Tacoma Green Transportation Summit & Expo

April 6, 2016
Presentation Overview

1. T4 Switcher Concept
2. CUMMINS QSX15 Engine - Tier 4 Emissions Solution
3. NRE’s ARB Verification process
1. Tier 4 Switcher Concept
Concept: Use heavy duty proven on-highway truck technology in a multi-engine switcher

Advantages:

- Use a proven, durable, and “latest technology” platform
- Tier 4 switcher emissions without SCR / urea
- Technology is mature today with over 170,000 similar engines in service since 2007

Cooled EGR + Diesel particulate filter

- 1.3 g/hp-hr NOx+HC / 0.03 g/hp-hr PM or lower
- 600 hp max rating / engine, 600/1200/1800 loco hp
2GS12B Layout
Unit #2015
NR156 2GS12B Tier 4 Locomotive

**LOCOMOTIVE ID:**
#NREX 2015

**ENGINES:** (2)
Cummins QSK15 Tier 4

**RATED POWER:**
600 horsepower (each)

**CYLINDER ARRANGEMENT:**
Inline 6

**DISPLACEMENT:**
15 Liters

**RATED ENGINE SPEED:**
18,000 rpm

**EMISSION CONTROL/AFERTREATMENT:**
Cooled EGR, DOC, DPF
Catalized DPF
2. CUMMINS QSX15 Engine Tier 4 Emissions Solution
QSX for Tier 4 Switchers

- Cummins Particulate Filter – fully integrated to delivery performance, reliability.

- Cummins design allows regeneration even in adverse operating conditions.

- Reduces PM by more than 90%
System Architecture Diagram

- Tier 4 Loco QSX15  New Features in Blue

Direct Flow Air Filter

External Hydrocarbon Doser for DPF soot regeneration

VGT

EGR-Cooler

XPI Common Rail Fuel System

Charge Air Cooler

Oxidation Catalyst

Cummins DPF Aftertreatment

Dripless Crankcase Breather

CM2250 Electronic Control Module
DPF Architecture, Internal
Passive Regeneration

• Aftertreatment Perspective
  – Passive Regeneration will occur once soot accumulates to a certain level, the soot accumulation rate is balanced by a natural oxidation of collected soot and driven by normal exhaust temperatures.

• Locomotive Perspective
  – Passive Regeneration happens during the normal operation of the machine. No change to engine operation is observed and no additional fuel is added because the temperature of the DPF is high enough to allow for regeneration to occur.
Active Regeneration – In Mission

• Aftertreatment Perspective
  – Active regeneration occurs during “in mission” machine operation. Based on the sensed condition of the DPF, the control system will initiate automatic regeneration when necessary.

• Locomotive Perspective
  – Active regeneration happens during the normal operation of the machine. No changes to the engine operation are observed but additional fuel is added in order to raise the temperature of the DPF to a level which will allow regeneration to occur.
US EPA SWITCHER PM EMISSIONS (g/bhp-hr)

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### US EPA SWITCHER NOx EMISSIONS (g/bhp-hr)

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QSX for Tier 4 Switchers

NRE packages the engine into a “POD” providing all support systems for a complete self sustaining POD.
NRE packages the engine into a “POD” which incorporates all needed support systems.

The final product is a complete self-contained POD.
2GS12B Layout
3. NRE’s ARB Verification Process
NRE performed the ARB Verification program at RPRC over a 2-year period, using NRE T4 model 2GS12B. Emission testing was performed at 0, 1500 & 3,000 operating hrs.
Three (3) emissions test on site at RPRC, requiring load box, portable emission testing equipment (ENTEC) and validated test fuel. Exhaust sampling was done at the exhaust outlet adapters.
SAYBOLT ANALYSIS REPORT – October 2014

Pages 1 and 2

Analysis Report

Issuer warrants that it has exercised due diligence and care with respect to the information and professional judgments embodied in this report. This report reflects only the findings at the time and place of the inspection and testing. Issuer expressly disclaims any further indemnity of any kind. This report is not a guarantee of quality or performance with respect to the grade of the property or performance of any party. Any opinion stating shall be limited to the test performed by the Issuer and its agent, and Issuer’s assurance shall be limited to its own test results. Issuer’s actions are limited to the extent required to complete the test work as described above. Issuer is not responsible for the accuracy of any information provided by the laboratory or any other third party.

**Analysis Results**

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<td>Cal. Oxygen by difference</td>
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<table>
<thead>
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<th>SPEC</th>
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<td>30% Recovered</td>
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<td>40% Recovered</td>
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<td>Losses</td>
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**Notes:**
1. Density data selected from Table 3.
2. Derived from ASTM D 4058.
3. Derived from ASTM D 4058.
4. Nonresolved coefficient.

(Signed by: [Name], Location Manager)
[Date: October 2014]

[Company Address]
Emission tests were conducted using U.S. EPA test methods as outlined in 40 CFR 1065. NOx, carbon monoxide, sulfur dioxide and total hydrocarbons emissions were determined by continuous sampling of the raw exhaust. The opacity of visible emissions was determined on the raw exhaust and PM emissions were determined by batch sampling of the diluted exhaust.
## ENTEC Summary October 30, 2014

### Tier 4 at 3000 Hours

### TABLE 2-1: LOCOMOTIVE TEST RESULTS SUMMARY

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<tr>
<th>LOAD SETTING</th>
<th>Idle</th>
<th>Notch 1</th>
<th>Notch 2</th>
<th>Notch 3</th>
<th>Notch 4</th>
<th>Notch 5</th>
<th>Notch 6</th>
<th>Notch 7</th>
<th>Notch 8</th>
<th>WEIGHTED AVERAGES (1)</th>
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<td>159</td>
<td>159</td>
<td>159</td>
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(1) non-weighted average. Measured fuel rate for idle was lower than expected, therefore, average data from Notches 1-8 were used.
# Estimated Fuel Consumption and MW-hrs for Field Demonstration

<table>
<thead>
<tr>
<th>Notch</th>
<th>Eng. Hr's. Percent in Each Throttle notch</th>
<th>Brake HP</th>
<th>Auxiliary HP</th>
<th>Traction HP (net)</th>
<th>Fuel rate measured, lb/bhp-hr</th>
<th>Engine Hours</th>
<th>lbs of fuel</th>
<th>MW-hrs (brake)</th>
<th>MW-hrs (net, traction)</th>
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<tr>
<td>Idle</td>
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<td>19</td>
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<td>164,005.475</td>
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**NOTE:**
- Engine hours from NFORCE statistics log download at 3031 hours
- Auxiliary HP from NFORCE real-time data logging during emissions tests
- Fuel Rate (BSFC) from Cummins factory data documents
Total Time in Each Notch and Duty Cycle

NREX2015 Total Time in Each Notch and Duty Cycle
(3,031 Total Hours)
Air Resources Board

Mary D. Nichols, Chair
1021 I Street - P.O. Box 3939
Sacramento, California 95812 • www.arb.ca.gov

Edmund G. Brown Jr., Governor

August 14, 2015

Mr. Stephen Sonni
Senior Executive Account Manager
NRE. Global Holdings, Inc.
5064 Midas Avenue
Rocklin, California 95677

Dear Mr. Sonni:

This letter responds to NRE. Global Holdings, Inc.’s (referred to as “NRE”), previously known as National Railway Equipment Company) request for Air Resources Board (ARB) verification of the NREX 2015 GenSet locomotive. NRE is the manufacturer of the NREX 2015 GenSet locomotive, a single, two, or three engine switcher class locomotive designed to achieve United States Environmental Protection Agency (U.S. EPA) Tier 4 emission levels.

As noted in your application, the NREX 2015 GenSet locomotive that was tested is powered by two Cummins GSX15 Tier 4 diesel engines rated at 950 horsepower each, or a total of 1,900 horsepower. The U.S. EPA had previously certified the Cummins GSX15 engine for locomotives.

The Cummins GSX15 engine utilizes cooled exhaust gas recirculation (EGR) along with a combustion system that has been optimized for low oxides of nitrogen (NOx), particulate matter (PM), and hydrocarbon (HC) emissions. In addition, this engine uses a diesel oxidation catalyst combined with a catalyzed diesel particulate filter for HC, carbon monoxide, and PM control. Active regeneration is used to maintain the diesel particulate filter. The NREX 2015 is part of the N-ViroMotive product line.

The N-ViroMotive product line consists of ultra-low-emitting four and six axle road and switcher locomotives that feature one or more self-contained modular power plants (MMFs) or power on demand (POD) technology. Each MMF/POD contains an engine, generator/alternator, and engine cooling system designed for installation and subsequent removal and replacement as one unit on a locomotive frame.

Based on ARB staff's evaluation of the application, the test data, and additional information provided, ARB staff hereby verifies that this locomotive configuration and technology achieves U.S. EPA Tier 4 emission standards. Specifically, ARB staff has verified the NREX2015 GenSet locomotive at switch NOx and PM emission levels at or below 1.0 and 0.01 g/bhp-hr, respectively. This verification will be applicable to NREX 2015 GenSet locomotives with one, two, or three engine configurations, within a range of 600 to 1,800 horsepower. If you have any questions about this matter, please contact Mr. Harold Holmes, Manager, Rail Strategies Section at (916) 324-8029 or Harold.Holmes@arb.ca.gov.

Sincerely,

Cynthia Marvin, Chief
Transportation and Toxics Division

cc: Mr. Dennis Johnson, Director
Technology Assessment Center
United States Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, N.W.
Mail Code: 640U
Washington, D.C. 20460

Mr. Harold Holmes, Manager
Rail Strategies Section
Transportation and Toxics Division

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New technology must seamlessly integrate into a nationwide network

Number of Freight Locomotives Used in South Coast Air Basin in 2013

- BNSF = 3,011
- UP = 5,961
- Total = 8,972

1 month in the life of a typical UP line-haul locomotive
A history of technology innovation

• Increased fuel efficiency: trains move 1 ton of freight 473 miles on 1 gallon of fuel
• Hundreds of lower-emission “Genset” locomotives
• 10 “Green Goat” battery-hybrid switchers were used in revenue service
• Developed/Demonstrated EGR on a locomotive
• Installed idle reduction devices
• Tested emissions capture device
• CHE innovations
  – New/Modernized yards utilize state of the art technology such as clean hostlers and cranes
• Yard infrastructure improvements, such as gate technology, reduce emissions
Innovations Conserve Fuel

4x MORE FUEL EFFICIENT THAN TRUCKS

1 BILLION GALLONS SAVED ANNUALLY

10% IF 10% OF FREIGHT WERE MOVED BY RAIL

AERODYNAMICS

DISTRIBUTED POWER

ROLLING RESISTANCE

STOP/START TECHNOLOGY
U.S. EPA locomotive standards

Tier 2 (new) ............ 2005
Tier 3 (new) ............ 2012
Tier 2+ (upgrade) ........ 2013
Tier 4 (new) ............ 2015

Key EPA Dates

EPA Tier Path

Tier 0 (1973-2001)
Tier 1 (2002-2004)
Tier 2 (‘05-’11)
Tier 3 (‘12-‘14)
Tier 4 (2015)

PM - Particulate matter
NOx - Oxides of nitrogen

Source: GE Transportation
Evaluating new technologies – sophisticated analysis

• Safety
  – Safety of employees & communities we serve
  – Regulatory compliance
• Emissions & health risk reduction
• Infrastructure & operational
  – Infrastructure & right of way compatibility
  – National/regional scalability
• Financial
  – Economic sustainability & competitiveness
What BNSF & UP are doing now

- Tier 4 locomotives:
  - GE commercial manufacturing & deliveries began in 2015
  - EMD field testing; targeting commercial production in 2016
- Evaluating dual-fuel LNG/diesel locomotives & tenders
- LNG equipment (i.e., hostlers)
- Electric equipment at new railyards
- Automated gate system technology (reduces dray delay)
- Pursuing efficiency initiatives (such as Colton Crossing – a grade separated mainline crossing)
Dual-fuel LNG/diesel locomotive and tender testing

- Exploring feasibility of dual-fuel LNG/diesel equipment and operations
- AAR devoting resources to development of LNG interchange standards
- Engaged with locomotive builders, cryogenic fuel tank manufacturers, and LNG suppliers
- Dual-fuel LNG/diesel retrofits for Tier 2 and Tier 3 locomotives under development
# Evaluating freight railroad technology

<table>
<thead>
<tr>
<th></th>
<th>Comments</th>
<th>Emissions</th>
<th>Infrastructure</th>
<th>Ops</th>
<th>Next Steps</th>
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<tr>
<td><strong>Tier 4</strong></td>
<td>Significant challenges in weight; Packaging</td>
<td><img src="green" alt="Emissions" /></td>
<td><img src="green" alt="Infrastructure" /></td>
<td><img src="green" alt="Ops" /></td>
<td>GE delivering EMD under development</td>
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<td><strong>Urea</strong></td>
<td>Infrastructure; Operationally challenging; Packaging</td>
<td><img src="yellow" alt="Emissions" /></td>
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<td><img src="yellow" alt="Ops" /></td>
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<td><strong>Dual-fuel/ Nat Gas</strong></td>
<td>Fueling; Tender challenges; Possible retrofit reductions</td>
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<td>Under development</td>
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<td><strong>Catenary Electric</strong></td>
<td>$30-300M/mile; National system or multiple exchange points; Catenary; Elect. Supply.</td>
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<td><img src="red" alt="Infrastructure" /></td>
<td><img src="red" alt="Ops" /></td>
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<td><strong>Dual Mode</strong></td>
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<td><strong>Battery Switcher</strong></td>
<td>Green Goat – Safety Issues. Limited productivity</td>
<td><img src="green" alt="Emissions" /></td>
<td><img src="green" alt="Infrastructure" /></td>
<td><img src="green" alt="Ops" /></td>
<td>Consider options</td>
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<td><img src="yellow" alt="Ops" /></td>
<td>None</td>
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Summary

• Rail plays a valuable role, and its inherent energy efficiency advantage makes it part of the solution for more sustainable freight

• Long history of collaboration and innovation

• Pursuing further environmental improvements

• Invest in technologies that can reliably operate on a continental network

• Questions?
Engine Manufacturer View:
EPA TIER 4 / IMO III and OTHER MARINE ISSUES

Mike Rochford
Director, Emissions Regulations
rochford_mike@cat.com
Caterpillar Marine Products

3500 Series
8, 12, 16 cylinder
526 – 2525 kW

C175 Series
16 cylinder
2001 – 2168 kW

C280 Series
6, 8, 12, 16 cylinder
1400 – 4000 kW

710 Series
6, 12, 16, 20 cylinder
1020 – 1710 kW

M 20 C
6, 8, 9 cylinder
1900 – 3000 kW

M 32 C / E / DF
6, 8, 9 cylinder
2880 – 5000 kW

M 43 C
6, 7, 8, 9 cylinder
6000 – 9000 kW

C 4.4
4 cylinder
93 – 123 kW

C 4
12, 16, 20 cylinder
10800 – 18000 kW

M 46 DF
6, 7, 8, 9 cylinder
5400 – 8100 kW

M 46 DF
12, 16 cylinder
12000 – 16000 kW

C9
6 cylinder
375 – 423 kW

M 43 C
12, 16 cylinder
6000 – 8000 kW

C12
6 cylinder
254 – 526 kW

C18
6 cylinder
339 – 847 kW

V M 32 C
12, 16 cylinder
6000 – 8000 kW

V M 46 DF
12, 16, 20 cylinder
10800 – 18000 kW

V M 43 C
12, 16 cylinder
12000 – 16000 kW

M 32 C
6, 8, 9 cylinder
2880 – 5000 kW

C7.1
6 cylinder
100 – 190 kW

M 46 DF
6, 7, 8, 9 cylinder
5400 – 8100 kW

710 Series
6, 12, 16, 20 cylinder
1400 – 4000 kW

M 20 C
6, 8, 9 cylinder
1900 – 3000 kW

M 32 C / E / DF
6, 8, 9 cylinder
2880 – 5000 kW

M 43 C
6, 7, 8, 9 cylinder
6000 – 9000 kW

C12
6 cylinder
254 – 526 kW

C18
6 cylinder
339 – 847 kW

C9
6 cylinder
375 – 423 kW

C 4.4
4 cylinder
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6, 7, 8, 9 cylinder
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6, 7, 8, 9 cylinder
5400 – 8100 kW

M 46 DF
12, 16 cylinder
12000 – 16000 kW

C7.1
6 cylinder
100 – 190 kW

M 46 DF
6, 7, 8, 9 cylinder
5400 – 8100 kW

M 46 DF
12, 16 cylinder
12000 – 16000 kW
US EPA Tier 4 Journey
Providing Customer Value & Meeting Emissions Standards

• **Marine EPA Tier 4 / IMO III Regulations** Inherently Drive Lower PM and Fuel Consumption (Lower CO₂)
  – Regulations Fit Well With Available SCR Technology
US EPA Tier 4 and IMO Tier III Marine
Applies to New Vessels Engineered for SCR Space Requirements

*Images not shown to scale relative to one another
Dual Fuel – New Builds or Retrofits
Significant GHG, NOx, and PM Reduction Opportunities

- Liquid fuel mode
  - Diesel (MDO/MGO)
  - Heavy fuel (HFO)

- Gas mode
  - Natural gas (NG)
  - Compressed natural gas (CNG)
  - Liquefied natural gas (LNG)

Total Exhaust Gas Emission Balance LNG vs Diesel

Total Greenhouse gas contribution in CO₂ equivalents
Up to 10% lower than M43 C
Marine Hybrid Solutions
Built on a Reputation of Reliability
• Required to upgrade to the highest available and compatible emissions Tier
  – IMO Tier II with a few exceptions for non US Vessels
  – EPA Requires highest available Tier
  – EPA Tier 4 IMO Tier III are generally not applicable to existing vessels due to vessel space and safety constraints
    • Funding of differential installation owning and operating cost could drive voluntary reductions from existing vessels

• Diesel Particulate Filters (DPF) in marine applications need provision for bypass for some failure modes.
Summary

• Low Emissions Products and Hybrid Systems are Commercially Available for New Vessels

• Voice of Customer defines need for Efficient, Reliable, Safety at Sea Products

• Existing Vessels may be Upgraded to Newer Technology, such as Dual Fuel but Feasibility and Cost Constraints are Important Considerations