

Low Sulfur Diesel Fuel an Enabling Technology for Future Low Emitting Diesel Engines

Paul Machiele
U.S. EPA

DOE/NREL Workshop
Exploring Low Emission Diesel Engine Oils

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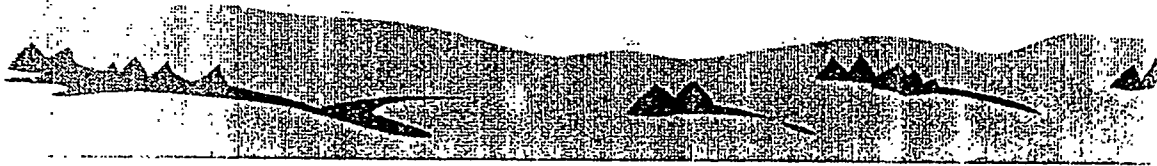
Diesel Popularity

- Diesel sales now top a million a year
- 4% annual growth in diesel truck-miles since mid-80's
- Nonroad applications proliferating
- Dieselization trend to smaller engines continues:
 - Industry preparing to introduce new models for light-duty truck market

Diesels and Air Quality

Rapid progress in emissions control BUT...

- NOx and PM inventories still large
- Diesel PM increasingly of concern:
 - Fine PM (~all diesel PM is <2.5 microns)
 - Air toxics (cancer, other respiratory effects)
 - Localized high concentrations



Increasing number and use of diesel vehicles and equipment

Increasing concern over emissions from diesel engines

Pressure to do everything to minimize emissions from diesel

“Reconcile the diesel engine with the environment”



Highway Diesels: Phase 1

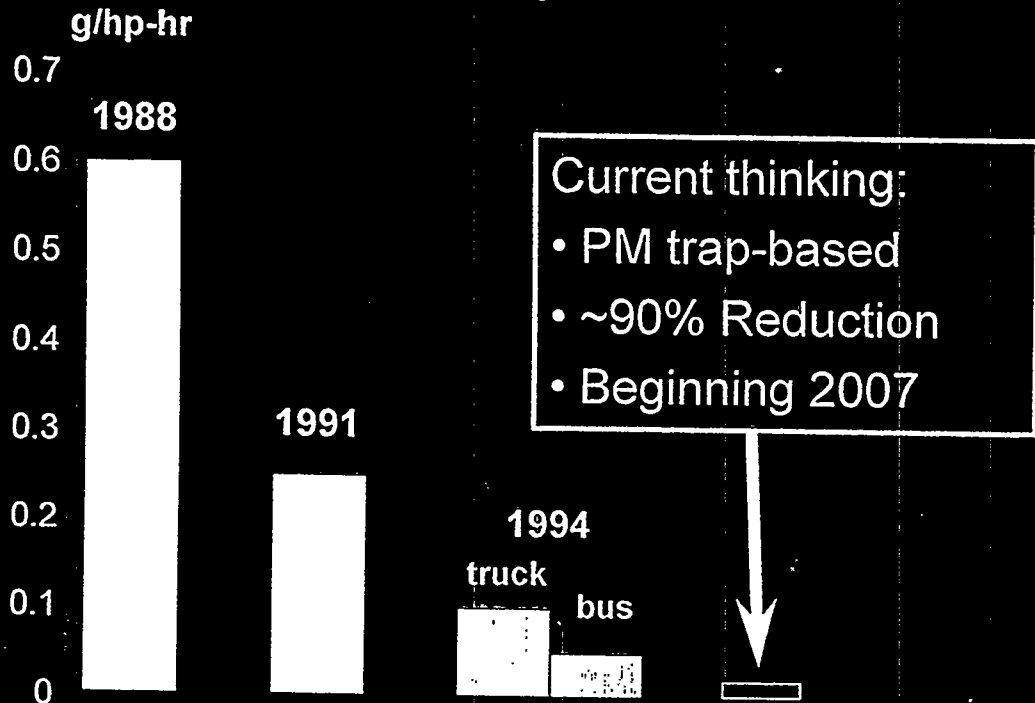
Proposal Last Fall:

- Affirms 2 g/hp-hr NO_x for 2004 diesels
- Codifies consent decree (in-use control) requirements for all diesel manufacturers

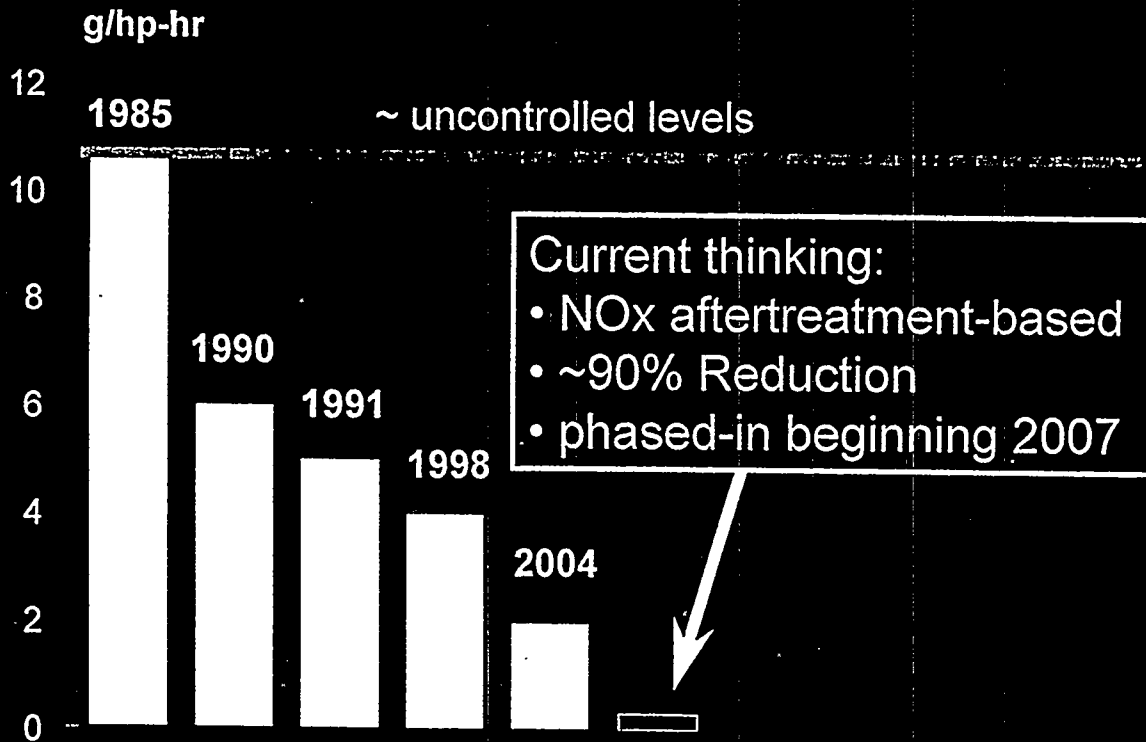
Highway Diesels: Phase 2

- Control focus is shifting to aftertreatment (PM traps, NO_x adsorbers)
- Potential for 90%+ emission reductions in NO_x, PM, and HCs -- gasoline-like levels
- Magnitude of control similar to auto's in 70's

Heavy-Duty PM Standards



Heavy-Duty NOx Standards



Pressure to Reduce Engine Oil Ash

- Inorganic ash from engine oils
 - is captured by the diesel particulate filter
 - builds up over time
 - Requires periodic maintenance
- High oil ash will cause more frequent PM filter maintenance intervals

More Flexibility on TBN

- Sulfur in diesel fuel contributes to acidification of engine lubricating oils
- Lower sulfur diesel fuel should simplify TBN control

What does this mean for Diesel Engine Lubricating Oils?

Pressure to Reduce Engine Oil Sulfur Concentration

Sulfur in engine oil raises similar issues as sulfur in diesel fuel

Assuming:

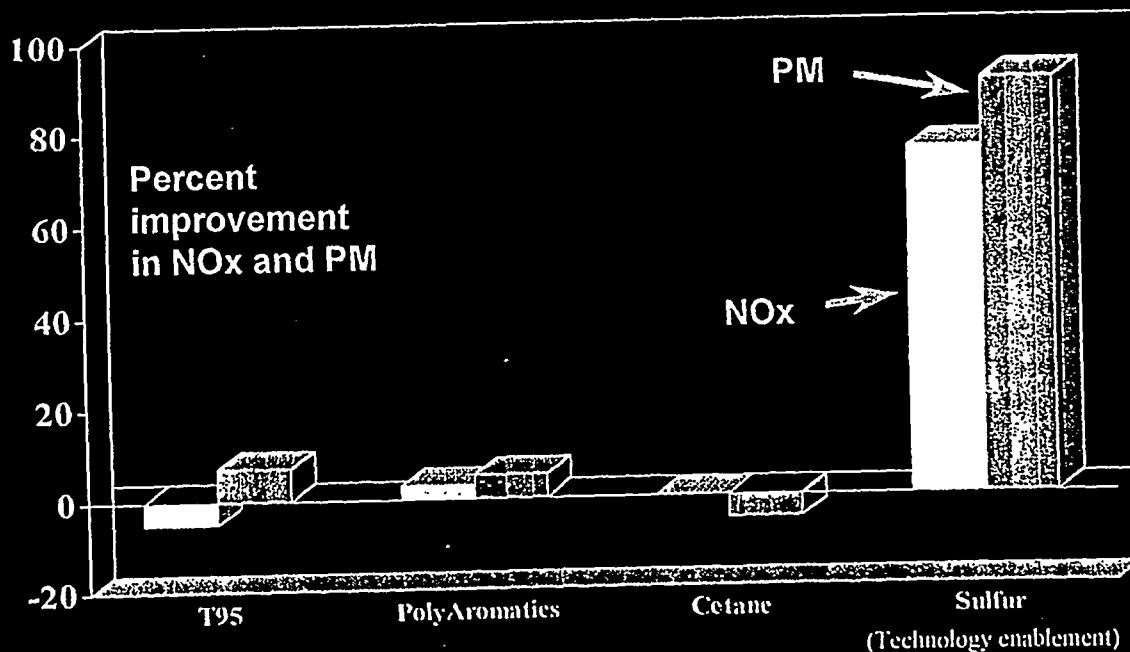
- 1oz Oil consumption per 100 lbm fuel consumption
- an average oil sulfur level of 5,000 ppm
- Is equivalent to ~3 ppm S in the fuel
- Could be much higher

Regulating the Fuel and Vehicle as a Single System

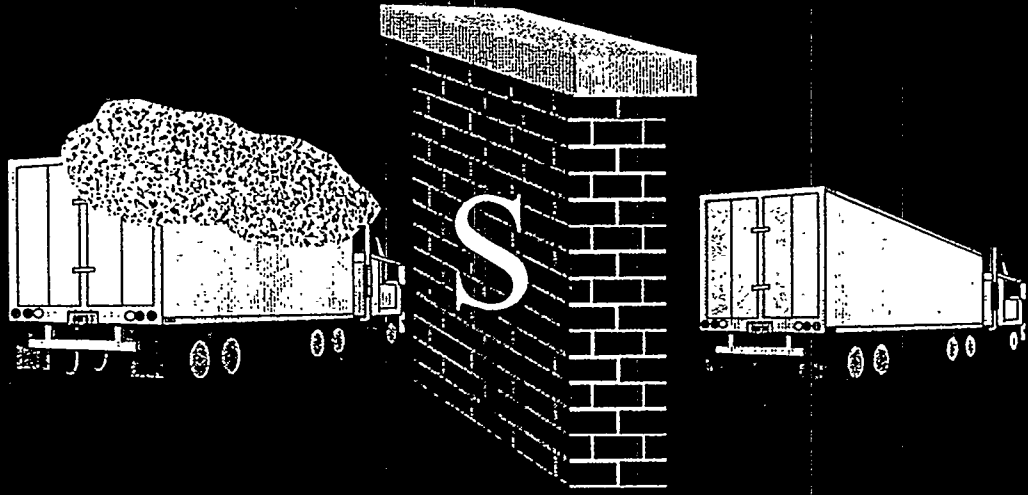
- Past rulemakings: separate fuel and vehicle programs
- Sulfur impact on diesel aftertreatment requires a systems approach:
 - Ultra-low sulfur diesel fuel by mid-2006...
 - ... in time for new standards in 2007

Why Sulfur Alone?

Some Preliminary Data On Fuel Effects



Barrier is Sulfur



Impact of Sulfur: NOx Adsorbers

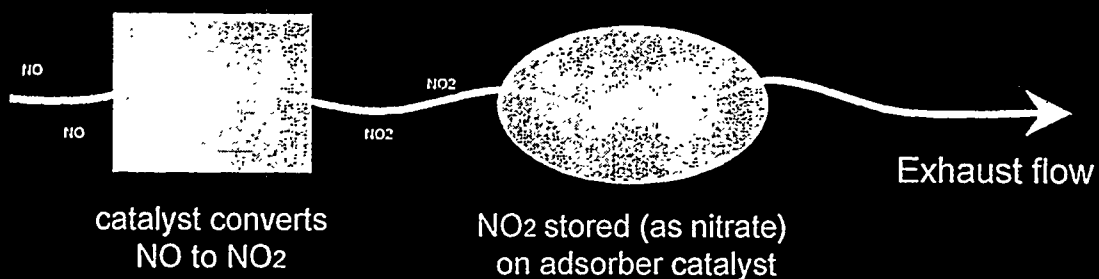
- Sulfur
 - “blocks” NOx storage sites
 - reduces NOx conversion efficiency
 - leads to a sulfur removal fuel penalty

Impact of Sulfur: Catalyzed Diesel Particulate Filters

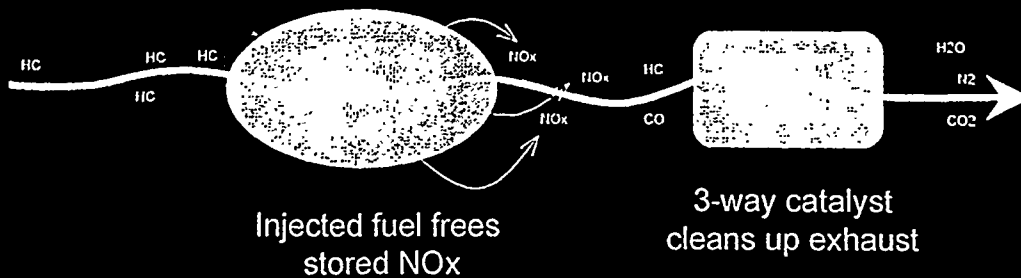
- Sulfur

- is converted to PM (hydrated sulfuric acid)
- inhibits filter regeneration
(DECSE: sulfur increase from 3 to 30 ppm increases balance point 25°C)

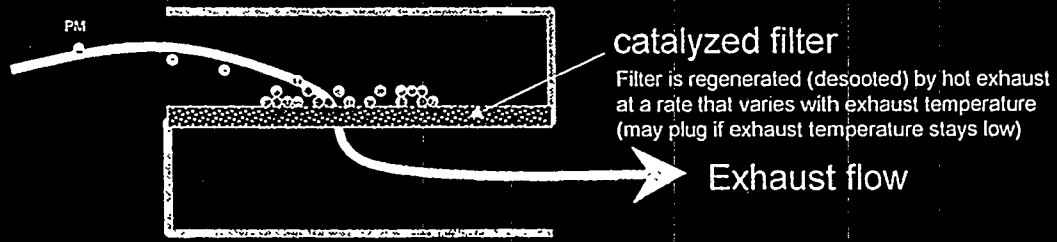
NOx Adsorber Catalyst



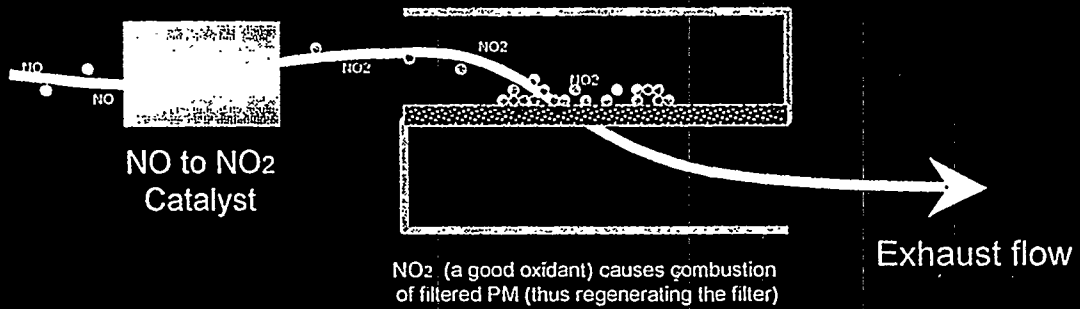
Rich (HC injection) Phase:



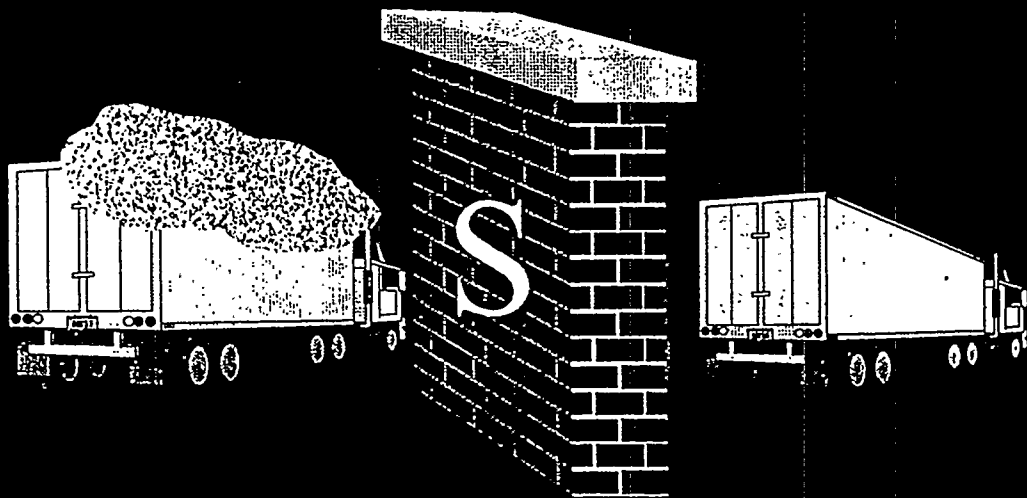
A Catalytic PM Trap Cell



A Continuously Regenerating PM Trap Cell



Barrier is Sulfur



What Does This Mean?

- EPA anticipates that these 2007 standards will lead to a new generation of engine oils
 - Lower sulfur content of oil
 - Low ash oils
 - TBN?
- We anticipate as in the past that industry will rise to this challenge