Application of Diesel Emissions Reduction Controls for Nonroad Construction Equipment

Croton Water Treatment Plant Case Study

2007 NvMA/MSHA/NIOSH DPM Workshop
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Elko, NV

Michael C. Block
Emisstar LLC
Project Overview

• Drinking Water Treatment Plant
• EPA consent decree
• North Bronx (Van Cortland Park)
• 3 phases
  • Excavation → ’05 – early ’07
  • Tunneling → early ’07 – ‘10
  • Construction → ’07 – ’12
• $1.5+B
• 1st U.S. Construction project using “BAT”
Emisstar LLC

“Mobile Emissions Technology, Policy, and Implementation”

- Formed in April 2005
- Focus on mobile sources diesel emissions remediation
- Over 60 years collective experience
  - Air quality science & engineering
  - Engineering & project management,
  - Business development, & strategic planning
  - Diesel engine and emissions control technology
- 3 Offices in United States
Site Activities

- 16 acre site
  - 9 acre excavation to approx. 100 feet
- Hydraulic Line Drilling
- Blasting
- Excavating/Hoe ramming
- Loading
- On-site hauling
- Rock crushing / stockpiling
- Off-site hauling
Croton – Site Overlook
NYC Local Law 77

- Law enacted by NYC Council in 2003
- DEP Rulemaking in 2005
  - Ch. 14 of Title 15, Rules of City of New York
- Addresses emissions from “non-road” diesel equipment
- All City Agencies and their contractors
LL77 – Requirements

• Any diesel powered equipment > 50 HP must be:
  • Powered by ULSD
  • Utilize BAT for reducing emissions
• Equipment includes:
  • Excavators, backhoes, cranes, compressors, generators, bulldozers, etc.
• Does not include on-highway vehicles
BAT Categories

BAT Definition:
• “Technology shall achieve the greatest reduction in emissions of particulate matter (PM) and shall in no event result in an increase in the emissions of either PM or nitrogen oxides (NOx)”

Category I
• System using diesel particulate filter (DPF)
  • Control PM + NOx or
  • PM Only

Category II
• System using diesel oxidation catalyst (DOC) or flow-through filter (FTF)
  • PM + NOx or
  • PM Only

Category III
• Emulsified Diesel Fuel (ULSD compatible)
BAT Selection Criteria

- Technology must be verified by either:
  - US EPA
  - California Air Resources Board (ARB)
- Non-verified if:
  - OEM installed without compromising performance
  - Demonstration-stage technology

http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm
http://www.arb.ca.gov/diesel/verdev/level1/level1.htm?PF=Y
Equipment Characterization

ECT Matching and Analysis

Vendor Ranking and Selection

Engineering and Design

Training, and Fabrication/Installation

Monitoring and Assessment

Project Implementation

- July – Oct, ‘05
- Nov – Dec, ‘05
- Dec ’05 – Jun ’06
- Ongoing – May ‘07
- Completion, July ‘07
Croton Vehicle Profile

• 25 – 30 Non-Road machines
• Major categories
  • Compressors
  • Loaders
  • Excavators
  • Dozers
  • Drills
  • Quarry Trucks
Equipment Characterization/Datalogging

- Tier 2 or 3 machines
- High EGT profiles, on average
  - 300 deg. C > 70 % duty cycle – PDPFs
- Quarry Trucks
  - Low to medium EGT
  - ADPF candidates
- Well maintained (Service ~ 250 hours)
High & Low EGT profiles

Komatsu PC 750 Excavator

Terex TR70 Quarry Truck (Trial 1)
ECT Providers

Engine Control Systems

• Passive Diesel Particulate Filter (PDPF) – Purifilter
• 90%+ PM Reduction
• EPA & ARB (Level 3) Verified
• 75% of the Croton construction equipment –
  • Excavators, dozers, compressors, drills, loaders
Engine Control Systems – “Cattrap™”

- 380 – 420 °C for 20% of duty-cycle.
- Base (not precious) metal catalyst coating.
- Zero nitrogen dioxide NO₂ emissions.
- Mining applications.
ECT Providers

CAT / Johnson Matthey (JMI) – “CRT” Principle

- Passive Diesel Particulate Filter (PDPF) – JMI CRT design.
  - 90%+ PM Reduction
  - EPA Verified
  - ARB “de-verified” due to excessive NO₂ production
  - One high HP excavator

- Deliberately generates NO₂.
- Excess NO₂ improves regen → lower EGT.
- But can produce excess NO₂ out the tailpipe.
Providers (cont.)

Rypos

• Active Diesel Particulate Filter (ADPF) – *RT-500 24 volt*

• On-board electrical regeneration.

• Three Terex TR 70 700 HP Quarry Trucks

• ARB Level 2 verification for stationary back-up generators (BUGs).

• ARB Level 3 verification for BUGs.
ADPF – Onboard Electrical Regeneration

- Filter Section
- Inlet Section
- Controller
- Flow controllers

RYPOS ADPF™
Huss

- Active Diesel Particulate Filter (ADPF) – *MK Fuel Burner Series*
- On-board fuel burner in exhaust system for regeneration.
- Croton: Terex TA-40 400 hp DDC Series 60.
- DSNY: Caterpillar D400 400 hp 3406.
- ARB Level 3 verification for on-highway and nonroad.
ADPF – Onboard Fuel Burner

Huss MK Burner System
Technology Deployment

- Custom, On-site Installations
  - Mechanics
  - Welders/metal fabricators
  - Technicians
- 8 to 16 hours per installation
- Nights and weekends
- For the most part, not pre-designed systems (Rypos is exception)
EGBP/EGT Monitoring

• All BAT systems require monitoring
• Utilized:
  • CRTdm for PDPF.
  • Supplier installed monitors for ADPF.
  • Handheld digital manometers as backup.
• Periodic diagnostics
• Alarm Triggered Event
  • Establish Retrofit Case History
In-Use Emissions Testing

Environment Canada ERMD’s ‘DOES2’

- Objectives
  - Conduct exhaust emission measurements on six diesel powered pieces of construction equipment operating under both real world and repeatable conditions.
  - Evaluate the impact of various emission control technologies – pre and post ECT.

- Why ‘DOES2?’
  - It most closely replicates engine laboratory conditions.
  - Is the most accurate and repeatable under varying equipment operation and climatic conditions.
  - Is capable of measuring PM.
  - It references EPA’s CFR new engine certification techniques for PM measurement.
## ISS Techniques

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>Analysis Method</th>
<th>Instrument</th>
<th>Sample Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>Non-Dispersive Infrared Detection (NDIR)</td>
<td>HORIBA Model AIA-210 LE</td>
<td>Cali-5-Bond™ (five layer) Sample bag</td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>Non-Dispersive Infrared Detection (NDIR)</td>
<td>HORIBA Model OPE-115</td>
<td>Cali-5-Bond™ (five layer) Sample bag</td>
</tr>
<tr>
<td>Oxides of Nitrogen (NOx)</td>
<td>Chemiluminescence Detection</td>
<td>California Analytical Instruments Model 400-HCLD</td>
<td>Cali-5-Bond™ (five layer) Sample bag</td>
</tr>
<tr>
<td>Nitric Oxide (NO)</td>
<td>Chemiluminescence Detection</td>
<td>California Analytical Instruments Model 400-HCLD</td>
<td>Cali-5-Bond™ (five layer) Sample bag</td>
</tr>
<tr>
<td>Total Hydrocarbons (THC)</td>
<td>Heated Flame Ionization Detection (FID)</td>
<td>California Analytical Instruments Model 300M-HFID</td>
<td>Cali-5-Bond™ (five layer) Sample bag</td>
</tr>
<tr>
<td>Particulate Matter (PM)</td>
<td>Gravimetric Procedure</td>
<td>Sartorius M5P-000V001</td>
<td>70mm Pall Emfab™ filters</td>
</tr>
<tr>
<td>Ammonia (NH₃)</td>
<td>To Be Determined</td>
<td></td>
<td>Citric acid coated filters</td>
</tr>
</tbody>
</table>

- **HORIBA Model AIA-210 LE**
- **HORIBA Model OPE-115**
- **California Analytical Instruments Model 400-HCLD**
- **California Analytical Instruments Model 300M-HFID**
- **Sartorius M5P-000V001**
- **70mm Pall Emfab™ filters**
## Equipment Tested

<table>
<thead>
<tr>
<th>Type</th>
<th>Manufacturer</th>
<th>Model #</th>
<th>Date of Mfg.</th>
<th>Engine</th>
<th>HP</th>
<th>Tier</th>
<th>ECT Type</th>
<th>Mfg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td>Ingersoll Rand</td>
<td>IR 600</td>
<td>2005</td>
<td>John Deere-6IRF8TE</td>
<td>170 HP</td>
<td>2</td>
<td>SCR+DPF</td>
<td>JMI SCRT</td>
</tr>
<tr>
<td>Dozer</td>
<td>Komatsu</td>
<td>D155-Ax-5B</td>
<td>2004</td>
<td>Komatsu SDA6D140E-3</td>
<td>332 HP</td>
<td>2</td>
<td>DPF</td>
<td>ECS</td>
</tr>
<tr>
<td>Excavator</td>
<td>Hitachi</td>
<td>Z Axis-800</td>
<td>2004</td>
<td>Isuzu GWG1XAB</td>
<td>483 HP</td>
<td>2</td>
<td>DPF</td>
<td>ECS</td>
</tr>
<tr>
<td>Hydraulic Drill</td>
<td>Tamrock</td>
<td>CHA 700</td>
<td>2005</td>
<td>Caterpillar 3506E</td>
<td>173 HP</td>
<td>2</td>
<td>DPF</td>
<td>ECS</td>
</tr>
<tr>
<td>Rubber Tire Loader</td>
<td>Caterpillar</td>
<td>966G</td>
<td>2004</td>
<td>Caterpillar 3176C ATAAC</td>
<td>259 HP</td>
<td>2</td>
<td>DPF</td>
<td>CAT/JMI CCRT</td>
</tr>
<tr>
<td>Quarry Truck</td>
<td>Terex</td>
<td>TR70</td>
<td>2005</td>
<td>Detroit Diesel 12V 2000</td>
<td>700 HP</td>
<td>2</td>
<td>ADPF</td>
<td>RYPOS ADPF-C</td>
</tr>
</tbody>
</table>

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**EMISSTAR**

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# Equipment Emissions

<table>
<thead>
<tr>
<th>Source</th>
<th>DPF</th>
<th>Test Equipment/Engine</th>
<th>Test Cycle</th>
<th>Applicability</th>
<th>Fuel</th>
<th>Mean Emissions Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johnson Matthey SCRT</td>
<td>Ingersoll Rand IR600 Compressor; 170 hp</td>
<td>Simple In-Use</td>
<td>Nonroad</td>
<td>ULSD</td>
<td>97</td>
<td>67</td>
</tr>
<tr>
<td>In-Use Emission Testing Program Conducted by Emisstar and Environment Canada</td>
<td>Komatsu D155 Dozer; 332 hp</td>
<td>Synthesized In-Use</td>
<td>Nonroad</td>
<td>ULSD</td>
<td>97</td>
<td>5</td>
</tr>
<tr>
<td>ECS Purifilter PDPF</td>
<td>Komatsu PC750 Excavator; 474 hp</td>
<td>Synthesized In-Use</td>
<td>Nonroad</td>
<td>ULSD</td>
<td>99</td>
<td>12</td>
</tr>
<tr>
<td>Johnson Matthey CRT</td>
<td>CAT 966G Rubber Tire Loader; 259 hp</td>
<td>In-Use</td>
<td>Nonroad</td>
<td>ULSD</td>
<td>99</td>
<td>7</td>
</tr>
<tr>
<td>ECS Purifilter PDPF</td>
<td>Tamrock CHA700 Tiger Drill; 173 hp</td>
<td>In-Use</td>
<td>Nonroad</td>
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</tr>
</tbody>
</table>

*The average PM reduction is 98% for data obtained from In-Use Emission Testing Program Conducted by Emisstar with Environment Canada*

*a To confirm the accuracy and repeatability of the emissions test results, 10-14 tests were performed on each piece of equipment over a pre-determined set of “micro-trips”.*
Challenges and Issues

- ECT Suppliers for the nonroad market
- Fleet Champion
- Technical
  - OEM Backpressure compliance
  - Well engineered & robust design
- Operational
  - Interrupting site-operations
  - Harsh conditions
    - Vibration
    - Dust
- Variability in Service & Support
  - Lead times
  - Servicing units
Successes

• Assuaged community concerns about health impacts of pollution.
• Deployed Category 1 BAT or higher on all 25+ machines.
• Working for over 1 year w/minimal downtime or interference.
• Quantified in-use emission reductions through ISS testing
Lessons Learned

• Fleet participation is critical
• Dedicated trained mechanic/support for large deployments
• Move project from “orphan” to “owner” phase as quickly as possible – champion
• Keep spare parts, supplies & filter cleaning station on-hand
• Documentation – installation, maintenance, repair, warranty
Technology Transfer To Mining

What are the similarities; what are the differences?

- Operating environment?
- Variability of equipment type?
- Interest from ECT providers?

What do you think?
Filter substrate failure
Croton – Hitachi Z-Axis 800 Excavator (2)
Croton – Hitachi Z-Axis 800 Excavator (2)
Croton – Hitachi Z-Axis 800 Excavator (2 machines)
Croton – Hitachi Z-Axis 800 Excavator (2)
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