

# DPM Reduction at the Stillwater Mine

# Early Stillwater Work

- The Stillwater Mine tested many technologies during the Isozone Studies.
  - Some techniques worked, some did not or were marginal
  - Some not desirable
  - No “one size or type fits all”
- Stillwater then concentrated on a few items as part of a complete package (Integrated Approach) to reduce DPM exposure.
  - Increase ventilation to the mine (completed before most Isozone studies)
  - Engines (Electronic Engine or Governor Retrofits)
  - Exhaust Treatments
  - Bio-Diesel Blends
  - Reduce diesel-powered mining techniques



# Improved Ventilation

- Change ventilation design to improve air to miners by increasing dilution
  - Replaced series ventilation paths with parallel ventilation paths
    - 600k to 1.0M SCFM – Completed by Q2-'02
    - 1.0M to 1.3M SCFM - planned for completion by Q4-'07
  - Changed auxiliary fan standard to provide engineered duct-to-fan fit for better efficiencies



# Direction of Main Efforts

Early investigation determined that three fleets contributed equally to Stillwater's DPM loading, providing a method of attack

- First Group Attacked – 28 Unit Muckhaul Fleet
  - Then 22 Trucks & 6 Locomotives
  - Now 23 Trucks & 6 locomotives
- Second Group Attacked – 77 Unit LHD Fleet
  - 77 Units originally in 6 different classes
  - 73 Units in 5 classes, soon to be 4 classes
- Third Group Attacked – 180 Unit Utility Fleet
  - Multiple types, sizes & variations



# Engines (Electronic Controls)

- Electronic engine & governor retrofits
  - Provide better fuel control
  - Easier to tune
  - Stay in tune longer
- Electronic governors available for part of our Deutz fleet
  - Peaked at 54 units
  - Currently at 47 units – reduction due to electronic engine replacement
- Currently, 68 Electronically-controlled Engines (13 are Tier 3)
- Total electronic engine controls in service
  - Muckhaul Fleet fully treated at 3 governors & 26 engines
  - LHD Fleet has 20 governors & 33 electronic engines
  - Utility Fleet has 24 governors & 8 engines



# Engines (Tuning)

- Maintain engine tune for best emissions
  - Keeps DPM at its lowest
  - Reduces DPM loading in DPF's
- EECOM for gas analysis
- Smoke Dot for PM indicator
- Train mechanics on components affecting DPM
- Emissions testing on a 28-day cycle



# Exhaust Treatments

- Electronic engines & governors showed minimal reduction and not available for approximately  $\frac{3}{4}$  of Stillwater's equipment.
- Stillwater's main direction towards exhaust treatments.
  - Muckhaul fleet 1<sup>st</sup> Group Attacked
  - LHD Fleet 2<sup>nd</sup> Group Attacked
  - Utility Fleet 3<sup>rd</sup> Group Attacked



# Exhaust Treatments

## First Group Attacked

### Muckhaul Fleet - Trucks & Locomotives

- High duty cycle & small number of equipment
- The “perfect” application for passive DPF’s
  - Catalyzed DPF
    - 19 MTI1604 haul trucks with Engelhard Sootfilters
    - 4 20-ton Brookville Loci’s with Engelhard Sootfilters.
  - Base Metal (non-catalyzed) DPF
    - DCL Mine-X<sup>®</sup> BM on fou Cat AD30’s
    - Excellent Duty Cycle EGT’s >900°F
    - Lower NO<sub>2</sub> production as well as DPM regeneration.  
(Recent field measurements – No detectable NO<sub>2</sub> behind two running trucks)





# Exhaust Treatments

## Second Group Attacked

### LHD Fleet - Large duty cycle variability

- Passive DPF's promising – 55 of 73 units
  - 43 passive DPF's (MTI LT270 – Cat/Elphinstone R1300)  
33 Engelhard & 6 DCL Mine-X<sup>®</sup> Sootfilters
  - 12 ESW Particulate Reactors <sup>TM</sup> (older MTI LT210 & LT270's that had low duty cycles and rapid plugging of DPF's.)
- Disposable filters 21 units (Historical)
  - High Hp and narrow vein size negate practicality
  - Not cost effective due to logistics for quantity
  - Blow out if operators do not change often
  - Removed by Q3-06 due to fire hazard



# LHD in Stope X-Sec

- Example of Stillwater's production area.
- No room outside engine compartment for exhaust treatments



# Exhaust Treatments

## Third Group Attacked

Utility Fleet consists of roughly 180 Units, with wide ranges of duty cycles and mostly low hp.

- Eight “medium” duty cycle equipment
  - Five delivery vehicles with dedicated number of operators have DCL Titan <sup>TM</sup> – active, catalyzed DPF’s that operate in passive mode with operator efforts for high EGT’s.
  - Three motor graders have Engelhard passive DPF’s
- Remainder of fleet have “Flow Through Filters” utilizing metal substrates.



# Flow Through Particulate Filters

- Initially, ceramic DPF's resulted in blown engines or plugged filters, or both.
- Needed a filter with lower backpressure and less chance of plugging
- Stillwater found two products with promising results:
  - ESW Particulate Reactor™ (also called M CAT™)
  - DCL Mine-X® Ultra
- These filters are less DPM efficient than ceramic DPF's
  - Reactor efficiency currently at 30%
  - Newer generation & Mine-X® Ultra claim efficiency >50% with ULSD.
  - Metal substrate – low thermal time constant
  - Catalyzed, passive, low backpressure filter
  - Both manufacturers will install within factory muffler



# Rypos Active On-Board DPF

## Elphinstone R1300's & Ceramic DPF's

- DPF's worked (within reason)
  - Fueling rate too easy for miners to “adjust”
- Need an alternative immune to fueling rates
- Rypos electric, active on-board DPF
  - '07 MSHA testing suggests +90% DPM reduction
  - Environment Canada suggests +90% DPM reduction combined with NO<sub>2</sub> reduction
  - Expect complete installation by June 30, 2007

# Bio-Diesel Blends

Isozone Studies and Stillwater experience determine that Bio-Diesel is the only alternative fuel providing DPM reduction

- Summer '05 – B5, B10 & B20 showed measurable reductions in discrete area of mine & no operational issues.
- Summer '06 –
  - B20 blended with #2 ULSD in complete underground
  - B50 & B99 in one captive LHD stope
    - Miners noticed improvement in their work environment
    - Noticeable change from B20 to B50 in Area & Personal samples
    - Not as noticeable a change from B50 to B99
  - Local Vendor stopped providing due to worries about gelling in his tank farm.
- Spring '07 –
  - B20 blended with ULSD #2 in early April
  - B50 with ULSD #2 on April 30
- Stillwater is developing storage facilities for winter use of  $\geq$ B50
- Stillwater currently has a few issues with Bio-Diesel
  - Winter delivery to the minesite & finding supply for year round consumption.
  - Engine manufacturers do not currently approve of bio-diesel greater than B5 (Cummins has some classes of engines approved for B20)



# Reduce Diesel-Powered Mining Techniques

- Electric power for haulage and some production areas to reduce diesel engines
  - 3500 Rail Haulage with battery locomotives removed the need for 5 haul trucks on one level
  - Future 2000 Level with battery locomotives to feed Kirunas
  - Future ABB Kiruna Trucks (Trolley-powered trucks)
    - Coupled with battery locomotives to deliver ore & waste from lower levels up to production hoist.
- Captive slusher mining
  - Convert 25% of production mining to captive slusher mining techniques



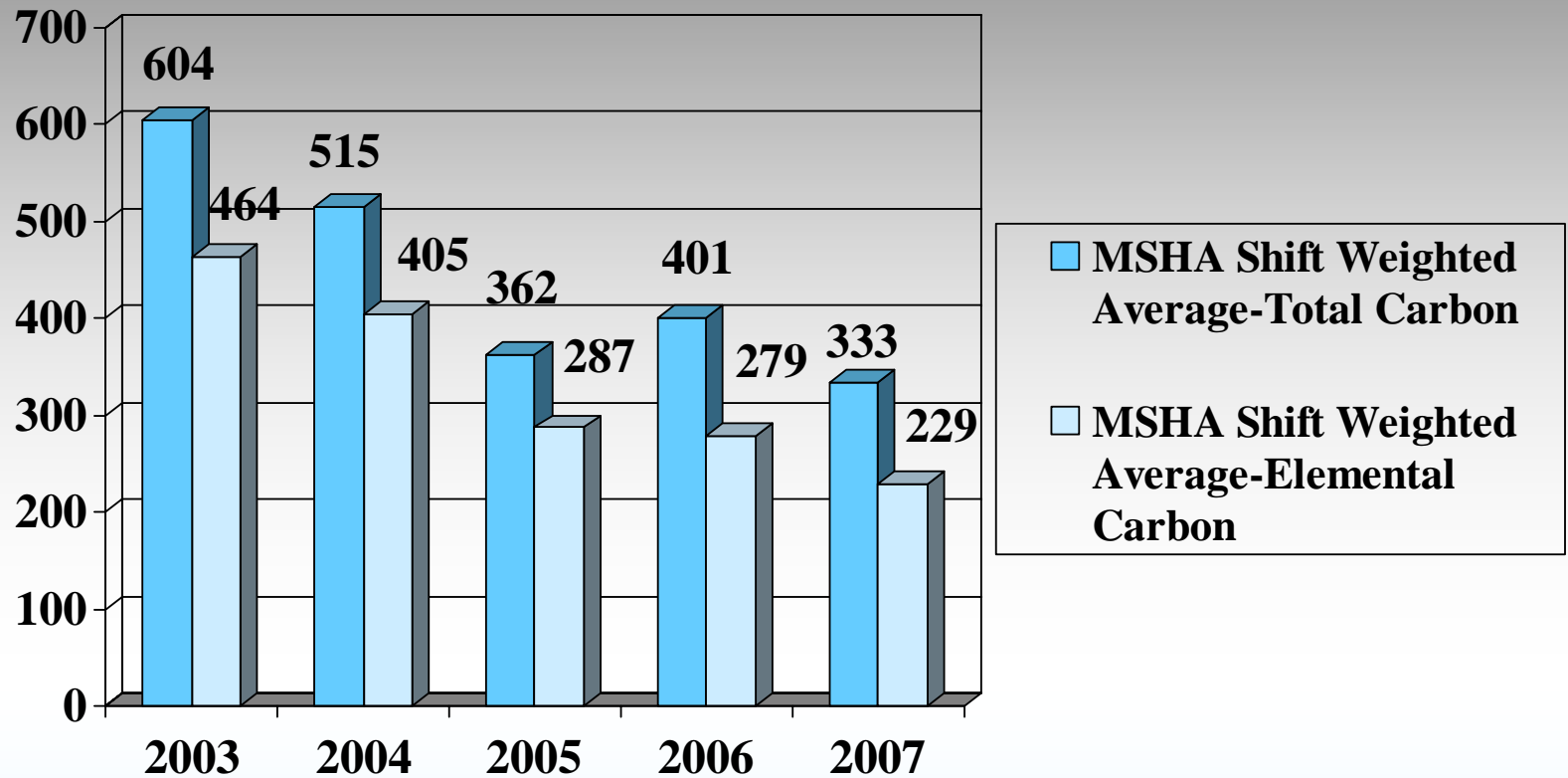
# Results

- By Q2-07 the Stillwater Mine installed 181 exhaust treatments
  - 5 Active DPF's operating passively (DCL Titan™)
  - 73 Passive (including three Base Metal units)
  - 102 ESW Particulate Reactors™
  - 1 DCL Mine X® Ultra
- Complete treatment of Muckhaul fleet reduced DPM by  $\frac{1}{3}$  at the Stillwater Mine
- Few passive DPF applications left.
  - Remaining applications will mostly be flow through filters with lower DPM efficiencies





# 2003-2007 YTD Average Sample History



# Final Comments

- Has Stillwater had success?
  - Passive DPF's on Muckhaul Fleet reduced overall DPM by  $\frac{1}{3}$ .
  - Passive DPF's on majority of LHD fleet.
  - Bio-D blends even with infrastructure difficulties.
  - Electrical-powered haulage & captive slusher stopes to replace diesel power
- Have Stillwater's efforts been perfect?
  - Not every technology works everywhere, wasted lots of energy on items that did not work.
  - Low duty cycle applications with "good" or "better" DPM efficiency not yet proven
- What prevents Stillwater from achieving its DPM reduction goal?
  - Need higher DPM efficiency for low duty cycle equipment
  - Current technology for flow through filters at 30% reduction
  - Need NO<sub>2</sub> reducing technologies not reliant upon EGT
  - Bio-Diesel not yet available year 'round due to local infrastructure.

