Meeting ACGIH Nitrogen Dioxide Limits in Mechanized Underground Mining

Overview

- Understanding the Challenge
  - Reduction in ACGIH NO₂ TLV
  - NO₂ Sources in Underground Mining
- Recognize the Opportunity
  - Diesel Engines
- Experience in Implementation
  - Vendor Consultations
  - Operations Feedback
  - Opportunities & Challenges
ACGIH NO₂ TLV Reduction

<table>
<thead>
<tr>
<th>Year</th>
<th>NO₂ Threshold Limit Value (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>3.0</td>
</tr>
<tr>
<td>2013</td>
<td>1.8</td>
</tr>
</tbody>
</table>

- 8 Hour Shift
- Extended Shift Length (11 Hour)

NO₂ Sources in Mining

- Direct Fired Heaters
- Blasting Operations
- Diesel Equipment
Mine Heating Contribution to Workplace NO$_2$

– Indirect heaters such as diesel units have no emission to the mine
– For direct firing heaters, high flame temperatures or “dwell” will cause NO$_2$ formation
– Burner emissions requirements were updated in 1999 by CSA Standard 3.7-1999 / ANSI Z83.4: less than 0.05 ppm as measured in the airstream
  – This is very low, but still >40% of an extended shift TLV
– Combustion performance is defined by burner design, not the overall heater system package.
  – Vendors report some improvements in burner product lines
  – NO$_2$ regularly measured/reported as zero in heated air
– For meeting ACGIH TLV, prefer indirect fired heating, but premium burner technology is improving and can likely beat CSA limit

Blasting Gas Contribution to Workplace NO$_2$

– Blasting NO$_2$ is a concern both in smoke plume and in residual gasses in the muck that are released during mucking
– Plume can easily exceed 150 ppm (>1000 x TLV)
– Test work in 2016 at Glencore’s Nickel Rim South Mine – seeking to quantify blast clear times
  – Testing both ANFO and emulsion explosives (2 ea.)
  – ANFO blasts both >100 ppm NO$_2$
  – Discovered NO$_2$ below detection with emulsion
– Emulsion explosive very promising for compliance
Diesel Engine Emission Control

Increasingly advanced engine technologies used to meet stricter emission regulations.

80% NOx reduction with Tier 4 Final

*Applicable for engines 130 – 560 kW
**Tier 2 and 3 emission standards are for sum of NOx and NMHC

Airborne NO2 Sensitivity

*Applicable for engines 130 – 560 kW
**Assumptions:
- Ventilation air rate of 74 cfm/bhp
- Ambient conditions of 20°C and 1.2 kg/m³
- 20% (wt%) NO2/NOx ratio
Vendor Consultation Experience

- Being Tier 4F certified does not guarantee an engine will meet workplace NO\(_2\) limits
- Compliance requires low NO\(_2\)/NO\(_x\) ratio
- Ratio can vary greatly across different engine operating modes
Vendor Consultation Experience

Operations Feedback

- Operator complaints about NO\textsubscript{x} smell with Tier 2/3 engines
- Mine in Quebec repowered 50T truck with SCR technology
- Change highly appreciated by operators due to:
  - Improved environment odour due to lower NO\textsubscript{x} content
  - Improved performance when trucks moving uphill
- Maintenance interval extended from 12,000 to 20,000 hours
  - Loss of diesel particulate filter helps reduce maintenance time
- Equipment found to be reliable and performs well in environment
Benefits in addition to reduced NO₂ emissions

- Economic & achievable ventilation air quantities are maintained
- Reduced or eliminated need for engine exhaust gas recirculation, which improves performance and increases fuel efficiency
- Less particulate matter formed with more efficient combustion process, which reduces strain on engine’s diesel particulate filter (DPF) or eliminates need for it
- Additional NOₓ generated can help support DPF regeneration (if needed)

Challenges

- Diesel exhaust fluid logistics and dispensing infrastructure
- Ammonia slip protection
- Readiness of engine vendors to bias SCR to NO₂ conversion
- NO₂ emissions during other engine operating modes
  - Start-up
  - Regeneration, etc.
Discussion and Questions?