MDEC 2009

NO_2 Emissions in Mines

1. Regulated Engine NOx Emissions

$NOx = NO + NO_2$

NO – nitric oxide
NO_2 – nitrogen dioxide

Nitrous oxide – N_2O (laughing gas) is not a regulated emission

2. Exposure Limits for Nitrogen Oxides

ACGIH TLV (TWA 8hr):

NO: 25 ppm

NO_2: 3 ppm

N_2O: 50 ppm

3. NOx Composition in Diesel Exhaust (no catalyst)

Older technology, naturally aspirated:

NO: 95%

NO_2: 5%

New, turbocharged diesel engines:

NO: 85%

NO_2: 15%

4. Oxidation of NO to NO_2

$2NO + O_2 \leftrightarrow 2NO_2$

- reaction occurring spontaneously in the atmosphere
- equilibrium reaction

5. Impact of Oxidation Catalysts

- Oxidation catalysts greatly increase the NO/NO_2 reaction rate.
- Pt/Al_2O_3 catalysts—common in diesel applications—are especially active.
- Pt-based catalytic filters widely used in US 2007 engines.

Conclusion: Emission controlled diesel engines have significantly increased NO_2 /NO ratio in their total NOx emission.

6. Implications of High NO_2 / NOx—Environmental Effects

- Suspected adverse effects, but the exact impact remains uncertain
- Future emission standards also require very low NOx; even at increased NO_2/NOx ratios, the absolute NO_2 emissions will be reduced
- Little concern in regards to future emission standards
- Concerns exist in DPF retrofit applications with older high NOx engines
- California ARB: NO_2 must not be more than 20% of total NOx (based on uncontrolled engine emission baseline) for verified emission retrofit technologies

7. Occupational Health

- Increased diesel NO_2 may contribute to exceeding TLV levels
- MSHA PIB P02-7, July 16, 2002: "...particulate filters introduced into the underground [coal] mine (...) must not cause an increase in NO_2 concentrations in the raw exhaust."

8. Diesel Smoke Opacity Measurement—NO_2 Interference

NO_2 absorbs green light and causes a false opacity reading. In DPF equipped engines, the majority of the opacity meter signal can be caused by NO_2, rather than by diesel soot.

9. NO_2 Control—Diesel Oxidation Catalysts

- Selective formulations optimized for low sulfate emissions appear to have also low NO_2 production
    - Base metal/low Pt technology
    - Vanadium doped formulations
- But:
    - low sulfate formulations may have low effectiveness in controlling HC, CO, odor, etc.
    - low sulfate catalysts will be abandoned as ultra low sulfur fuels become available

10. NO_2 Control—Diesel Particulate Filters

- Passive DPF systems
    - Less active formulations possible (e.g., base metal DPFs), but require higher regeneration temperatures
        - can be applied only on very hot vehicles
    - Wide consensus on using Pt in passive and quasi-passive DPF systems (US heavy-duty engines, EU passenger cars)
- Fuel additive regenerated filters
    - low regeneration temperatures, low NO_2, but doping the fuel with additive often inconvenient
- Active DPF systems
    - There are no NO_2 problems, but no automated systems available for U.S. Mining market
    - Manually regenerated systems (electric off-board, shore power, ...)—no NO_2 increase, but high maintenance involved