

MDEC 2009

NO₂ Emissions in Mines1. Regulated Engine NO_x Emissions

$$\text{NO}_x = \text{NO} + \text{NO}_2$$

NO – nitric oxide

NO₂ – nitrogen dioxide

Nitrous oxide – N₂O (laughing gas) is not a regulated emission

2. Exposure Limits for Nitrogen Oxides

ACGIH TLV (TWA 8hr):

NO: 25 ppm

NO₂: 3 ppm

N₂O: 50 ppm

3. NO_x Composition in Diesel Exhaust (no catalyst)

Older technology, naturally aspirated:

NO: 95%

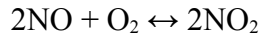
NO₂: 5%

New, turbocharged diesel engines:

NO: 85%

NO₂: 15%

4. Oxidation of NO to NO₂



- reaction occurring spontaneously in the atmosphere
- equilibrium reaction

5. Impact of Oxidation Catalysts

- Oxidation catalysts greatly increase the NO/NO₂ reaction rate.
- Pt/Al₂O₃ 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 NO₂/NO ratio in their total NO_x emission.

6. Implications of High NO₂ / NO_x—Environmental Effects

- Suspected adverse effects, but the exact impact remains uncertain
- Future emission standards also require very low NO_x; even at increased NO₂/NO_x ratios, the absolute NO₂ emissions will be reduced
- Little concern in regards to future emission standards
- Concerns exist in DPF retrofit applications with older high NO_x engines
- California ARB: NO₂ must not be more than 20% of total NO_x (based on uncontrolled engine emission baseline) for verified emission retrofit technologies

7. Occupational Health

- Increased diesel NO₂ 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 NO₂ concentrations in the raw exhaust.”

8. Diesel Smoke Opacity Measurement—NO₂ Interference

NO₂ absorbs green light and causes a false opacity reading. In DPF equipped engines, the majority of the opacity meter signal can be caused by NO₂, rather than by diesel soot.

9. NO₂ Control—Diesel Oxidation Catalysts

- Selective formulations optimized for low sulfate emissions appear to have also low NO₂ 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. NO₂ 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 NO₂, but doping the fuel with additive often inconvenient
- Active DPF systems
 - There are no NO₂ problems, but no automated systems available for U.S. Mining market
 - Manually regenerated systems (electric off-board, shore power, ...)—no NO₂ increase, but high maintenance involved