

Stillwater Mine DPM Reduction

Exhaust Aftertreatment
Implementation



Stillwater Mine Experience

- Isozone Studies followed by actual operation
 - Some techniques worked, some marginal.
 - No “one size fits all”
- Types of Aftertreatment Devices
 - Active DPF's
 - Arvin-Meritor “Fuel Burner”
 - DCL Titan
 - Passive Units
 - Catalyzed & Base Metal DPF's (Engelhard & DCL Mine-X)
 - ESW Particulate Reactors
 - Disposable filters



Preliminary Information

Three equipment groups contribute equally to DPM loading at the Stillwater Mine (based upon Hp)

- Muck haul Fleet
 - 26 Units
 - Trucks & Locomotives
- LHD Fleet
 - 77 Units
- Utility Equipment
 - <200 Units of multiple types & variations



First Group Attacked

Muckhaul Fleet - Trucks & Locomotives

- High duty cycle & small number of equipment
- Passive DPF's work well - "Perfect" application
 - Catalyzed
 - 19 MTI1604 haul trucks with Engelhard
 - 1 Cat/Elphinstone AD30's with DCL Mine-X Sootfilter
 - 4 20-ton Brookville Loci's with Engelhard.
 - DCL Mine-X Sootfilter BM (base metal) on two Cat AD30's for NO₂ reduction
 - Excellent Duty Cycle with High EGT's >900°F
 - NO₂ reduction as well as DPM regeneration
 - Second unit installed in December '06
 - Plan to install on the remaining AD30 in '07



Six System Engine Preventive Maintenance (EPM) Form

Site 2900 Shop

Date 10/2/06 (m/d/yy)

Vehicle # UT202 Model AD30 Hourmeter 7,547.00

Engine Make & Model 3406E CAT

Pre PM Cleaning

- Steam clean engine and surrounding compartments
- Clean radiator and coolers with degreaser and high volume-pressure water hose
- Air Cooled: Remove inspection covers – degreaser and steam clean cylinders and cooler

Perform Emissions Test

- > Warm up engine to 180°F oil temperature
- > Engine Speed @ hi-idle no load 2330 RPM
- > Engine Speed @ hi-idle transmission stall 1983 RPM
- > Engine Speed @ hi-idle transmission & hydraulic stall RPM
- > Measure emissions @ transmission & hydraulic stall

Emissions Testing Performed at:

Full Throttle Transmission Only Stall - Steady State

	Inlet Side	Outlet Side
Smoke Index	8.00	1.00
O ₂ %	11.50	11.50
CO ppm	106.70	27.50
NO ppm	359.10	368.40
NO ₂ ppm	26.40	15.10
CO ₂ %	7.00	7.00
T. Gas °F	338.00	646.90
MEQI Cert Index	27.40	20.90
NO _x ppm	385.50	383.50

- > DOC Conversion Efficiency
 - o $[1 - \text{CO Out} / \text{CO In}] \times 100 = 74.23\%$
 - o Action required if less than 75% OR greater than 75 ppm CO @ tailpipe after DOC

Second Group Being Attacked

LHD Fleet - Large variability in duty cycles

- Disposable filters placed on 21 units
 - Larger LHD's - plug within minutes
 - High Hp and space limitations negate practicality
 - Not cost effective due to logistics
 - Blow out if operators do not change often
 - Removed all by Q3-06
- Experimentation with passive DPF's promising
 - 39 passive DPF's (MTI LT270 – Cat/Elphinstone R1300) 33 Engelhard & 6 DCL Mine-X
 - 9 ESW Particulate Reactors (older MTI LT210 & LT270's that had low duty cycles and rapid plugging of DPF's.)



ESW Particulate Reactor

ESW Particulate Reactor

- “Super” catalytic converter
- Passive, low backpressure filter
- Less efficient than DPF (<30% DPM removal)
- Originally intended for Mules, skid steers, tractors, & smaller engines.
- Installed on small LHD’s with low duty cycles to find a solution without plugging issues.





Six System Engine Preventive Maintenance (EPM) Form

Site Select One

Date 11/22/06 (m/d/yy)

Vehicle # mu116 Model MTI Hourmeter 1,692.00

Engine Make & Model DUETZ 4M 1013 C

Pre PM Cleaning

- Steam clean engine and surrounding compartments
- Clean radiator and coolers with degreaser and high volume-pressure water hose
- Air Cooled: Remove inspection covers – degreaser and steam clean cylinders and cooler

Perform Emissions Test

- > Warm up engine to 180°F oil temperature
- > Engine Speed @ hi-idle no load 2125 RPM
- > Engine Speed @ hi-idle transmission stall 2090 RPM
- > Engine Speed @ hi-idle transmission & hydraulic stall 2090 RPM
- > Measure emissions @ transmission & hydraulic stall

Emissions Testing Performed at:

Full Throttle Transmission + Hyd Stall - Steady State

	Inlet Side	Outlet Side
Smoke Index	7.00	3.00
O ₂ %	11.70	12.40
CO ppm	176.20	60.00
NO ppm	806.40	847.10
NO ₂ ppm	46.60	22.30
CO ₂ %	6.80	6.30
T. Gas °F	447.40	553.30
MEQI Cert Index	54.90	43.70
NO _x ppm	853.00	869.40

- > DOC Conversion Efficiency
 - o $[1 - \text{CO Out} / \text{CO In}] \times 100 = 65.95\%$
 - o Action required if less than 75% OR greater than 75 ppm CO @ tailpipe after DOC

Six System Engine Preventive Maintenance (EPM) Form

Site 6100 Shop

Date 9/28/06 (m/d/yy)

Vehicle # AV021 Model Mule Hourmeter 985.00

Engine Make & Model Kawasaki 1DHXL

Pre PM Cleaning

- Steam clean engine and surrounding compartments
- Clean radiator and coolers with degreaser and high volume-pressure water hose
- Air Cooled: Remove inspection covers – degreaser and steam clean cylinders and cooler

Perform Emissions Test

- > Warm up engine to 180°F oil temperature
- > Engine Speed @ hi-idle no load 3813 RPM
- > Engine Speed @ hi-idle transmission stall RPM
- > Engine Speed @ hi-idle transmission & hydraulic stall RPM
- > Measure emissions @ transmission & hydraulic stall

Emissions Testing Performed at:

Free Snap Acceleration X 3 - Transient

	Inlet Side	Outlet Side
Smoke Index	9.00	7.00
O ₂ %	15.90	16.30
CO ppm	1194.30	917.00
NO ppm	102.50	141.70
NO ₂ ppm	15.50	2.40
CO ₂ %	3.80	3.50
T. Gas °F	388.40	233.40
MEQI Cert Index	57.00	43.10
NO _x ppm	118.00	144.10

- > DOC Conversion Efficiency
 - o $[1 - \text{CO Out} / \text{CO In}] \times 100 = 23.22\%$
 - o Action required if less than 75% OR greater than 75 ppm CO @ tailpipe after DOC

Rypos Active On-Board DPF

Cat/Elphinstone LHD's and ceramic DPF's

- DPF's worked well as long as fueling rate was at specification
- Need an alternative immune to fueling rates
- Rypos electric, active on-board DPF
 - MSHA testing suggests +80% DPM removal
 - Started conversation with Rypos in May '06
 - Tight quarters for location.



SMC Efforts 2005 to Present

Utility Equipment - Most Difficult to Solve

- <200 units of multiple types & variations
- Wide range of duty cycles, mostly low
- 3 Passive DPF's on motor graders (Engelhard)
- 5 Active DPF's - no longer available (DCL Titan)
- 54 ESW Reactors installed - additional units scheduled
- 21 Fork Lifts & Skid Steers considered low priority due to DPM Sampling
- 18 units limited by hearing conservation (cowl mufflers)
- 25 J Deere tractors replaced with lower emitting Kawasaki Mules. The mules work very well with ESW Reactors.



Results to date

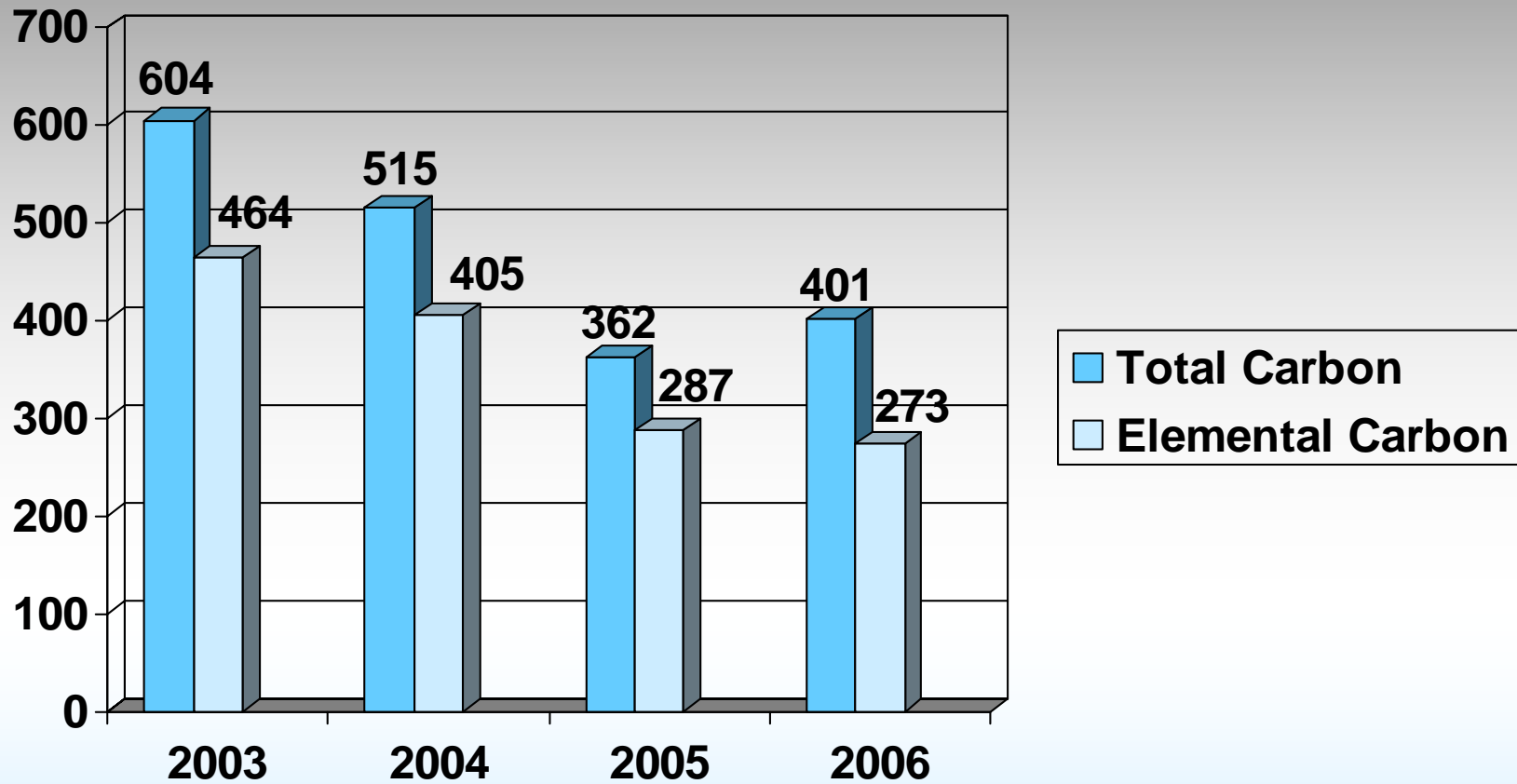
By the end of '06 the Stillwater Mine installed
142 exhaust treatments

- 5 Active DPF's
- 68 Passive
- 69 ESW Particulate Reactors

Complete treatment of Muck haul fleet reduced
DPM by $\frac{1}{3}$ at the Stillwater Mine



2003-2006 Sample History



Results to Date

- Have Stillwater's efforts been perfect?
 - No, realized some setbacks.
 - Not everything that works for others have worked well for Stillwater.
- Has Stillwater had success?
 - Overall Stillwater has had success.
 - Not satisfied – Exhaust treatments are only a part of the overall DPM solution.
 - Other technologies combined with exhaust treatments are SMC's plan.

