Effect of Altitude on Diesel Engine Emissions

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Mine Safety and Health Administration
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Altitude Topics

- MSHA Part 7 Subpart E Approval
  - Altitude Fuel Deration requirement
- Adjustments on NA engines
- Altitude Compensators for NA engines
- Altitude effects on Turbo-charged engines
  - Field Tests
  - Lab Tests
- Regulatory considerations

Part 7 Subpart E Approval

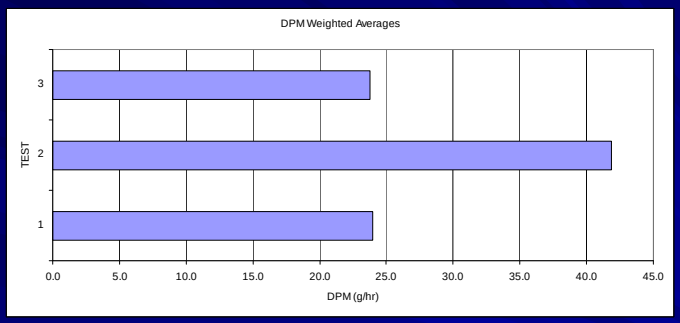
- ISO 8178 emission tests
- Maximum fuel air ratio determined
  - Cat. A: CO < 3000 ppm; NOX < 2000 ppm
  - Cat. B: CO < 2500 ppm; NOX < 2000 ppm
- Requires a fuel deration chart
  - Maximum F/A ratio is not exceeded at altitude
- Ventilation rate established
- DPM output determined and documented

Naturally Aspirated Engines

- Isuzu C240, tested in field and lab
- Cat 3306 PCNA tested in lab
  - Altitude simulator

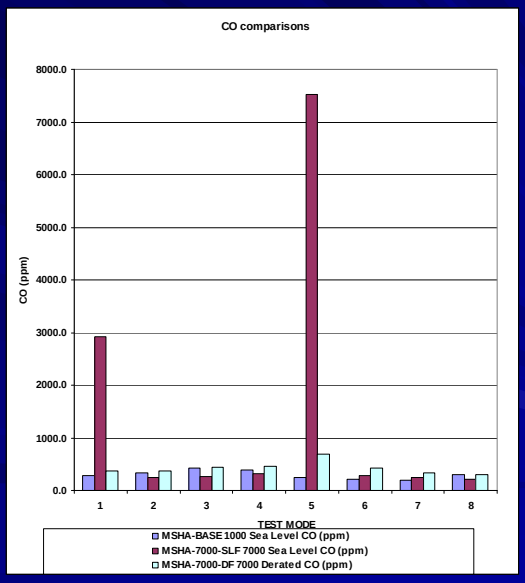
Altitude Simulation
Cat 3306 PCNA

CAT 3306 PCNA Tests

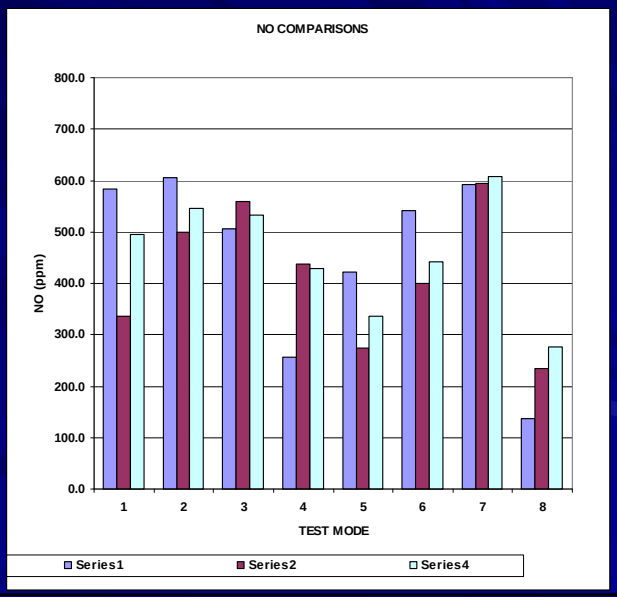


- Test 1: DPM weighted avg Baseline ~ 1100 ft.
- Test 2: DPM weighted avg – no deration – 7000 ft
- Test 3: DPM wght avg – derated 3%/1K – 7000 ft.

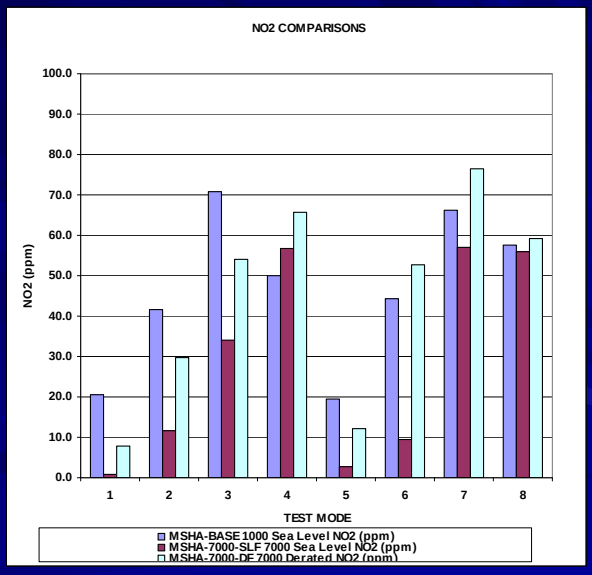
CAT 3306 PCNA – CO effects



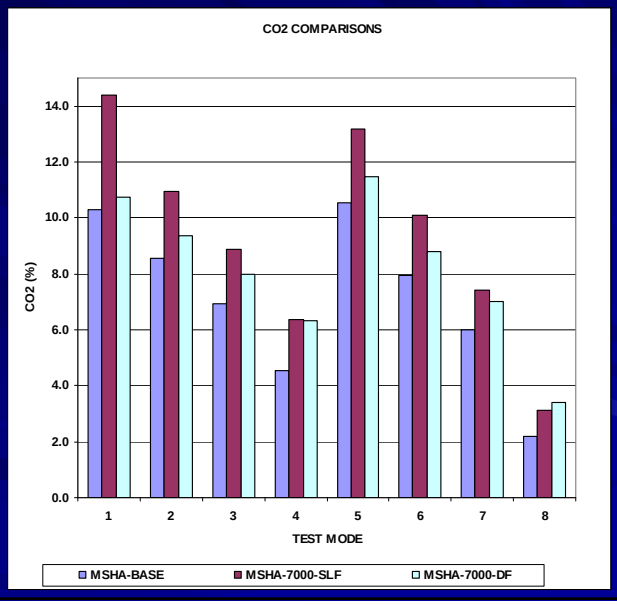
CAT 3306 PCNA – NO Effects



CAT 3306 PCNA – NO2 Effects

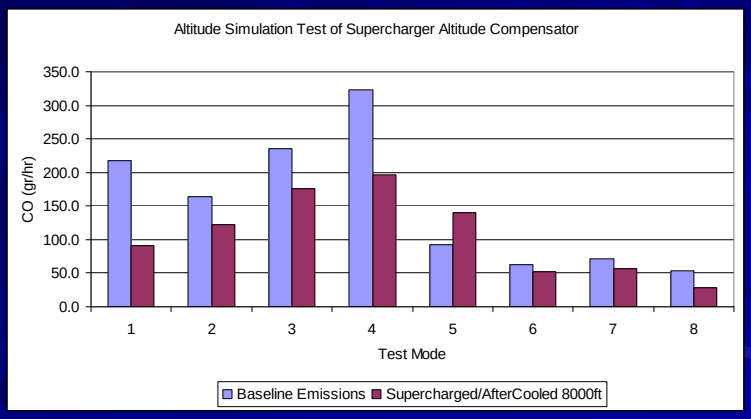


CAT 3306 PCNA – CO2 Effects

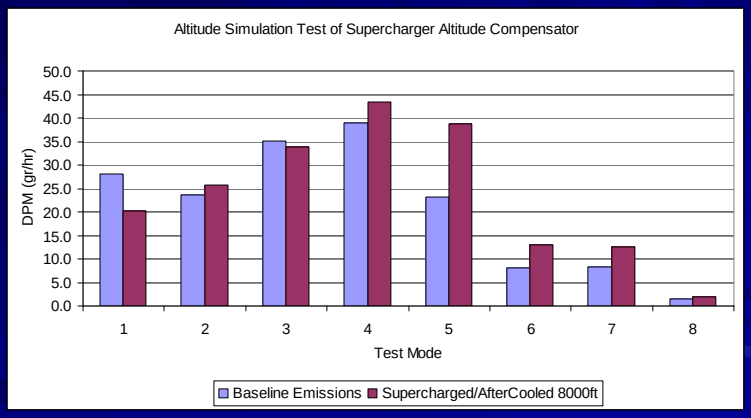


Supercharged 3306 PCNA

Supercharged 3306 – CO effects



Supercharged 3306 – dpm effects



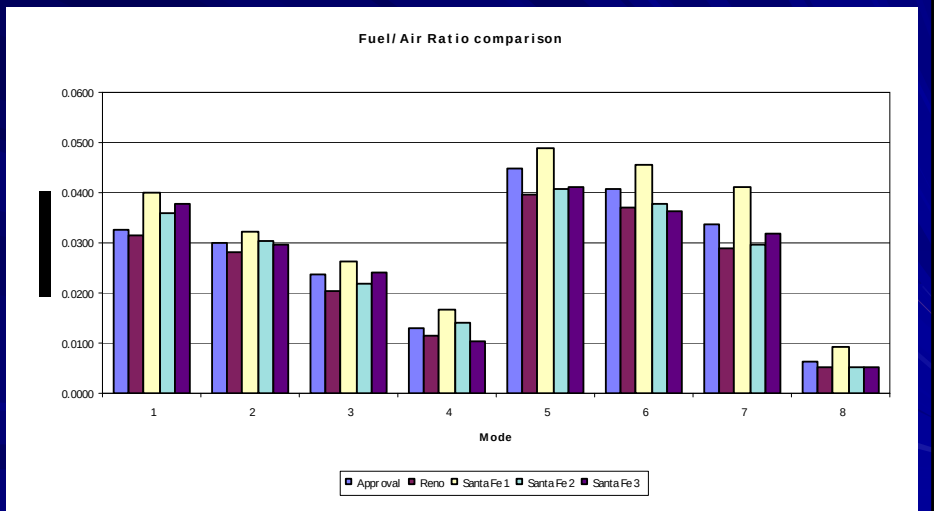
Turbo-charged Engines Configuration Diversity

- Turbo-charged – non wastegated
- Turbo-charged – wastegated
- After-cooled
- Fuel deration – manual
- Fuel deration - electronic
- Timing – electronic
- Combinations of the above

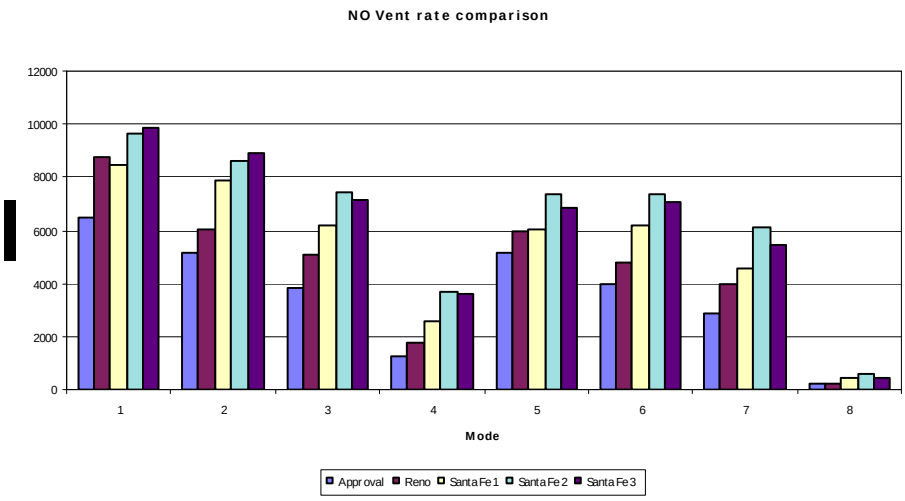
Turbo-charged Engine Tests

- Mercedes – 904 Field Tests
  - Wastegated, charged air cooled, timing changes
- Deutz – BF4M1013FC – Field Tests
  - Wastegated, charged air cooled, fuel deration
- Cummins CTAA8.3-C – Laboratory Tests
  - Non-wastegated, charged air cooled

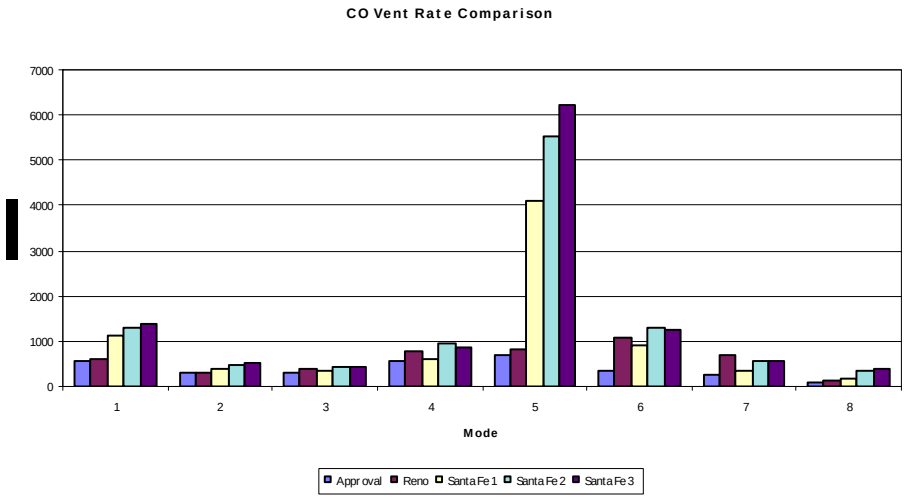
Mercedes 904 Tests – F/A



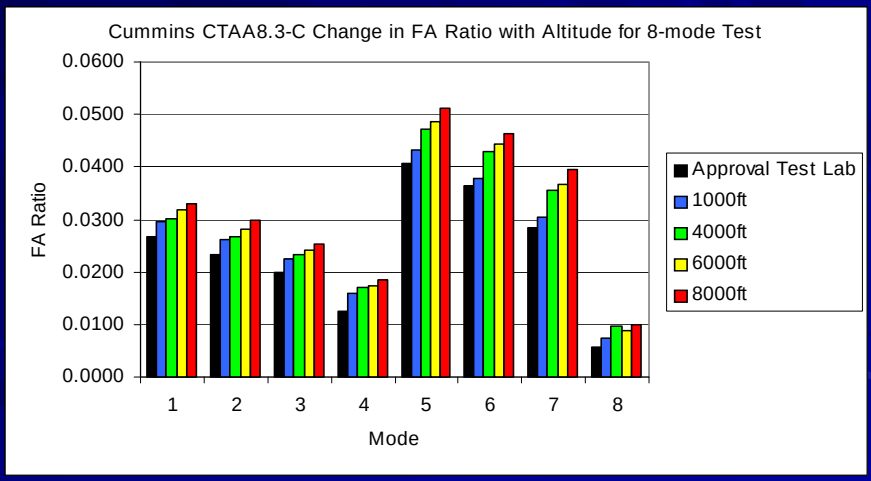
Mercedes 904 Tests – NO Vent



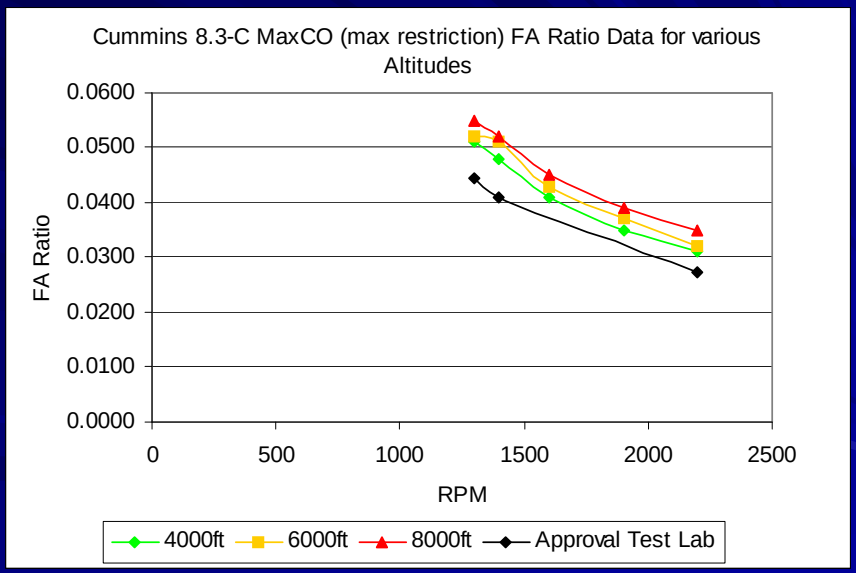
Mercedes 904 Tests – CO Vent



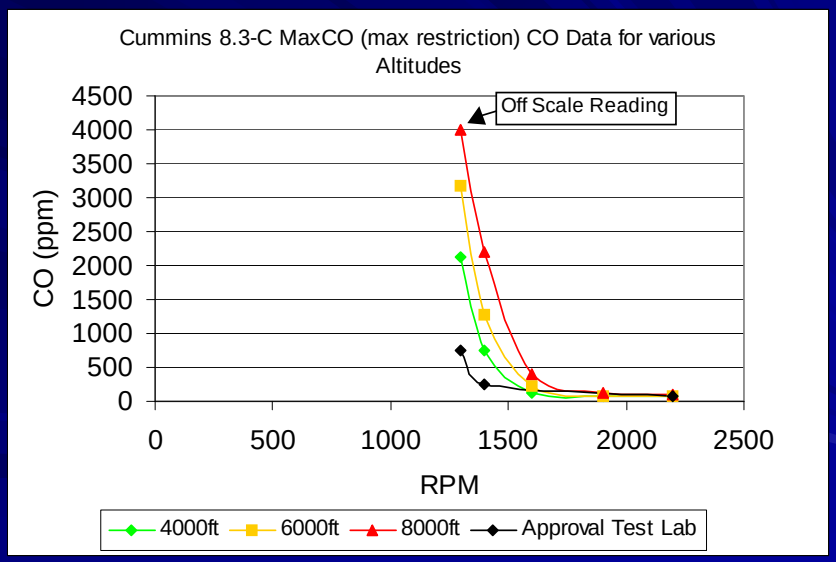
Cummins CTAA8.3-C – F/A



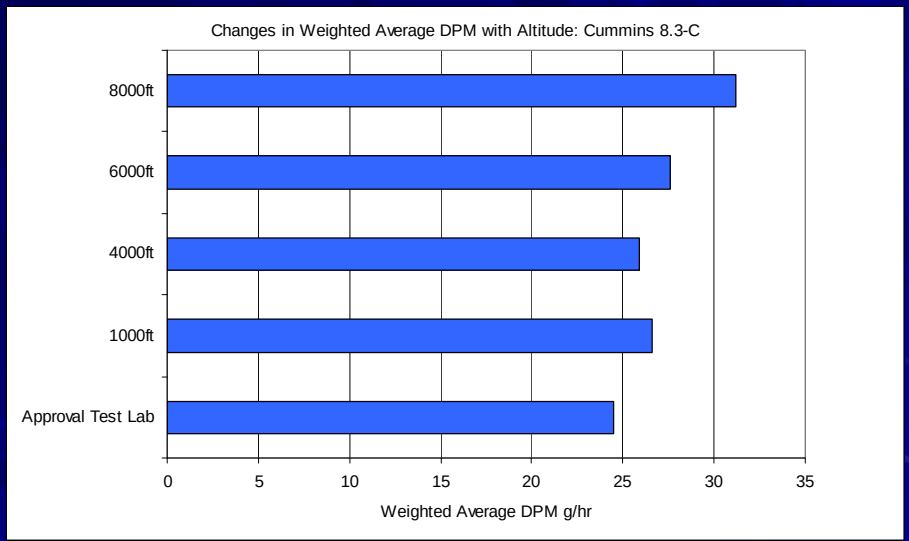
Cummins F/A Altitude Effects



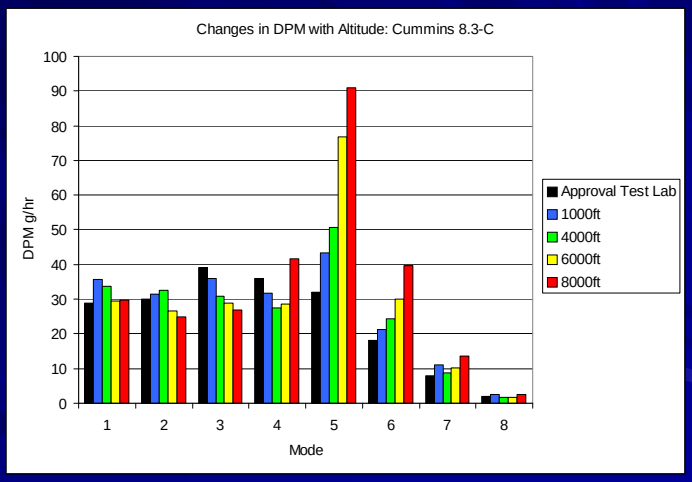
Cummins CO Results



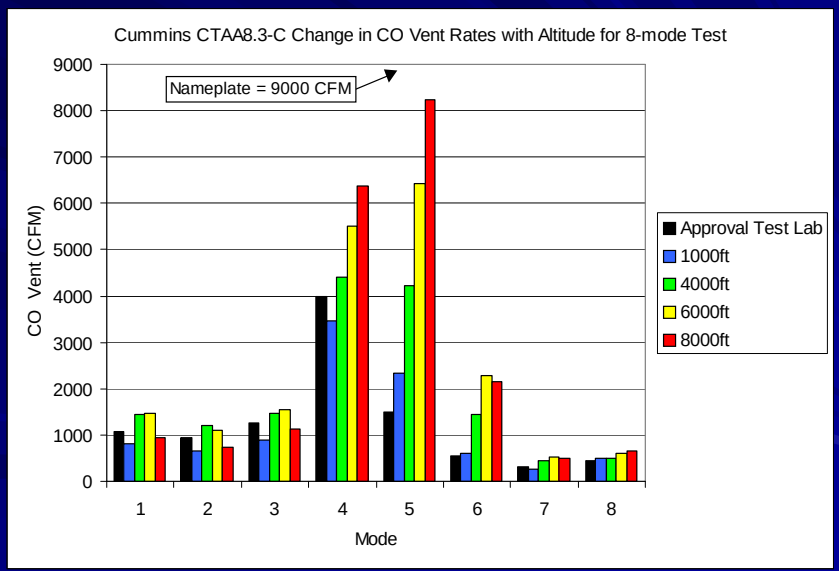
Cummins – DPM effects



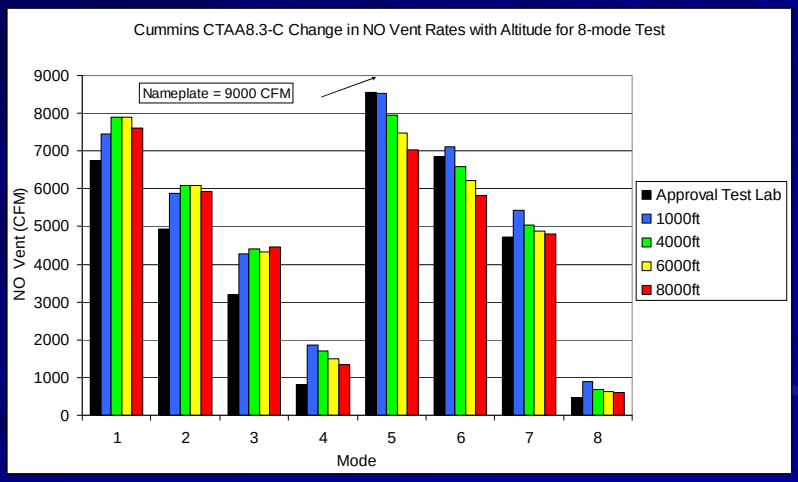
Cummins – DPM Effects



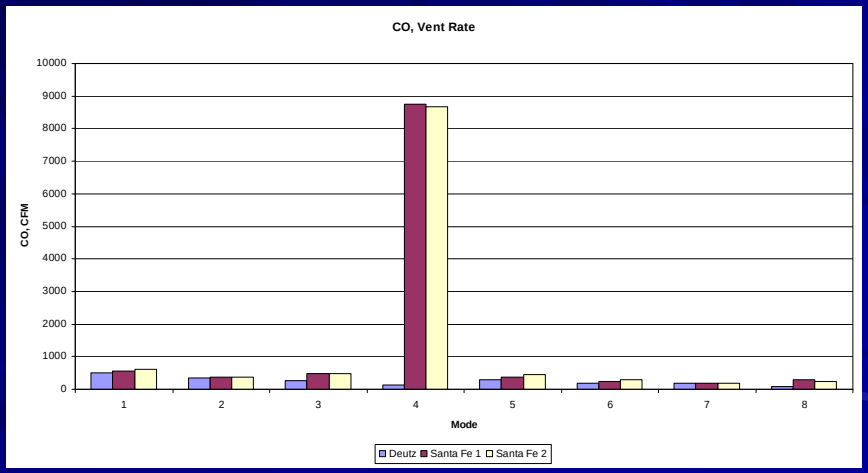
Cummins – Altitude Effect on CO



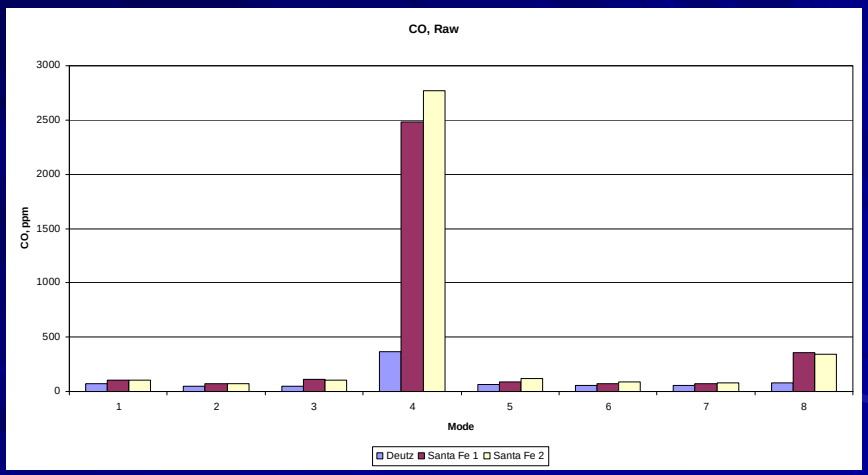
Cummins – Altitude effects on NO



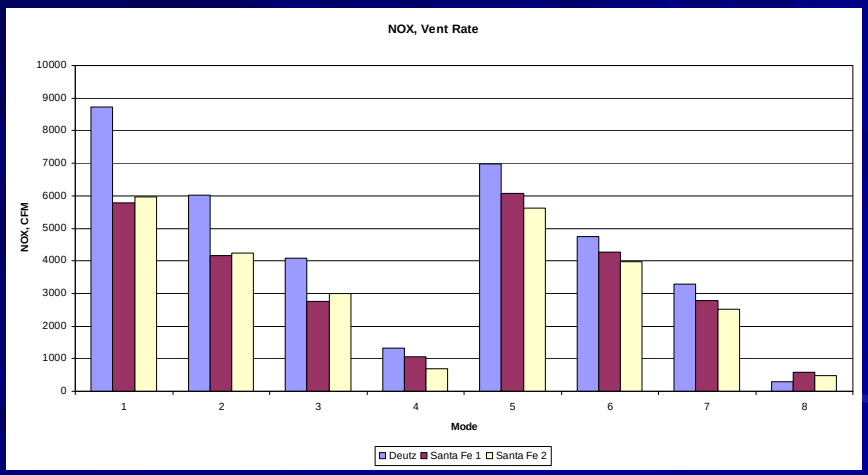
Deutz BF4M1013FC – Effect on CO – Vent Rate



Deutz Effect on Raw CO



Deutz - Effect on NOX Vent Rate



Future Test Plans – MSHA Lab

- Mercedes 904
- Cummins
- Deutz
- Cummins 3.3
- Isuzu 4JG1T
- CAT 3126

Altitude Deration Requirement

- MSHA Position Being Developed
- Engine Manufacturers may be unwilling to make special settings for mining
- If F/A increases with altitude, this may be OK provided miners at high altitude mines are afforded the same degree of health protection as those at sea level.
- Must define same degree of health protection

Health Protection of MSHA Approved Engine

- Category A produces no more than 3000 ppm of CO and 2000 ppm of NOx in raw exhaust under any condition of operation
- Category B produces no more than 2500 ppm of CO and 2000 ppm of NOx in raw exhaust under any condition of operation
- Establishes a ventilation rate which dilutes exhaust gas to 5000 ppm CO2; 50 ppm CO; 25 ppm NO; and 5 ppm NO2.
- Determines dpm output of the engine – limits established for usage.

Summary

- Work in Progress
- Open for Input
- Will Continue to Conduct Tests
- MSHA will be working with a committee formed by the Coal Diesel Partnership
- Questions?