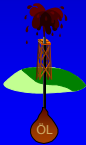


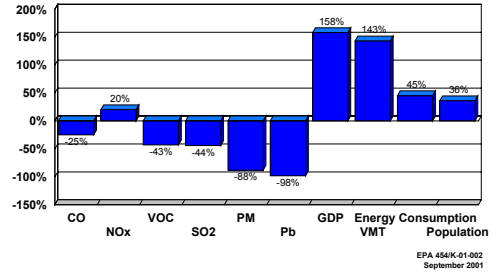
Beyond Lead: The Sulfur Challenge

Seminar on Clean Fuels and Vehicles
in Western Asia and North Africa
Beirut,
17-19 March 2004

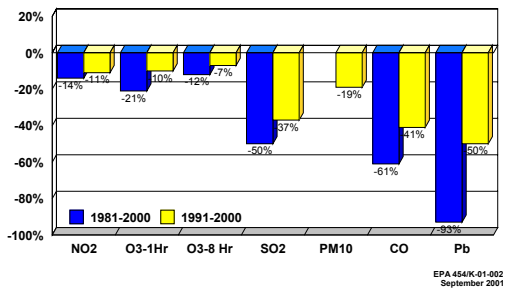


Michael P. Walsh
(www.walshcarlines.com)

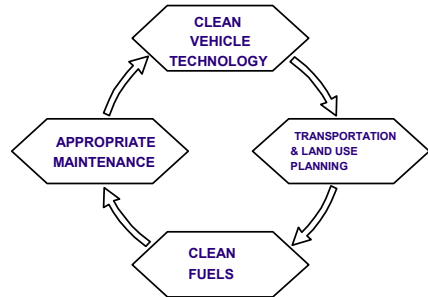
Growth Areas and Emissions Trends in the US (1970-2000)



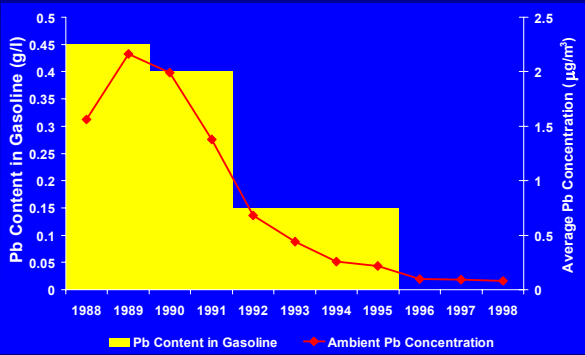
Percent Change in Air Quality Across The US



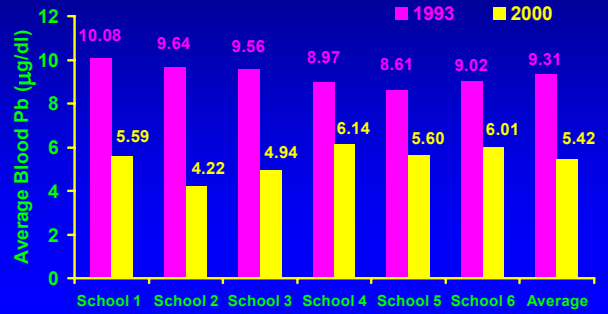
ELEMENTS OF A COMPREHENSIVE VEHICLE POLLUTION CONTROL STRATEGY



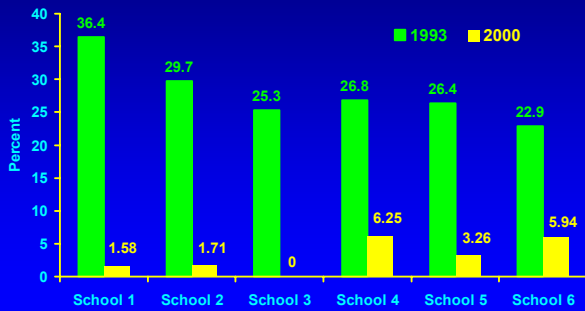
Ambient Pb Concentrations in Bangkok and Pb in Gasoline from 1988 - 1998



Comparison of Average Blood Pb Levels in Children at 6 Schools in Bangkok between 1993 and 2000



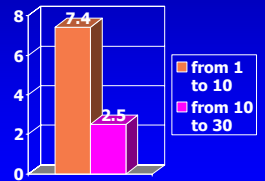
Percentage of School Children with Blood Pb Levels ≥ 10 µg/dl



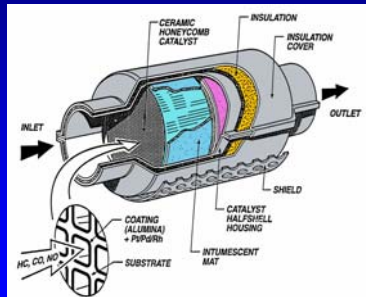
Recent Study Indicates Largest Impact at Very Low Lead Levels

- New England Journal of Medicine (4/17/2003)
- 172 children tested at 6, 12, 18, 24, 36, 48, 60 months
- Corrected for confounding variables
- 101 children never above 10µg/dl
- Blood lead significantly associated with I/Q

IQ Loss as Lead Increases



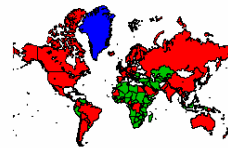
The Three-way Catalytic Converter: A Familiar Technology Re-Engineered for High Performance in Close-coupled and Underfloor Applications



- Layered washcoat architectures and support materials with high thermal stability
- Integrated HC adsorption functions
- Mounting materials with improved durability
- High cell density ceramic or metallic substrates
- Insulation schemes for heat management

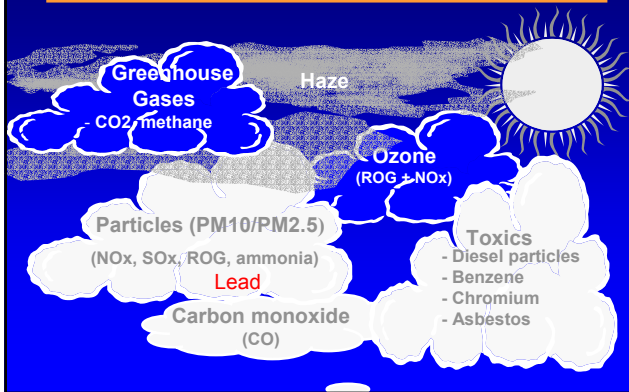
Can Only Be Used With Lead Free Fuel

Worldwide Status of Leaded Gasoline Early 2004

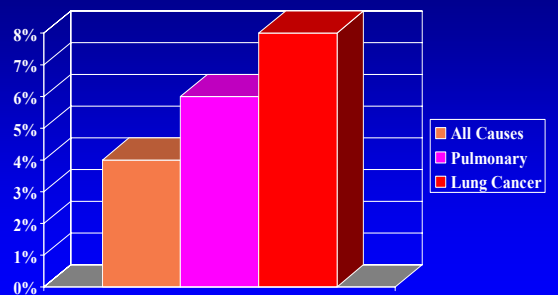


- Lead Free
- Still Some Leaded
- Unknown

What pollutants are of concern?

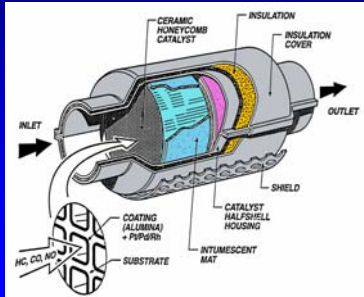


Increased Risk of Premature Mortality Due To 10 μg/m³ PM_{2.5}



JAMA, March 2002

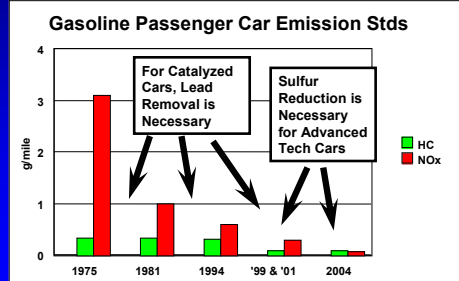
The Three-way Catalytic Converter: A Familiar Technology Re-Engineered for High Performance in Close-coupled and Underfloor Applications



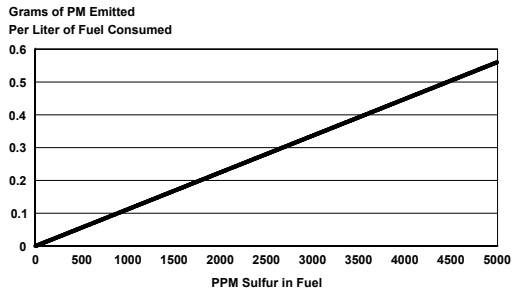
- Layered washcoat architectures and support materials with high thermal stability
- Integrated HC adsorption functions
- Mounting materials with improved durability
- High cell density ceramic or metallic substrates
- Insulation schemes for heat management

Maximum Emissions Performance Is Only Achieved With Near Zero Sulfur Fuel

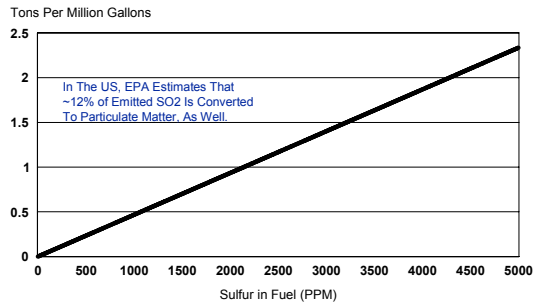
**Enabling Emissions Control
Sulfur Is The Lead of the New Century**
Gasoline Cars and Trucks



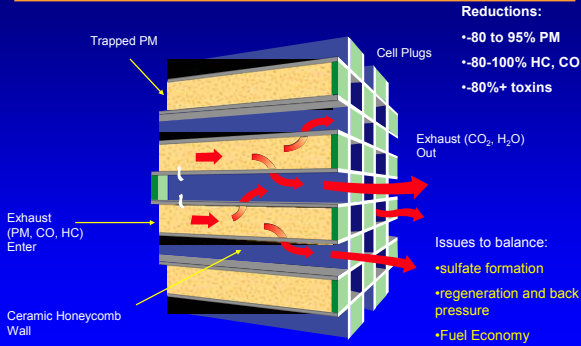
**Direct PM Emissions As A Function
Of Diesel Fuel Sulfur Level**



**Tons of Directly Emitted PM
From Diesel Fuels Sulfur**

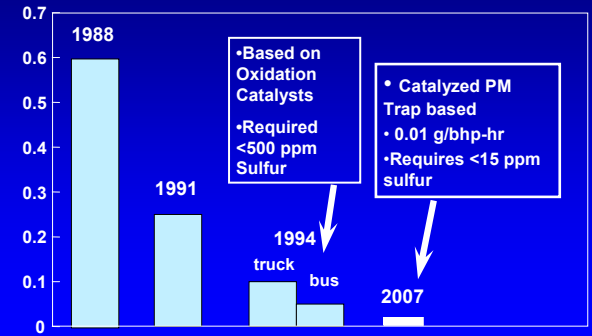


Diesel Particulate Filters



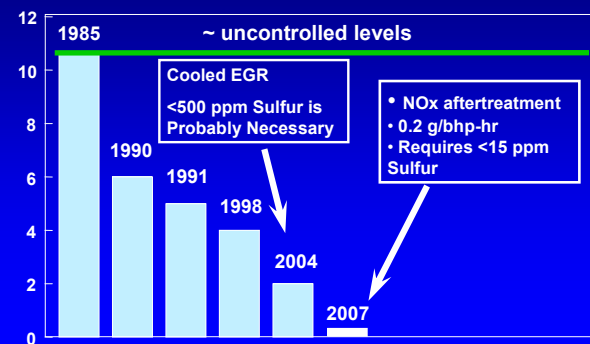
Enabling Emissions Control

US PM Standards for Diesel Engines

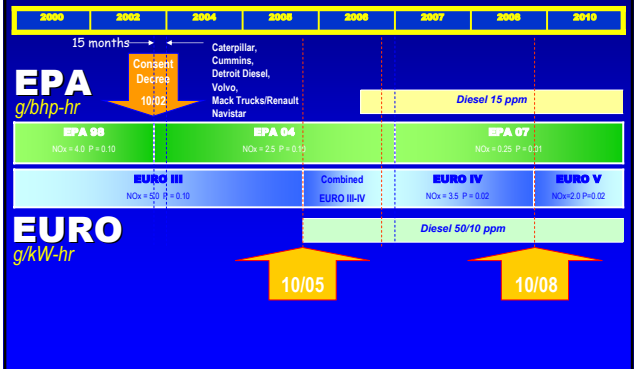


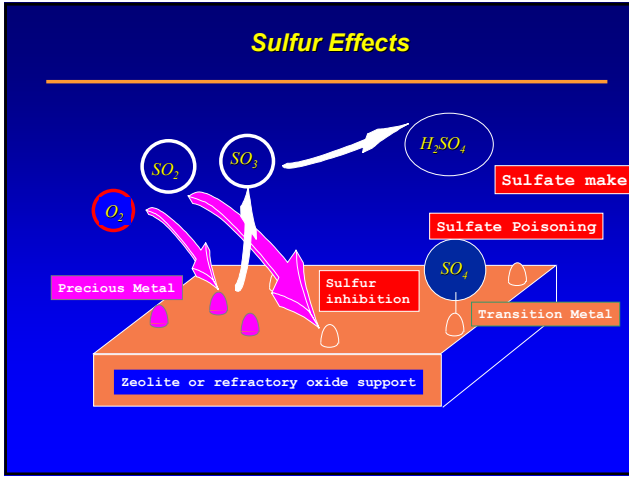
Enabling Emissions Control

US NOx Standards for Diesel Engines



Close Linkage Between Vehicle Emissions Standards and Fuel Sulfur Levels





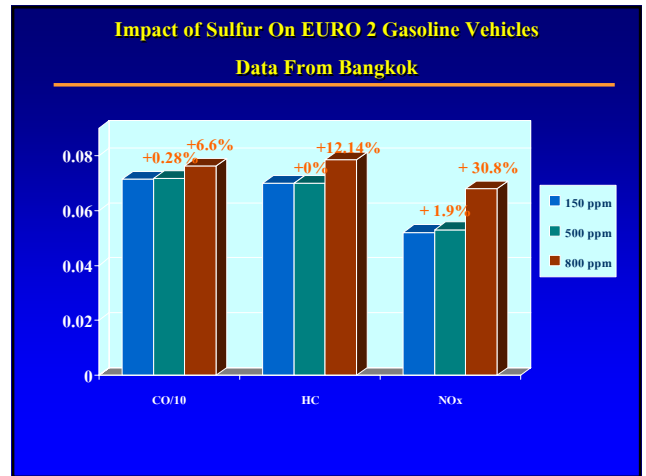
Summary of Influence of Fuel Sulfur on Gasoline and Diesel Exhaust Emission Control Devices

● Control Technology	● Sulfur Effects
- TWC	- Sulfur Inhibition
- Oxidation Catalyst	- Sulfur Inhibition, Sulfation
- Lean NOx Catalyst	- Sulfur Inhibition, Sulfation
- SCR with Urea	- Sulfur Inhibition, Sulfation
- Catalytic Filters	- Sulfur Inhibition, Sulfation
- NOx Adsorbers	- Extreme Sulfur Inhibition
- Hybrid With TWC	- Sulfur Inhibition

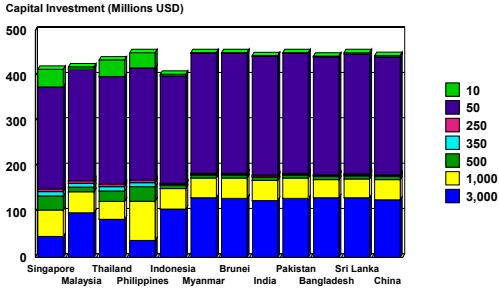
Fuel Sulfur Negatively Affects Catalyst-Based Emission Control Technology

- Sulfur Inhibits Emission Control Performance and in Some Cases Is a Barrier to the Use of Certain Technologies
- Catalyst-Based Technologies Adversely Affected by Sulfur Includes
 - Automotive Catalysts
 - Oxidation Catalysts for Diesel Engines
 - Lean NOx Catalyst-Based Technologies for Automotive and Diesel Applications
 - Catalyst-Based Diesel Particulate Filters

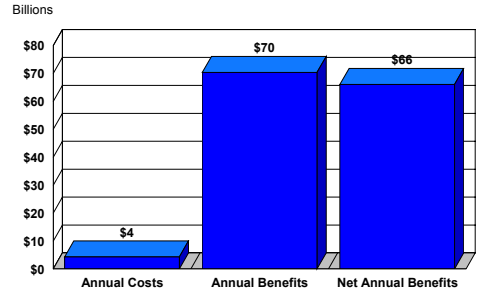
All Catalyst Technologies Adversely Affected



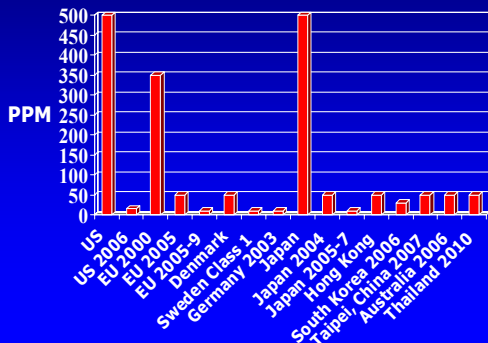
Cost of Reducing Sulfur in Diesel Fuel in Asia (High Sulfur Crude)



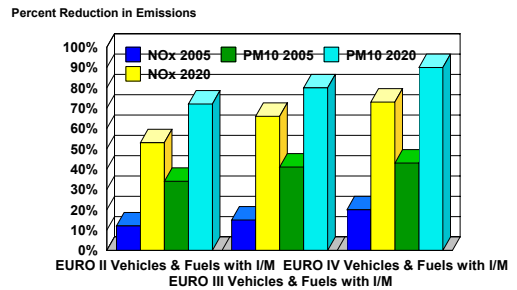
Costs and Benefits of Low Sulfur Diesel Fuel (<15 PPM) and Very Stringent Heavy Duty Engine Standards in the US



Ultra Low Sulfur Diesel Fuel Is Necessary and Spreading

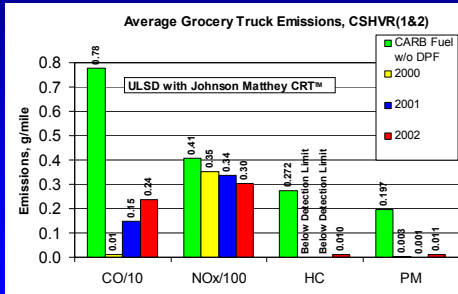


Impact of Clean Vehicles and Fuels On Diesel Vehicle Emissions

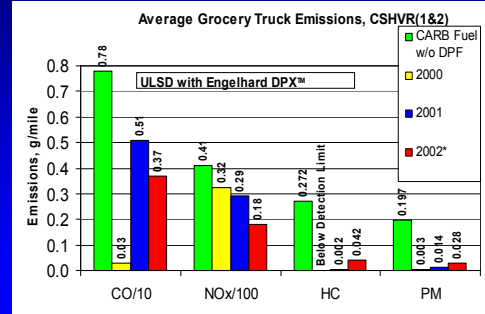


Source: Camarsa, BAQ 2003

Retrofit Durability & Reliability



Retrofit Durability & Reliability



Conclusions

- Highest Priority Remains the Elimination of Lead in Gasoline
 - Direct Health Benefits
 - Enables Catalyst Technology
- As Technology Advances, Sulfur Increasingly Important
 - Direct and Indirect Impacts on PM
 - Sulfur Dioxide
 - Lower Sulfur Improves Catalyst Performance
 - Very Low Sulfur Enables Certain Advanced Technologies
 - Diesel Retrofit Opportunities Enhanced