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# Application of Diesel Emissions Reduction Controls for Nonroad Construction Equipment

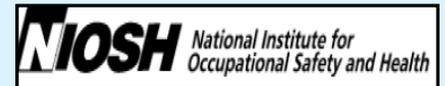
## Croton Water Treatment Plant Case Study

2007 NvMA/MSHA/NIOSH DPM Workshop

June 5, 2007

Elko, NV

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Emisstar LLC



# Project Overview

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- 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
- 1<sup>st</sup> U.S. Construction project using “BAT”

# Emisstar LLC

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## *“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

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- 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

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- 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

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- 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

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## 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

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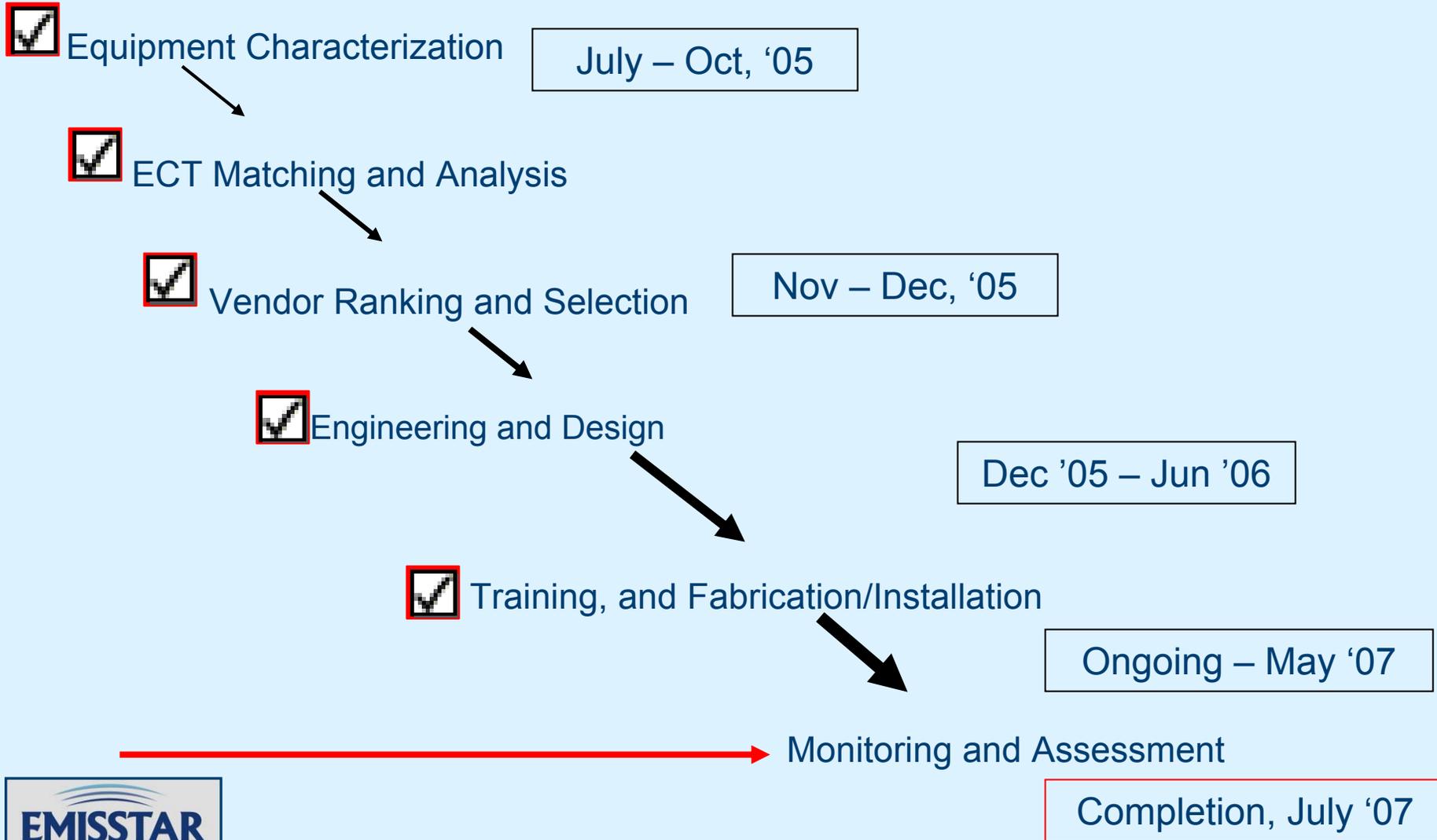
- Technology must be verified by either:
  - US EPA
  - California Air Resources Board (ARB)
- Non-verified if:
  - OEM installed without compromising performance
  - Demonstration-stage technology

<http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm>

<http://www.arb.ca.gov/diesel/verdev/level1/level1.htm?PF=Y>

# Project Implementation

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# Croton Vehicle Profile

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- 25 – 30 Non-Road machines
- Major categories
  - Compressors
  - Loaders
  - Excavators
  - Dozers
  - Drills
  - Quarry Trucks

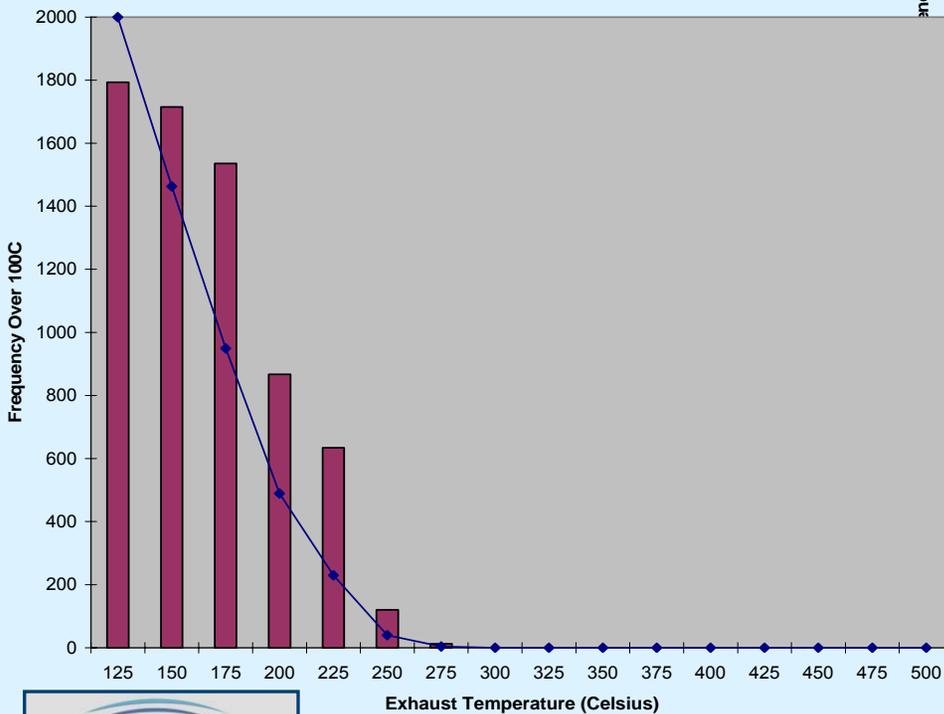
# Equipment Characterization/Datalogging

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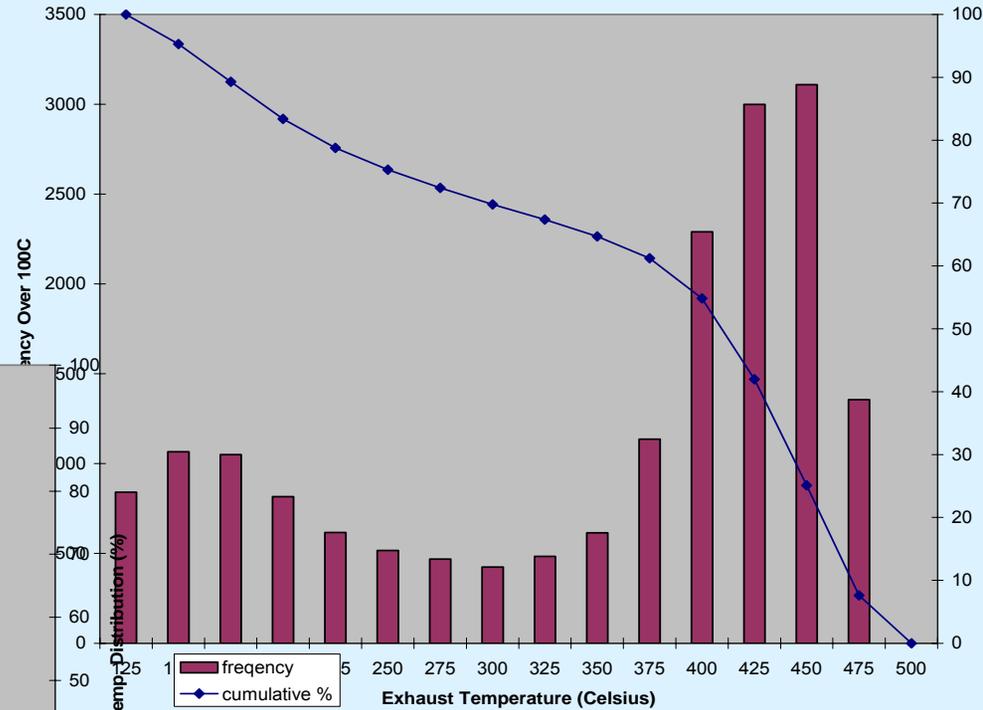
- Tier 2 or 3 machines
- High EGT profiles, on average
  - 300 deg. C > 70 % duty cycle – PDPFs
- Quarry Trucks
  - Low to medium EGT
  - ADPF candidates
- Well maintained (Service ~ 250 hours)

# High & Low EGT profiles

Terex TR70 Quarry Truck (Trial 1)



Komatsu PC 750 Excavator



# 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



# ECT Providers

## Engine Control Systems –

### *“Cattrap™”*

- 380 – 420 °C for 20% of duty-cycle.
- Base (not precious) metal catalyst coating.
- Zero nitrogen dioxide NO<sub>2</sub> emissions.
- Mining applications.

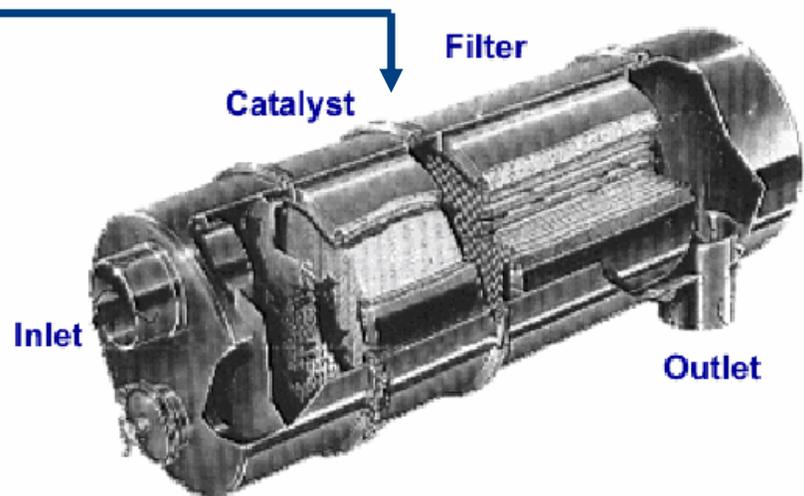


# ECT Providers

## 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 NO<sub>2</sub> production
  - One high HP excavator

- Deliberately generates NO<sub>2</sub>.
- Excess NO<sub>2</sub> improves regen → lower EGT.
- But can produce excess NO<sub>2</sub> out the tailpipe.



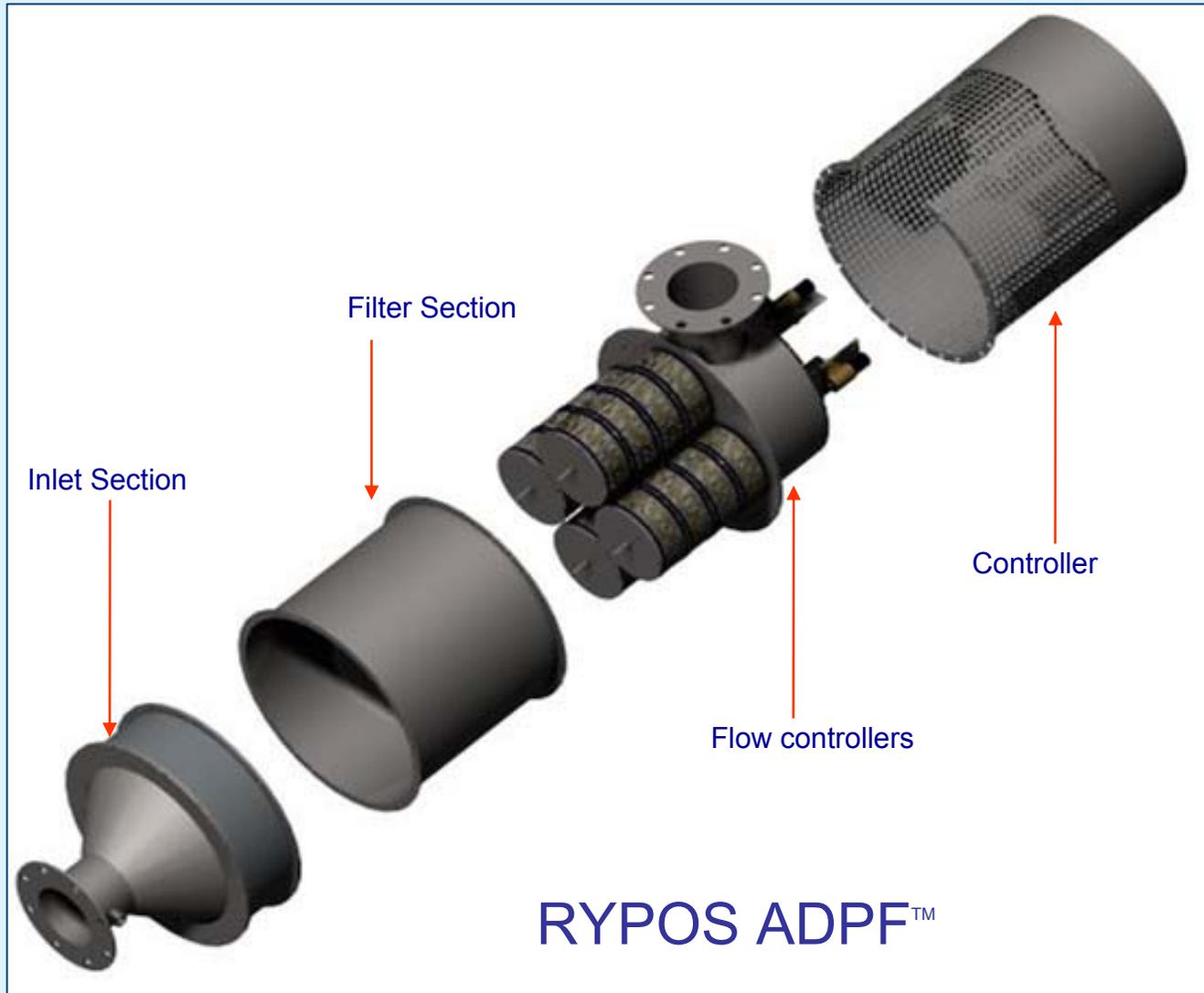
# Providers (cont.)

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## 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.

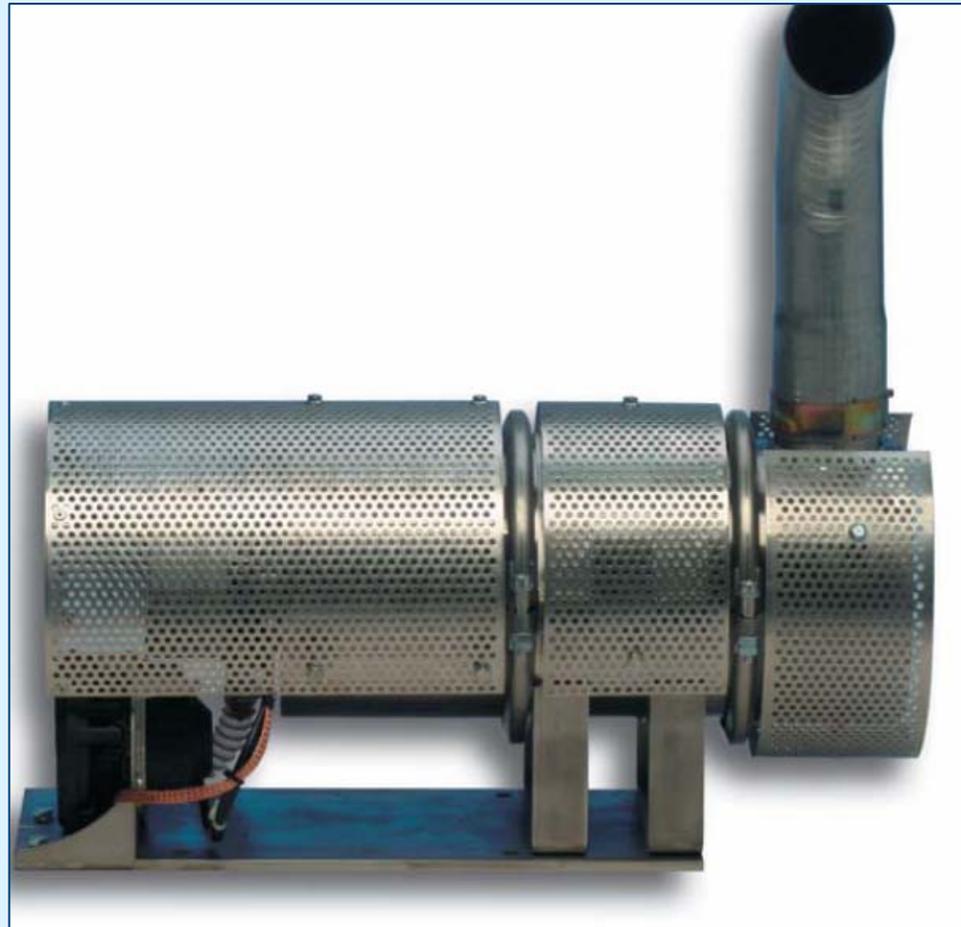
# ADPF – Onboard Electrical Regeneration



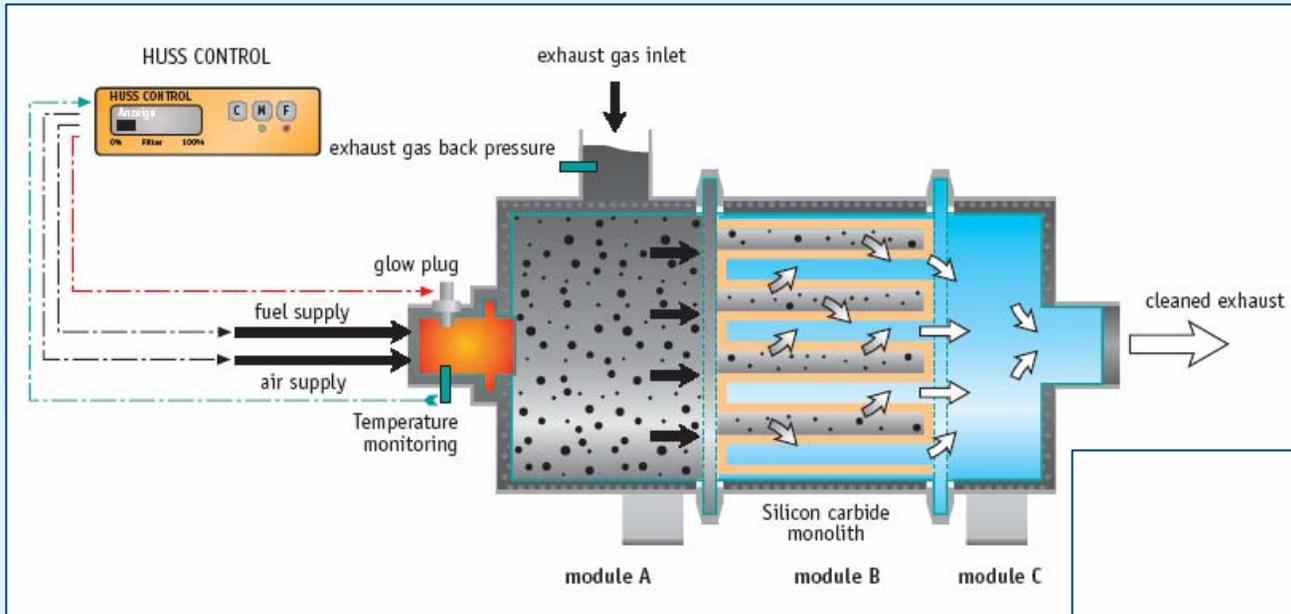
# Providers (cont.)

## Huss

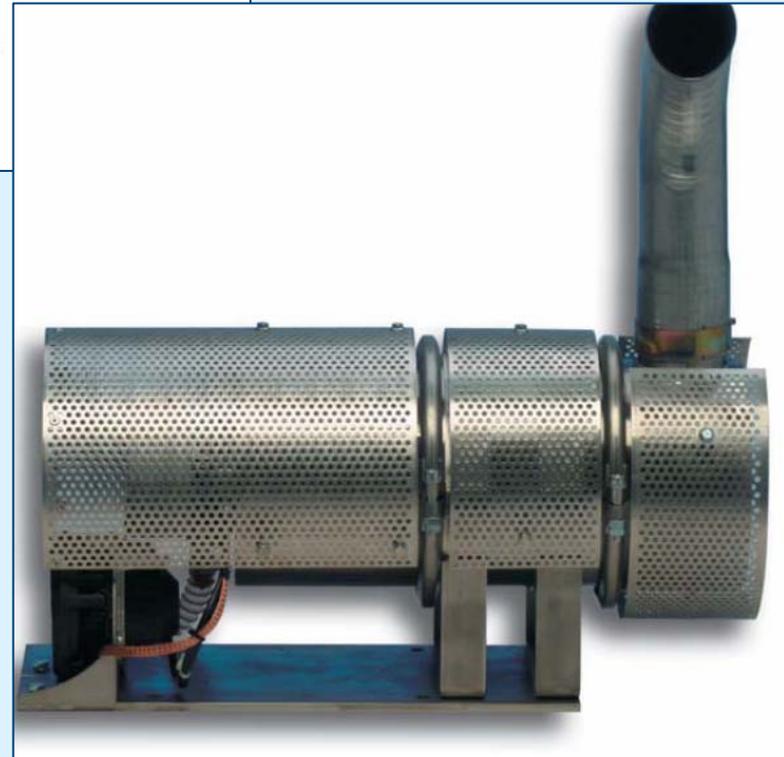
- Active Diesel Particulate Filter (ADPF) – *MK Fuel Burner Series*
- On-board fuel burner in exhaust system for regeneration.
- Croton: Terex TA-40 400 hp DDC Series 60.
- DSNY: Caterpillar D400 400 hp 3406.
- ARB Level 3 verification for on-highway and nonroad.



# ADPF – Onboard Fuel Burner



## Huss MK Burner System



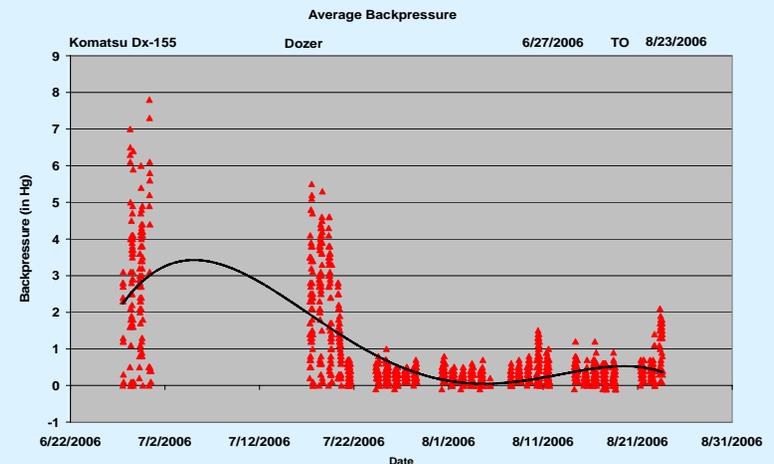
# Technology Deployment

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- 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

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## 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

COMPOUND	Analysis Method	Instrument	Sample Collection
Carbon Monoxide (CO)	Non-Dispersive Infrared Detection (NDIR)	HORIBA Model AIA-210 LE	Cali-5-Bond™ (five layer) Sample bag
Carbon Dioxide (CO <sub>2</sub> )	Non-Dispersive Infrared Detection (NDIR)	HORIBA Model OPE-115	Cali-5-Bond™ (five layer) Sample bag
Oxides of Nitrogen (NO <sub>x</sub> )	Chemiluminescence Detection	California Analytical Instruments Model 400-HCLD	Cali-5-Bond™ (five layer) Sample bag
Nitric Oxide (NO)	Chemiluminescence Detection	California Analytical Instruments Model 400-HCLD	Cali-5-Bond™ (five layer) Sample bag
Total Hydrocarbons (THC)	Heated Flame Ionization Detection (FID)	California Analytical Instruments Model 300M-HFID	Cali-5-Bond™ (five layer) Sample bag
Particulate Matter (PM)	Gravimetric Procedure	Sartorius M5P-000V001	70mm Pall Emfab™ filters
Ammonia (NH <sub>3</sub> )	To Be Determined		Citric acid coated filters

# Equipment Tested

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

# Equipment Emissions

Source	DPF	Test Equipment/Engine	Test Cycle <sup>a</sup>	Applicability	Fuel	Mean Emissions Reduction (%)			
						PM <sup>a</sup>	NO <sub>x</sub>	HC	CO
In-Use Emission Testing Program Conducted by Emisstar and Environment Canada	Johnson Matthey SCRT	Ingersoll Rand IR600 Compressor; 170 hp	Simple In-Use	Nonroad	ULSD	97	67	94	99
	ECS Purifilter PDPF	Komatsu D155 Dozer; 332 hp	Synthesized In-Use	Nonroad	ULSD	97	5	93	99
	ECS Purifilter PDPF	Komatsu PC750 Excavator; 474 hp	Synthesized In-Use	Nonroad	ULSD	99	12	79	98
	Johnson Matthey CRT	CAT 966G Rubber Tire Loader; 259 hp	In-Use	Nonroad	ULSD	99	7	81	93
	ECS Purifilter PDPF	Tamrock CHA700 Tiger Drill; 173 hp	In-Use	Nonroad	ULSD	99	5	52	99

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

*<sup>a</sup> 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

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- 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

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- 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

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What are the similarities;  
what are the differences?

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

*What do you think?*

# Filter substrate failure

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# Croton Picture Gallery



Muffler → PDPF



# Croton – Furukawa Hydraulic Drill

ECS PDPF



# Croton – Hitachi Z-Axis 800 Excavator (2)

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# Croton – Hitachi Z-Axis 800 Excavator (2)

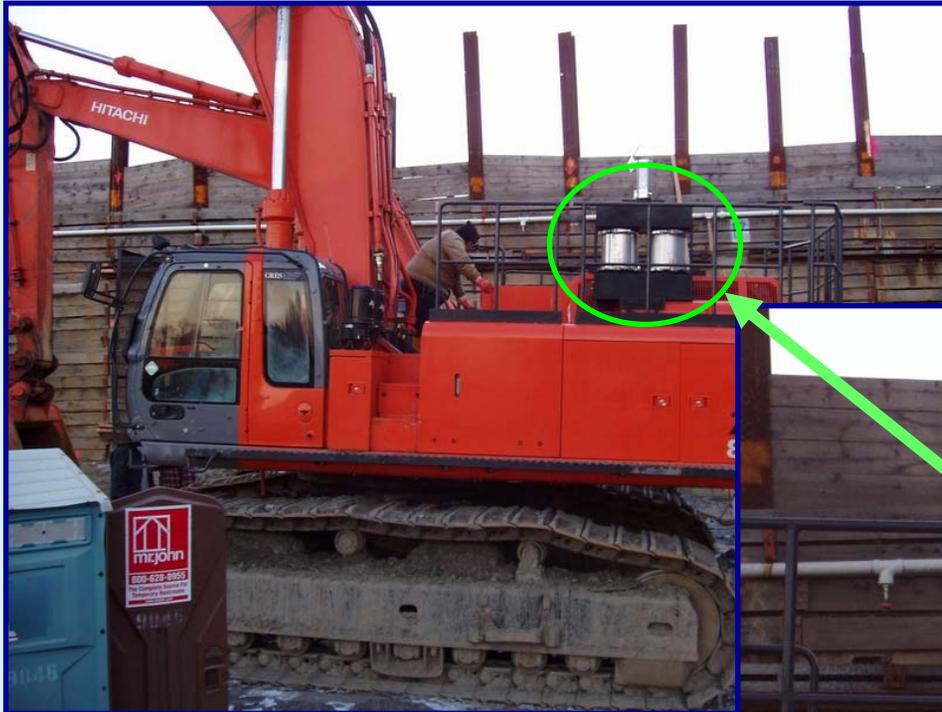


# Croton – Hitachi Z-Axis 800 Excavator (2 machines)

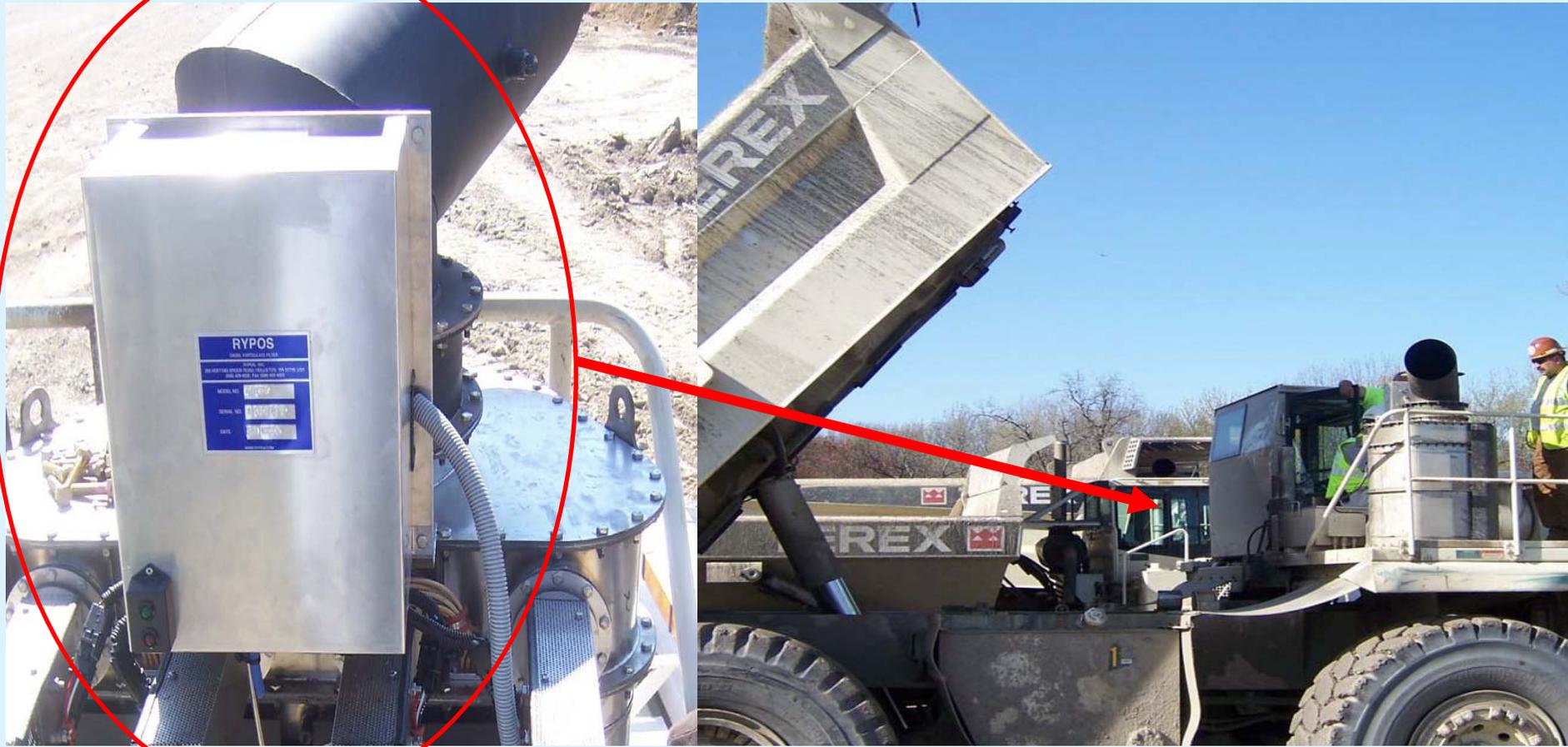
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# Croton – Hitachi Z-Axis 800 Excavator (2)



# Croton – Terex TR 70 w/Rypos ADPF/C



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