put in place to ensure continuation of the program as it moved from development to implementation phase. It also covers practical issues such as what contractors do with the emission control devices once the equipment leaves the project.

INTRODUCTION

The need for reducing emissions from heavy-duty diesel engines is clear. The diesel engine has been a workhorse of the 20th century. It is reliable, fuel-efficient, durable, easy to repair, and inexpensive to operate. But diesel engines produce significant levels of particulates (PM) and nitrogen oxides (NOx), mostly when overloaded during acceleration from a stop.

Current estimates indicate that emissions from such engines in the Northeast States account for roughly 33% of the NOx and 80% of the PM emitted by all mobile sources. In addition,

since diesel engines that power construction equipment are more polluting than equivalent diesel engines for normal highway use (due to the lack of any emission controls until 1996), the reduction of these emissions has not only the potential to improve ambient air quality for the region, but more importantly, it has significant air quality benefits to those who live or work in or adjacent to construction areas.

A major step in reducing diesel emissions was taken in May 2004 with the approval of the new U.S. Environmental Protection Agency (EPA) Clean Non-road Diesel Rule. This new Tier 4 emission standards for non-road engines will apply to diesel engines used in most kinds of construction, agricultural, and industrial equipment. The new rule includes a nationally mandated reduction of sulfur content in non-road diesel fuel from approximately 3,000 parts per million (ppm) average today to 500 ppm by 2007, and 15 ppm by 2010, and the phased implementation of emission control technology on non-road diesel engines after 2008. However, due to the durability of diesel engines it will take almost two decades to have the diesel engines that power construction equipment replaced with the new mandated cleaner engines.

The diesel engine retrofit program discussed in this paper started as a way to reduce emissions before cleaner fuels and cleaner engines become part of the standard manufacturing process. Currently, there is an expanding list of emission reduction technologies, which has been approved by Environmental Protection Agency (EPA) and California Air Resources Board (CARB) for diesel engines and clean fuels. The most commonly known technologies can be grouped into three main categories:

- Fuel modifications: including synthetic diesel, water-in-diesel emulsions, biodiesel, ultra low sulfur diesel, and fuel additives.
- Engine Design/fuel modifications: including exhaust gas recirculation (EGR), dimethyl ether, and natural gas.
- After Treatment /add-on pollution control devices: including oxidation catalysts, diesel particulate filters (DPF), lean catalysts, and selective catalytic reduction (SCR).

The I-95 NHHC diesel emission control program focused on add-on pollution control devises with the option of cleaner diesel fuels. Since currently there are several areas within the US where these types of programs are being evaluated and/or are starting to be implemented, the experience of this large transportation project can serve as a road map toward implementation of these programs in other areas.

I-95 NHHC OVERVIEW

The I-95 NHHC administered by the Connecticut DOT consists of the construction of a new State Street Commuter Railroad Station, the widening of I-95 from Exit 46 in New Haven to Exit 54 in Branford, the replacement of the existing Pearl Harbor Memorial Bridge (Q Bridge) with a new 10 lane bridge, and the reconstruction of the I-95/I-91/Route 34 Interchange. The existing Q Bridge built in 1958 to carry 40,000 vehicles per day, was operating in 1993 at a

level of over 120,000 per day. By 2015 a traffic level of 140,000 to 150,000 vehicles per day has been forecasted.

The project is located in the municipalities of New Haven, East Haven and Branford, which are a serious non-attainment area for ozone (O_3), and non-attainment for PM_{10} and $PM_{2.5}$ for the New Haven area only.

The construction of this 7.2-mile corridor, which started in 2002 and will take more than twelve years to complete, will include more than 200 pieces of diesel powered construction equipment. Construction is divided in five phases under four major contracts. Four contracts have been awarded with the first one completed in June 2004. The first contract (called Contract D) started June 2002. Contract C1 (working in the East Haven area) is scheduled to finish November 2005. Two other contracts have just been awarded.

DIESEL EMISSION CONTROL PROGRAM DEVELOPMENT

The DOT started to look at the possibility of a retrofit program linked to the I-95 NHHC one year before the advertising of the first construction contract. In October 2000, DOT formed an air quality working group, which investigated the benefits and costs of implementing a diesel emission control program. The group included personnel from various offices within DOT, and experts from Parsons Brinckerhoff (PB), New England States for Coordinated Air Use Management (NESCAUM), Connecticut Department Environmental Protection (DEP), Department of Motor Vehicles (DMV), and Connecticut Construction Industries Association (CCIA).

It was decided early on that the Diesel Emission control Program called "Connecticut Clean Air Construction Initiative" would combine the non-road diesel powered equipment with the inspection of highway diesel vehicles. The highway diesel vehicles are already regulated by the DMV under a heavy-duty diesel emissions regulation. In the state of Connecticut the DMV conducts opacity tests on heavy-duty diesel vehicles.

Selected Technologies

Four different scenarios (technologies) that could be implemented to reduce air emissions during construction were identified. Two included diesel engine retrofit technologies, such as oxidation catalysts and/or four way catalysts; while two others included the use of cleaner fuels, Biodiesel B-20 Blend™ and/or PuriNOx™. Any of these four technologies could be applied partially and in combination with the others. All had logistical and cost advantages and disadvantages that were evaluated prior to implementation.

An evaluation of emission benefits and costs for each technology was performed during 2001. The methodology used to estimate the emission reductions from the diesel retrofit and/or clean fuels program followed the same procedure used for State Implementation Plan credit calculations recommended by NESCAUM, i.e.:

- Estimation of baseline emission factors for CO, HC, NOx and PM_{10} by equipment type in grams per brake horsepower hour.

- Estimation of baseline emissions (tons/year) based on equipment type, usage, and hours of operation.
- Estimation of emission reductions for each type of equipment retrofitted and/or type of fuel for applicable pollutants.

Emission rates for CO, HC, NOx, and PM from diesel powered construction equipment were estimated using the EPA NONROAD Emission Model.

A paper presented by the same authors at the 2002 AWMA annual meeting (Paper No. 42536) described the technology selection process up to the development of the emission control specifications (pre-construction phase).

Considering that this was a voluntary pilot program for DOT, it was decided to use the most widely accepted technology and fiscally responsible emission reduction options.

As such, the following technologies were selected:

- Oxidation catalysts due to its wide acceptance and proven experience,
- Clean fuels listed with the EPA or CARB which could achieve specific NOx and PM emissions reductions.

It was decided that the program would include the option of either retrofitting with oxidation catalysts or use a clean fuel such as the emulsified diesel fuel PuriNOx^{TM}. This would provide the contractors more flexibility in situations where equipment would not remain on site for long periods of time.

Four way catalysts were considered to be too experimental and too costly for a pilot program. The use of Biodiesel was rejected because of the possible NOx increases.

A blind survey of construction equipment conducted by CCIA indicated that the Connecticut non-road equipment fleet is primarily an average of 1980's vintage. The makeup of the construction fleet can range from brand new to 55 years old. Construction companies nursed their equipment from job to jobs and large companies sell their old equipment to smaller firms extending the equipment life cycle.

The existence of so many pre-1994 (Tier 1) pieces of equipment limited the option of using diesel particulate filters (DPF). The success of DPFs have been mostly on highway trucks and buses, with more limited cases on construction equipment. In addition, most of the manufacturers of DPF listed in the EPA retrofit technology list are designed for post 1994 diesel engines, and also require the use of ultra low sulfur diesel.

DPFs require exhaust temperature profiles above 210 degrees Centigrade for at least 40% of time, and the NO_x /PM ratio greater than 20%, preferably greater than 30%. Pre 1994 non-road construction equipment engines typically have extremely low NOx/PM ratios. Essentially they are spewing a lot more PM. In addition, they were designed for a higher sulfur fuel, which presents additional hurdles for the proper functioning of DPFs.

Emission Reductions Potential and Costs

Oxidation Catalysts

At the time the evaluation for the I-95 NHHC Program started, the Central Artery/Tunnel (CA/T) Project in Boston, Massachusetts had already installed approximately 70 oxidation catalysts on a variety of construction equipment with positive results. Based on the EPA technology retrofit list, oxidation catalysts are expected to achieve a minimum of 20% reductions for PM, 40% reductions for CO, and 50% reductions for HC in all heavy-duty diesel engines. The average cost per piece of equipment in the CA/T project was $ 2,500, which translated into a cost of $8/Horse-power (HP), which was used for this assessment.

Table 1 below presents a summary of the emissions reductions and costs for each one of the major contracts as forecasted during the pre-construction evaluation.

Table 1: Projected Emission Reductions and Cost of Diesel Oxidation Catalysts

Contract	Total Number of Units	Total Engine HP	Total Utilized Annual Hp-hr	Annual Emission Reductions			Total Projected Cost
				CO	HC	PM_{10}	
	#	hp	hp-hr/yr	tons/year	tons/year	tons/year	(dollars)
Contract B	71	18,999	17,255,587	29.3	11.1	2.5	151,992
Contract C	62	15,817	14,212,442	24.2	9.0	2.0	126,536
Contract D	31	8,367	7,781,314	14.3	5.4	1.2	66,936
Contract E	58	15,592	14,070,826	25.6	9.7	2.1	124,736

Source: Guido Schattanek, Technical Memorandum – I-95 NHHC – Projected Air Pollution Benefits and Costs of Diesel Retrofit and/or Clean Fuels Program For Construction Phase, Connecticut. Department of Transportation, December 4, 2000

Clean Fuels

PuriNOx™ is an emulsified diesel fuel manufactured and distributed by Lubrizol Corp. in Ohio. It can be used on any diesel engine without modifications. It was considered as a good alternative to reduce NOx and PM_{10} since the EPA retrofit technology list certifies that use of this fuel can reduce PM from 16 to 58% and NOx from 9 to 20%.

The cost of PuriNOx™ at the time was approximately 16-cents per gallon above the cost of N°2 diesel fuel according to the Massachusetts distributor. Since PuriNOx ™ contains close to 20% of water, the relative cost differential depends on the wholesale cost of diesel fuel (i.e. the higher the diesel fuel cost the lower the differential). It also carries a fuel consumption penalty since water has no caloric power, making the real cost to the contractor higher than the fuel cost differential.

Table 2 below also presents a summary of the emissions reductions and costs for each one of the major contracts as forecasted during the pre-construction evaluation.

Table 2: Projected Emission Reductions and Cost of use of PuriNOx™ fuel.

Contract	Total Number of Units	Total Engine HP	Total Utilized Annual Hp-hr	Annual Emission Reductions		Total Projected Cost
				NOx	PM_{10}	Annualized
	#	hp	hp-hr/yr	tons/year	tons/year	(dollars)
Contract B	71	18,999	17,255,587	30.0	2.5	138,045
Contract C	62	15,817	14,212,442	24.9	2.0	113,700
Contract D	31	8,367	7,781,314	13.7	1.2	62,251
Contract E	58	15,592	14,070,826	24.8	2.1	112,567

Source: Guido Schattanek, Technical Memorandum – I-95 NHHC – Summary of Projected Air Pollution Benefits and Costs of Diesel Retrofit and/or Clean Fuels Program For Construction Phase, Connecticut. Department of Transportation, December 7, 2000

Equipment Size Applicability And Length Of Time On Site

An evaluation of the emission benefits, as a function of HP-hours of operation and fuel consumption for each contract, indicated that if all equipment with engine size over 60 HP were retrofitted, more than 98% of the emission benefits of retrofitting all equipment would be achieved. As a result, 60 HP became the smallest engine size that would be retrofitted. In terms of duration of the equipment on the construction site, the main issues were if specialized equipment would need exemption because they would be only needed for some special operation, and how to deal with rental equipment without limiting the contractor's options. The minimum time limit required for exemption started at 100 days, and latter was

shortened to 30 days in order to limit the possibility that contractors will rotate equipment to avoid complying with the program.

Payment Options

Current DOT standard specifications related to environmental compliance are in the form of either "incidental" or "pay" items.

- Pay items are those that the contractor bids a unitary price for, can be measured on site, and once verified by an inspector, are paid for according to the contract's unitary price. This payment method is common for such items as the application of calcium chloride, water for dust control, and/or fences for wind or erosion control. The contractor has to perform these tasks in order to get paid.
- Incidental items are those where that the cost is included in a contractor's overall bid price, and not specifically identified. One of the critical issues associated with incidental items is enforcement (i.e., what monies are retained for non-compliance). DOT has a 24-hour provision normally used for environmental aspects, where once the contractor is notified that they are not performing a contractual task, the Department can have the task performed by a third party, with the cost billed to the contractor.

It was decided that the retrofit program would be included in project contracts as an incidental item, with some special enforcement provisions.

Diesel Vehicle Emissions Controls Specification

Current DOT standard specifications related to airborne emissions include 1.10.04 Air quality Control, 9.42 Calcium chloride for dust control, and 9.43 Water for dust control. The retrofit/clean fuel program has been issued in what is called a Notice to Contractors (NTC). In the bid package the NTC is a legally binding specification in the Special Provision portion, and is linked to all future I-95 NHHC contracts.

The final form of the specification can be summarized as follow:

- All diesel powered construction equipment with engine horsepower (HP) ratings of 60 HP and above, that are on the project or are assigned to the contract for a period in excess of 30 days shall be retrofitted with Emission Control Devices and/or use Clean Fuels in order to reduce diesel emissions. In addition, all motor vehicles and/or construction equipment shall comply with all pertinent State and Federal regulations relative to exhaust emission controls and safety.
- The reduction of emissions of CO, HC, NOx, and PM will be accomplished by installing retrofit emission control devices or by using less polluting clean fuels.
- The retrofit equipment shall consist of oxidation catalysts, or similar retrofit equipment control technology that is included in the EPA Verified Retrofit Technology List, and certified to provide a minimum of emission reductions of 20% PM, 40% CO, and 50% HC.
- The Clean Fuels shall consist of PuriNOx^{TM}, or other low NOx and PM emission diesel fuel that can be used without engine modification, and it is certified to reduce

the emission of NOx, and PM by more than 10% and 30% respectively when compared to N°2 diesel fuel as distributed and sold in the State.

- Construction shall not proceed until the contractor submits a certified list of the diesel powered construction equipment that will be retrofitted with emission control devices or that will use Clean Fuels. The list shall include (1) the equipment number, type, make, and contractor/sub-contractor name; (2) the emission control device make, model and EPA certification number; and/or (3) the type and source of fuel to be used.
- The contractor shall submit monthly summary reports, updating the same information stated above, and include certified copies of the clean fuel delivery slips for the report time period, noting which vehicles received the fuel. The addition or deletion of diesel equipment shall be included on the monthly report.
- The contractor shall establish truck-staging zones that are waiting to load or unload material at the contract area. Such zones shall be located where the diesel emissions from the trucks will have minimum impact on abutters and the general public.
- Idling of delivery and/or dump trucks, or other diesel powered equipment shall not be permitted during periods of non-active use, and it should be limited to three minutes in accordance with Regulations of Connecticut State Agencies 22a-174-18, subsection (a)(5).
- A Diesel Emissions Mitigation plan will be required for areas were extensive work will be performed in close proximity (i.e. less than 50 feet) to sensitive receptors.

If a diesel equipped vehicle is found to be in non-compliance with this specification, the contractor will be issued a Notice of Non-Compliance and given a 24-hour period in which to bring the vehicle into compliance or remove it from the project.

Heavy-Duty Diesel Highway Vehicles Emissions Opacity Test Regulation

The DMV performs the inspections in conjunction with any safety or weight requirement at any official weighing area or other location designated by them.

The DMV Program specifies that only diesel-powered commercial motor vehicles consisting of the following characteristics should be tested:

- Vehicles over 26,000 lbs. GVWR
- Vehicles designed to transport sixteen or more passengers
- Vehicles transporting hazardous material and those required to be placarded

Roadside tests have been in operation for 4 years. The failure rate is averaged at approximately 16-18 percent. Vehicles that fail are subject to a potential $300 fine, and must submit proof of repairs. Second encounters with previously failed vehicles show a drastic reduction in smoke opacity. For the year 2003, a total of 1447 vehicles were tested out of which 246 exceeded the states opacity standards.

The I-95 NHHC program arranged with the DMW for a pre-construction opacity test for all contractors and sub-contractors. DMV goes to either the maintenance garage or a convenient job site to run through the opacity / safety testing.

The benefit of the DMV being invited by the contractor is that a waiver of fines and an opportunity to correct any safety violation within a reasonable time. If the contractor is caught on the road, a fine is levied and potential loss by automatic towing. The system reduces the chance of the contractor having delays and increase safe and emission compliant equipment on these Contracts. A visual inspection tag is applied to all equipment that passes the DMV inspection.

Contractor Information Process – Public Notice of Retrofitting

Once the requirements for the diesel vehicle control specification were determined, the air quality working group started the preparations for a contractor information and dissemination program. This program focused on how to explain the benefits and requirements of the Connecticut I-95 Diesel Emission Control Program to contractors and prospective bidders. One of the main purposes was to acquaint contractors with specification requirements and with vendors of emission control devices and clean fuel distributors. CCIA distributed invitations and several presentations were made at the DOT training facility.

These presentations included speakers from DEP, EPA, NESCAUM, Caterpillar, DOT, DMV, and the CA/T retrofit program. Emission control vendors and clean fuel distributors were also invited to set up booths with their products. The presentations lasted a full morning which included an overview of federal and state regulations, the experience obtained through the CA/T retrofit program, engine-manufacturers points of view, the specification requirements, and a demonstration of the smog opacity test performed by the DMV on heavy-duty vehicles.

DIESEL EMISSION CONTROL PROGRAM IMPLEMENTATION

By the fall of 2004 the program had installed approximately 72 oxidation catalysts on a variety of construction equipment with positive results. This represents 60 percent of all the equipment used during the current contracts. From the beginning of the first contract the DOT had devised a tracking system where each contractor and sub-contractor had to provide a list of the non-road diesel powered equipment with detail information for each piece of equipment that will be allowed to operate within the construction area.

The following information was required for each piece of non-road diesel powered equipment:

- Contractors/ Sub-Contractors name
- Date of Equipment arrival on Site
- Equipment number (ID)
- Equipment Type (Description)
- Make, Model & Task (i.e. Caterpillar M318 Excavator)
- Rental/Lease company and name
- The Make of the Emission Control Devise

- Model/number
- EPA verification number

When the equipment is on site for 30 days:

- Date of installation of retrofit device
- Or option to use clean fuels

It was also required to prepare a monthly report including:

- What has been retrofitted and the date
- Make, model number, manufactures make
- What Equipment has left the site and the date of departure
- Copies of certified clean fuel delivery
- What piece of equipment received clean fuel

Emission Controls Selected - Benefits and Costs

The diesel oxidation catalysts manufactured by Lubrizol Engine Control Systems (ECS) and Clean diesel Technologies (CDT) have been the vendors of choice by the Contractors and Sub-Contractors. Both oxidation catalysts are certified by EPA to achieve a minimum of 20% reductions for PM, 40% reductions for CO, and 50% reductions for HC.

The prices have ranged from $800 to $2000. The only problem was the availability because the demand increase during the start of the second contract associated with the I-95 Program.

In conjunction with CDT catalysts, a Sub-contractor is using the CDT Fuel Borne Catalyst Plus in their aged on-road fleet and non-road construction equipment. This product combination is certified by EPA to achieve up to 50% reductions for PM, CO, and HC. The sub-contractor appears to be very satisfied with the results based on their fuel economy and the emission reduction with the catalysts.

While a number of papers have been published on the long-term durability of oxidation catalysts used in highway diesel applications, relatively few data are available on the durability of catalysts used in non-road construction machines. As of now, some of the oxidation catalysts have been operating for two years on this program without any complaints from the contractors. No tests have been performed yet, but we hope that in the future some of the emission control equipment could be tested to verify the durability of their performance.

None of the contractors and subcontractors opted for *PuriNOx*™ as a clean fuel alternative. All of the contractors have gone with oxidation catalysts. The worries voiced by the contractors regarding the use of *PuriNOx*™ were that the fuel needed agitation, and freezing concerns over winter temperature while in the construction vehicles. No test of *PuriNOx*™ have been performed on any the I-95 NHHC contracts.

An important aspect of these contracts is that all contractors and sub-contractors had been using on-road diesel fuel for all of their non-road and on-road equipment. The on-road diesel fuel has an average sulfur content of 400 ppm today in New England versus a 3,000 ppm sulfur content average for the non-road diesel fuel. By using on-road (400 ppm sulfur) diesel

fuel for construction equipment (which is not required by law today) the PM reductions due to the lower sulfur content are in the order of 30% when compared to the non-road high sulfur fuel.

The sub-contractors were at a disadvantage because very few primary contractors help the sub with the cost of retrofit equipment. DOT is looking into programs willing to dispersing funds for these disadvantage sub-contractors in permanently putting retrofit equipment on their old non-road equipment.

One of the issues that we have been investigating is what contractors do with the emission control devices once the construction equipment leaves the work area. Various strategies were implemented with different contractors. The first primary contractor (Out of State) purchased 22 oxidation catalysts and moved them on and off the 28 pieces of construction equipment as they came in and out of the job site. Now that the job is finished all the retrofit devices are removed from the equipment and in storage. The attachment of the retrofit devices was engineered for easy detachment and therefore not as permanent installation.

The second primary contractor (Major Connecticut firm) has committed to keep the retrofit devices on even after the equipment has left the job site. This firm has 17 pieces of construction equipment retrofitted with oxidation catalysts at this time working on other jobs throughout the State of Connecticut. The installation of the retrofit devices engineered by this company was more secure and sturdy, and therefore more permanent.

The difference between the two primary contractors might be that the two-year difference between the first and second contract has made the retrofit program more accepted. The CCIA commitment to educate, and be a working partner with the contractors also had a important positive effect.

Highway Vehicles Opacity Test Results

As of this date, there have been six inspections by the DMV to insure that the On-Road vehicles met Connecticut standards. Approximately 15 vehicles are tested at a time. Approximately five have fail since the Opacity/safety checks were started and were corrected within a week. New inspections are scheduled for Contract C1 when new equipment comes on the job site and/or any new Sub-contractor starts working. Two new contracts starting in 2005 will also have the DMV inspection program coordinated with the contractors on site.

CONCLUSION

The I-95 NHHC retrofit program had the advantage of using the experience of the CA/T project in Boston, which had retrofitted over 100 pieces of equipment by the time this program started implementation. The most positive aspect of initiating the retrofit program was the creation of an air quality-working group that met on a regular basis (every six weeks) almost one year before the bid documents had to be ready for the advertising of the first contract.

The group was able to convince all of the affected parties to buy into the retrofit program. It was very important to obtain a clear understanding of the program benefits, costs, who was going to pay, and how the concept would be translated into a required specification as part of the bid documents early on in the program.

It was also critical to include the requirement for emission control equipment in the contract's bid package. By doing so, the cost of the retrofit equipment was included as part of the overall contract cost, thus avoiding the use of economic incentives to bring contractors into the program.

The major concerns expressed by contractors who participated in the I-95 NHHC retrofit program were to get assurances from the manufactures of emission control equipment that the emission control device will not affect equipment performance. Once those issues were resolved, it was also very important to have a good tracking system to make sure that the contractors and sub-contractors would not avoid the retrofit requirements by rotating equipment or using other clever maneuvers.

The I-95 NHHC diesel retrofit program proved that retrofitting construction equipment with oxidation catalysts is very feasible, and that it has significant benefits in terms of emission reductions, odor control, and visible smoke. When considering that the costs of the oxidation catalysts are on the order of one percent of the total cost of the construction equipment to be retrofitted, and the emission reductions are in the order of 20 to 50 %, this program is a very effective way to reduce diesel emissions and odor. By having this requirement in the final remaining contracts, it is estimated that an additional 130 pieces of off-road construction equipment will be retrofitted with oxidation catalysts. This should bring the total number of retrofits to approximate 200 by the time the I-95 NHHC project ends.

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