Fundamentals of Sulfur Trap For Diesel Engine Emission Control

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DEER Workshop, 2000
August 21-24, 2000

Sulfur Effects on Diesel Engine Emission

- Increase SO2 emissions
- Enhance TPM generation and emission
- Degrade NOx reduction catalysts, e.g. NOx adsorber catalyst
- Cause corrosion in EGR system

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Current Sulfur Levels in fuel and Lube

- Current diesel fuel sulfur
  300 ~ 600 PPM (wt.)

- Lubricant oil sulfur
  3000 ~ 5000 PPM (wt.)
  (equivalent to 3 ~ 10 PPM fuel sulfur)

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SO2 in Exhaust Gas

- Most of fuel sulfur element and compounds convert into SO2 during combustion
- Concentration of SO2 in exhaust gas is a function of fuel sulfur level and air-fuel ratio (AFR)

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Exhaust SO2 Calculation

$$C_{eSO2} = \frac{M_{SO2}}{M_S} \frac{1}{(1+R_{a/f})} C_{fS}$$

C_{eso2}	SO_2 concentration in exhaust gas (ppm)
C_{es}	S concentration in fuel (ppm)
M_{so2}	SO_2 molar weight
M_s	S molar weight
$R_{a/f}$	Air to fuel ratio

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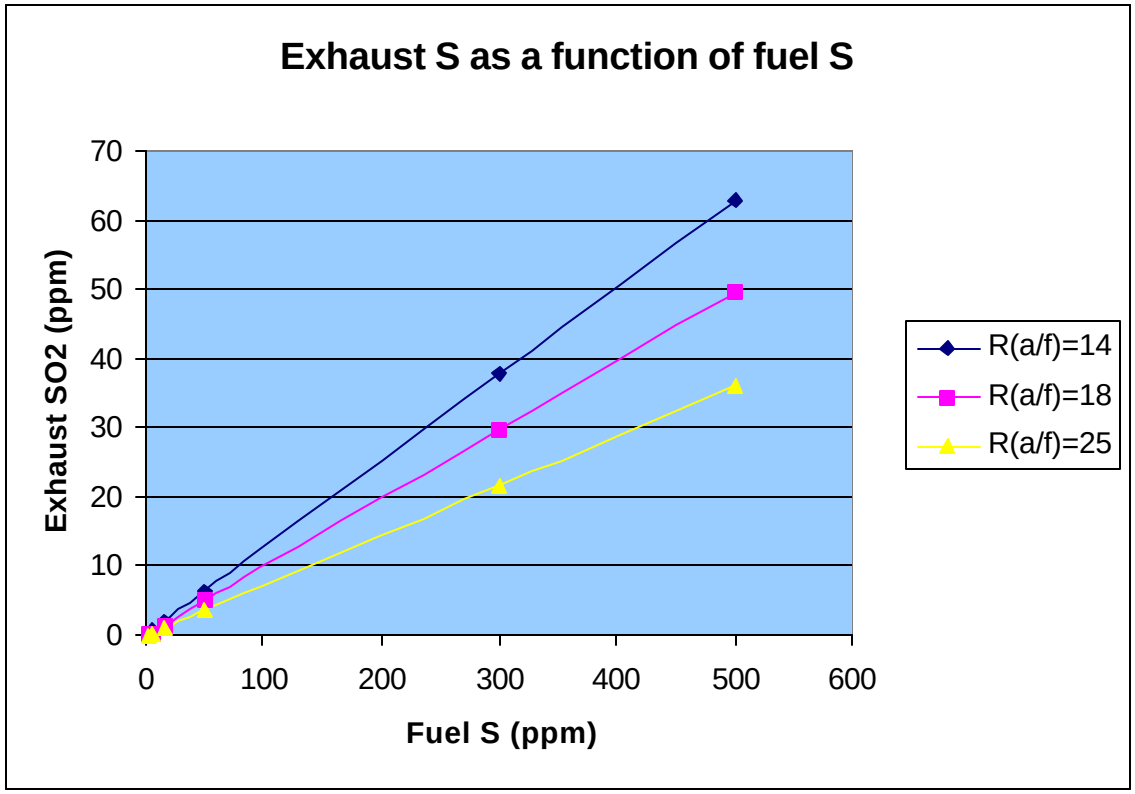
Exhaust SO2 as Function of Fuel-S and AFR



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Sulfur Poisoning Mechanisms

- React with washcoat
- Destroy active sites for NOx adsorption
- Difficult to remove from catalyst once reacted with washcoat

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SO2 Trap Development and Test

Tasks	Key Questions	Resources / Skills
Material Development	1. What is the maximum trap capacity? 2. Which parameter influences the capacity most? 3. How to minimize SO2 slip at low temperature? 4. How to change washcoat loads and subtracts structure to improve trap performance?	Cummins / Engelhard
Sulfur trap characterization	1. How to determine SO2 break through points? 2. How to determine trap size and life? 3. How to identify trap efficiency at various temperature?	Cummins
Thermodynamics, kinetics, and modeling of SO2 trap process	1. What are the adsorption and reaction mechanisms? 2. How to modeling the sulfur trap process? 3. How to predict the maximum trap capacity and life?	Cummins

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Key Design Factors

- Type: Reversible / Irreversible
- Operating temperature
- SO2 break-through point
- Trap capacity / efficiency
- Replacement interval
- Back pressure
- Durability
- Cost

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Current SO2 Trap Performance

- Trap catalyst development in progress at Engelhard and preliminary results promising:

- Trapping Capacity
  7.5 g SO2 / Litter of Trap
  @70K 1/h VHSV& 2 ppm inlet SO2

- Trapping Efficiency
  >99% for 120 hr aging @ 240 °C

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SO2 Trap Volume Requirement

- Trapping capacity: 7.5 g SO2 / L
- Fuel sulfur: 10 ppm
- Fuel economy: 60 mile / gal
- Replacement interval: 10,000 mile

- Required Trap Size: 1.43 L

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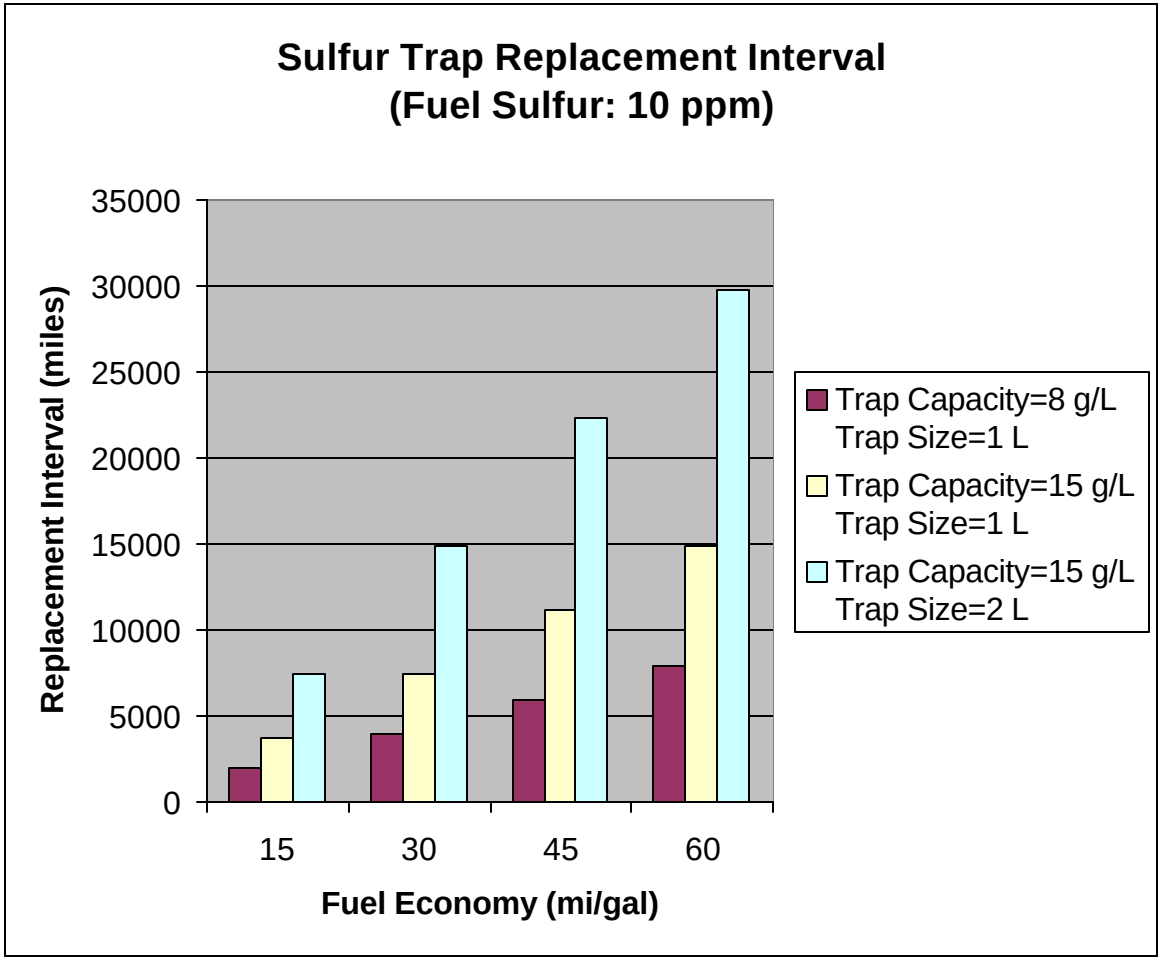
SO2 Trap Size



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Current Development and Test

- Cummins is using a AMI-2000 reactor facility to conduct parametric study of SO2 trap catalyst @ various conditions:
  - Temperature
  - Space velocity
  - SO2 concentration
  - Feed gas composition
- Engelhard is making improvements on the material development to increase trap capacity and minimize SO2 slip

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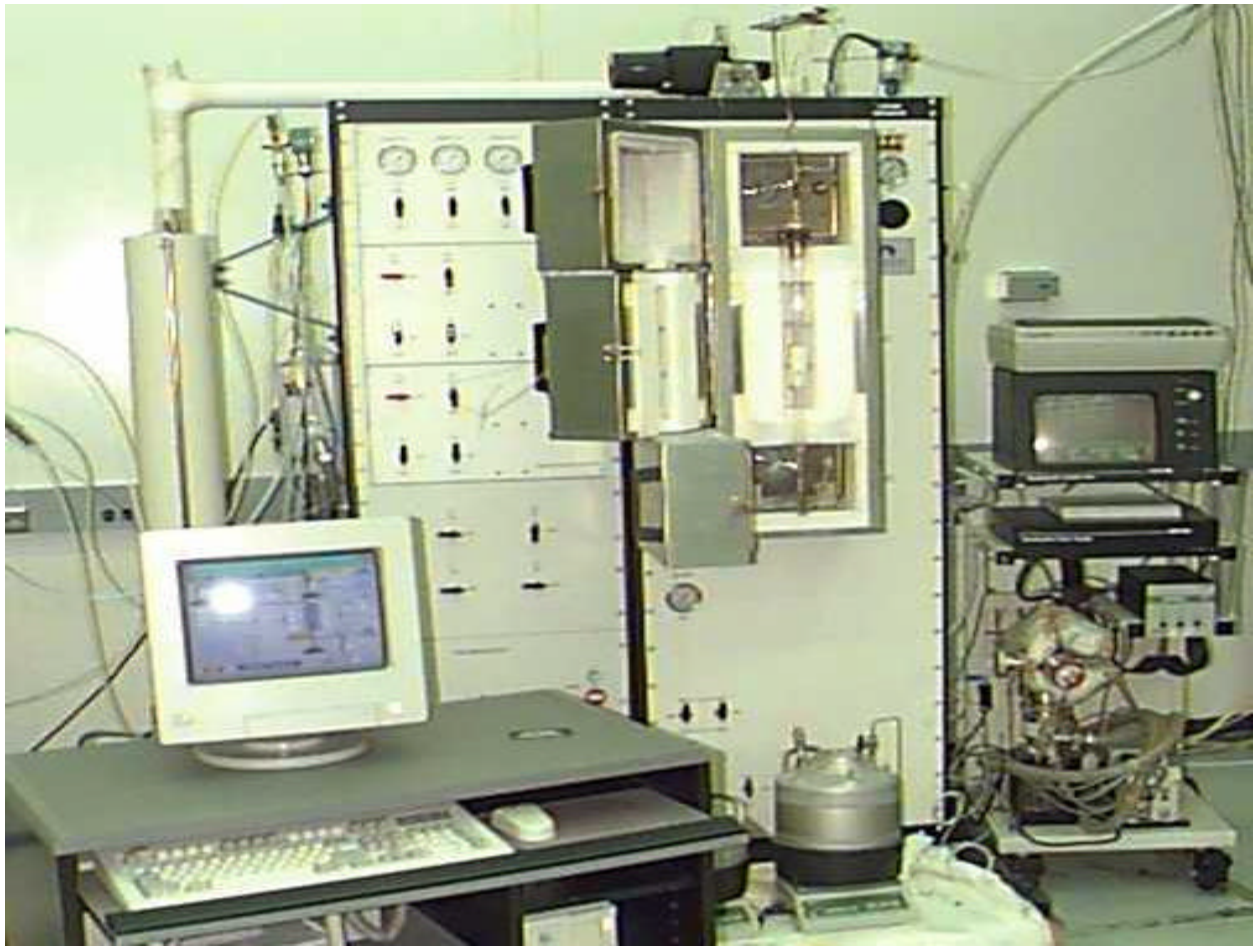
Sulfur Trap Reactor Testing Facility



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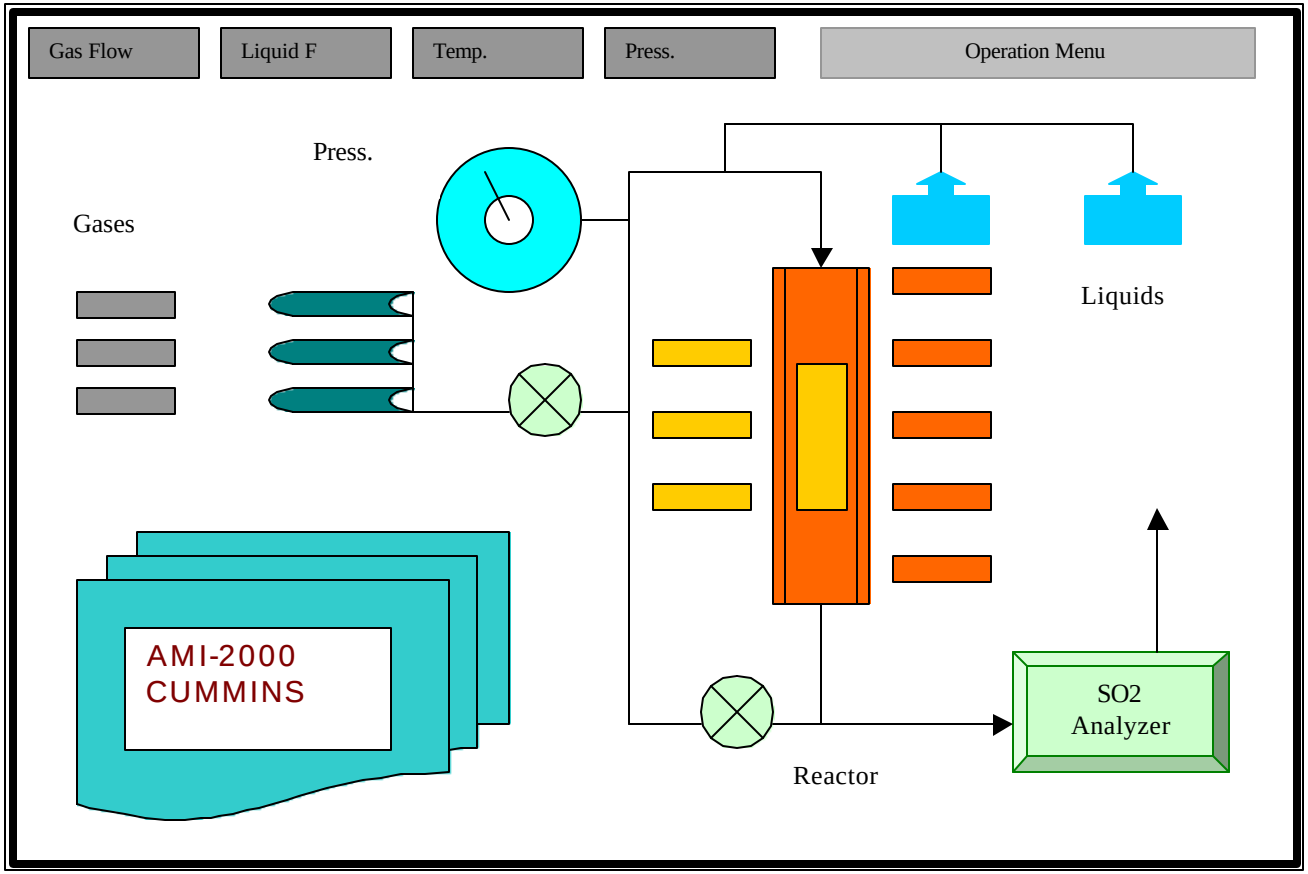
Reactor Control Panel



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Path Forward

- Improve sulfur trap capacity and life:
  - 7.5 => 32 g SO2/L
  - 7,000 => 35,000 miles
- Minimize SO2 slip
- Study sulfur trap characterizations and mechanisms
- Develop sulfur trap model
- Install and verify sulfur trap on engine

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