US EPA ARCHIVE DOCUMENT
Challenges of Emissions Upgrade Repowers
Cummins Inc.

- Founded in 1919 by Clessie Cummins
- Currently 16 North American Distributors
  - 14 US
  - 2 Canada
- Annual Sales in 2008 were $14.1B
- Independent Engine Manufacture
What is a Repower?

- Generally accepted definition
  - Removal of the existing engine/power train and replacing with a newer and more efficient power train for the purposes of extending the useful vehicle life.
  - Reduce the price to repair the existing power train
Reason to repower

- Specialty piece of equipment that is very expensive to replace
- Emissions reduction
  - Requirement of jobsite, bid or local laws
  - Potential grant availability
- Obsolete engine
- Take advantage of technology
- Extend the life of the unit
- Reduced operating costs
Port Crane Repower
The Challenges of this repower

- Location
- Removal of old engine
  - In this example 200 feet in the air
  - Removed the roof and lift engine out of the top of the engine container ($42K)
- Cooling system
  - Adding Charge Air Cooling
- Electronic controls
  - Integrating existing machine controls and safeties designed for a mechanical engine into an electronic engine
Design Issues
Controls and Wiring

- Mechanical Engines have simple safeties and shut down systems
- Modern Engines capable of monitoring and managing engine functions at a level unknown to the mechanical products
- Proper wiring and controls are critical to avoid electronic interference and noise issues.
- Complicates tying old systems into the new systems
Controls
Challenges

- Intake and exhaust systems
  - Reuse or replace
  - Flows and connections
- Driven Components
  - Torsional analysis
  - Differences in engines
  - Center line
- Acceptance of smaller engines
  - Platform Switching
Coupling and Drive
DC Generators (five total)
Center Line issues
Second generator in the Crane

- Provided power
  - 110V lighting
  - Heaters
  - Tools
  - Controls

- Old unit was a Tier Zero N855
  - Replaced 14L engine with a new QSB7 (6.7L) generator with better power and performance
  - Simple removal and replacement using existing space and wiring (stand alone)
New QSB7 Gen Set
Benefits for the customer on this repower

- Reduced Emissions
- Reduced fuel consumption
- Improved light load fuel efficiency
- Improved Oil Drain intervals
- Improved speed controls
- Improved governor stability and load response
- Reduced noise
  - 52 Liters (38L + 14L) down to less than 30L combined
What can you Repower?
Candidates for Repower

- Equipment with remaining useful Life
- Return on Investment
- Space constraints
  - Engine
  - Controls
  - Sub-systems (e.g. cooling)
- Buses and Trucks
  - Diesel or Natural Gas
- Off Highway Equipment
- Virtually Anything
MCI Bus S60 Detroit to ISL-G
C130 Tug, Tier Zero 6BTA5.9 to Tier 3 QSB6.7
Dredge Crane in Maryland
Electric Motor to QSK19 Tier 3
Tier 4 Technology Path
EPA Emissions Reduction

- Off-highway lags on-highway effect by a few years

<table>
<thead>
<tr>
<th>Tier</th>
<th>Year</th>
<th>NOx + HC (g/kW-hr)</th>
<th>NOx (g/kW-hr)</th>
<th>PM (g/kW-hr)</th>
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<tbody>
<tr>
<td>Tier 2</td>
<td>2001</td>
<td>6.4</td>
<td>-</td>
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<tr>
<td>Tier 3</td>
<td>2005</td>
<td>4.0</td>
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<tr>
<td>Tier 4 Interim</td>
<td>2011</td>
<td>2.0</td>
<td>-</td>
<td>0.13</td>
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<td>Tier 4 Final</td>
<td>2014</td>
<td>0.4</td>
<td>-</td>
<td>0.02</td>
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</table>

Most stringent emission levels shown >130 kW (174 hp)
Best Technology

- Cummins is uniquely positioned to succeed at Tier 4:
- Ownership of the key enabling technologies
- Fully integrated air-intake to exhaust aftertreatment solution
- Leveraging proven EGR, VGT & DPF hardware
## Technology Portfolio

- Broadest technology portfolio in the industry
- Access to global automotive technology means we can optimize our Tier 4 products to lead the off-highway market

<table>
<thead>
<tr>
<th>Application</th>
<th>Date</th>
<th>In-Cylinder Only</th>
<th>Cooled EGR/VGT</th>
<th>NOx Adsorber</th>
<th>SCR</th>
<th>PM Aftertreatment</th>
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<tbody>
<tr>
<td>Tier 3 / EU Stage IIIA</td>
<td>2005</td>
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<td>Euro 4 On-Highway</td>
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<td>EPA 07 On-Highway</td>
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<td>EPA 07/10 Pickup Truck</td>
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<td>Euro 5 On-Highway</td>
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<td>EPA 10 On-Highway</td>
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<td>75-173 hp, 2012</td>
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750,000 EGR engines operating 450,000 DPF & 250,000 SCR systems produced 2.5 million VGTs produced
Technology Learning Curve

- Cummins has gained experience on the technology learning curve since EPA 2002 that others have not.
- The emissions requirement for later off-highway markets were part of the initial design profile of EGR, VGT & DPF.
- We use our automotive platforms to develop World Class products for the off-highway market.

Over 7 billion miles accumulated with EPA 2007 technology.

Emissions Technology – Cummins MidRange and Heavy-Duty Diesel Engines

- **EPA/CARB On-Highway**
  - Mechanical
  - Mechanical
  - Mech/Elect
  - Electronic
  - EGR & VGT
  - Aftertreatment

- **EPA/CARB Off-Highway**
  - Mechanical
  - Mechanical
  - Mech/Elect
  - Electronic
  - EGR & VGT
  - Aftertreatment

- Fuel System/Controls (mechanical to electronic)
- Charge Air Temperature Control (jacket-water aftercooled [JWAC] to air-to-air aftercooled [CAC])
- EGR (cooled Exhaust Gas Recirculation) and VGT (Variable Geometry Turbocharging)
- Exhaust Aftertreatment
Leading The Way To Final

- Our technology & experience allows us to lead the industry through the 2011-2014 transition to Tier 4 Final
- Incremental SCR aftertreatment is Cummins presumed direction for Final
- Space claim for Final identified
- We know more about SCR than anyone else:
  - Used for Euro 4 since 2006
  - One of largest SCR manufacturers
  Integrated EPA 2010 aftertreatment
Tier 3 Architecture

System Architecture For Above 173 hp Shown
System Architecture For Above 173 hp
EGR/DPF architecture is the most effective installation route to Final with SCR used as incremental aftertreatment

- Reduces overall installation cost & complexity
Making Repowers Easier with Power Units
Tier 4 Beta Power Unit
DPF=Top & AC=Side
Tier 4 Beta Power Unit
Pedestal Mounting
Installation Quality Assurance Requirements (IQA)

- Fill, Drawdown and dearation test
- Limiting Ambient Temperature test
- IMTD and IMPD Emission Testing
- Intake Restriction test
- Exhaust Restriction test
- Aftertreatment Leakage test
- Aftertreatment Temperature Drop test
- Aftertreatment Vibration test
- ADVISOR IQA Document
- Electrical System test
- Fuel Restriction/Temperature
- Mounting system verification

Saves customer and sales resources

Completed here for every CPP Power Unit
Closing

- Repowers for Emissions
- Repowers for Economy
- Repowers to Extend life
- Repowers to Obsolete (old technology)

- Questions