

# Emissions Control Technology for Tier 4 Locomotive Applications



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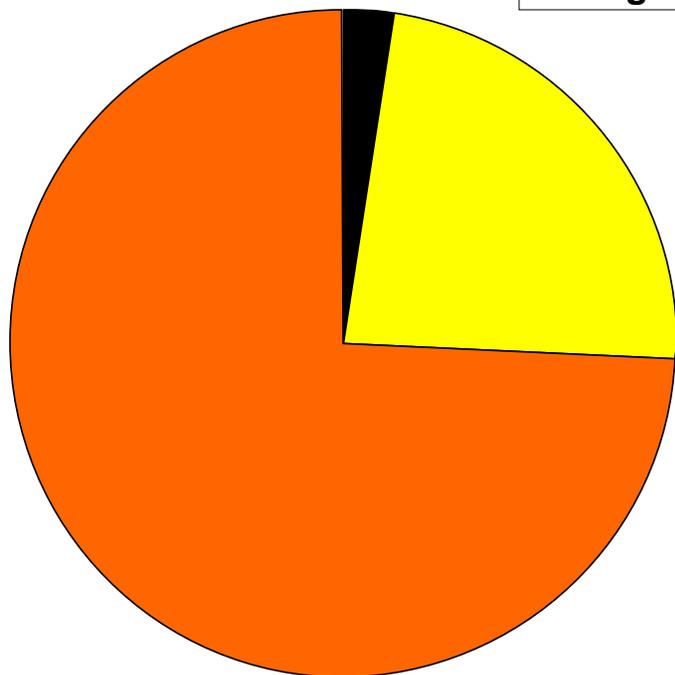
# Outline

- Line-haul locomotive PM emissions characterization
- PM Controls
- NOx Controls
- Ash maintenance and lubricant formulation

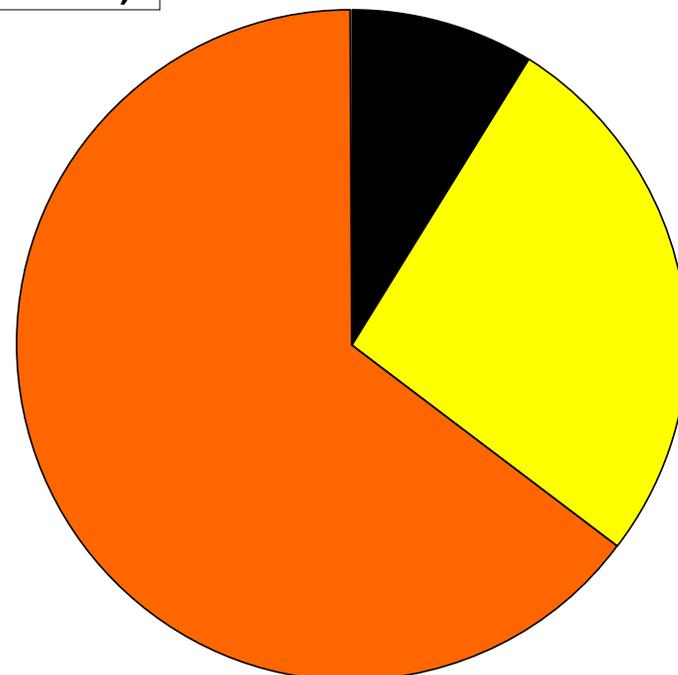


# Locomotive PM Emissions Dominated by Semi-volatile Organic Compounds

- Elemental Carbon (soot)
- Sulfate
- Organic Compounds (chiefly lube oil)

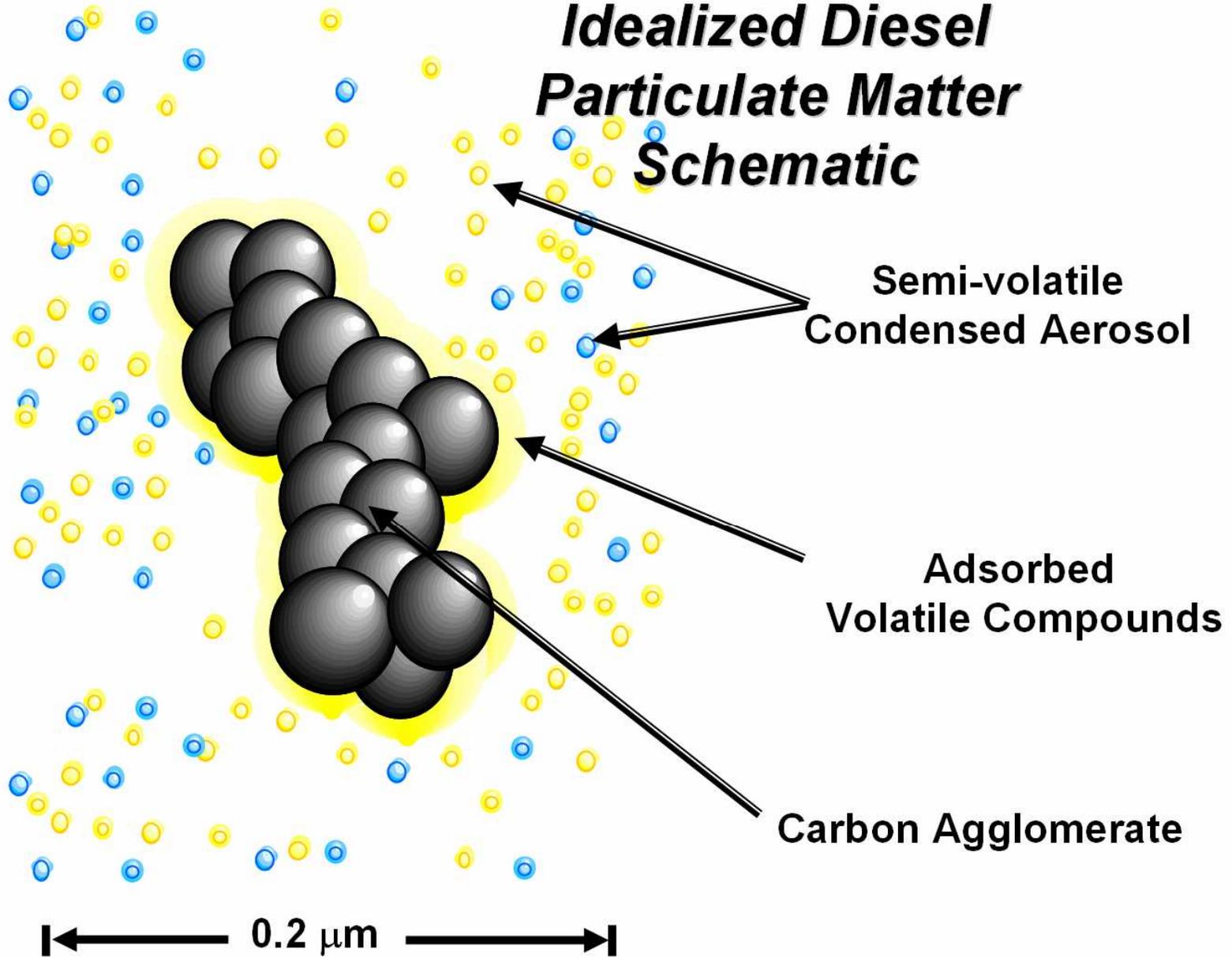


Tier 2 EMD SD70Ace 2-Stroke Locomotive



Tier 2 GE GEVO 4-Stroke Locomotive

# ***Idealized Diesel Particulate Matter Schematic***



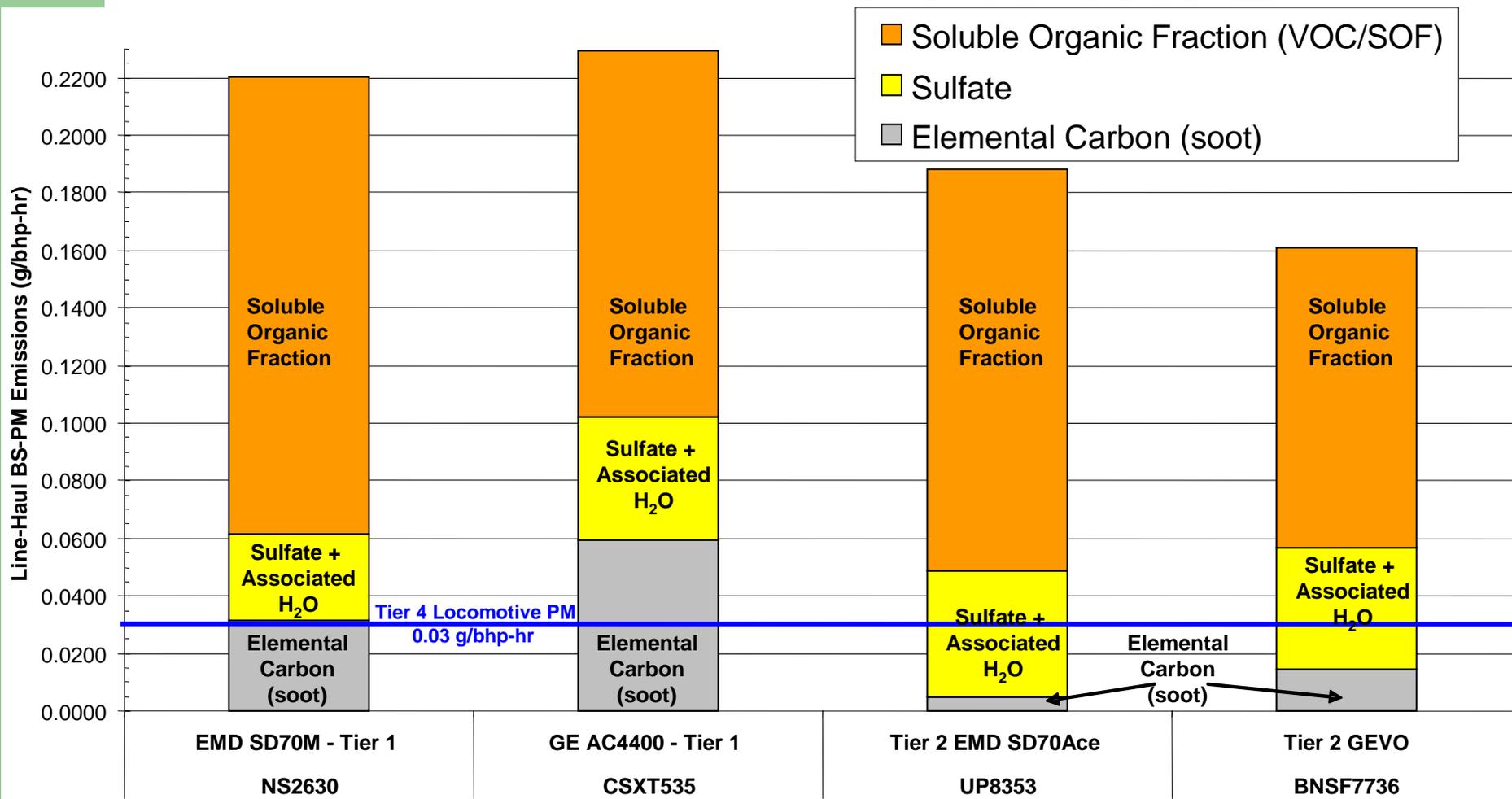


## Reasons for low soot in total PM

- Low soot
  - High pressure injection
  - Low engine speed
    - ~1000 rpm
    - more time for soot oxidation
  - Low BMEP for EMD 2-stroke engine



# Historical Data: Tier 1 to Tier 2

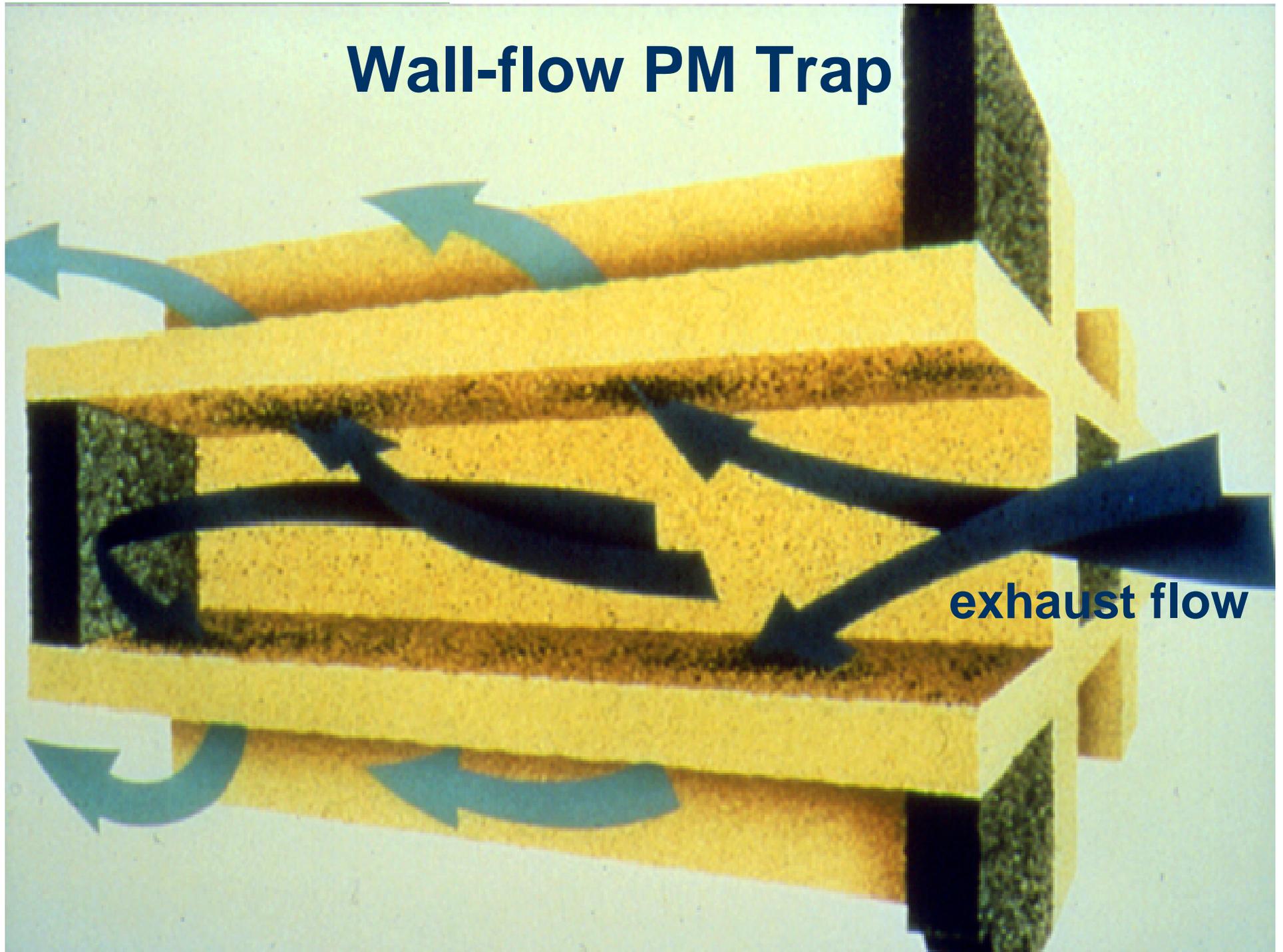




# PM Controls

- Further incremental reductions in lubricating oil consumption + use of low SAPS oils
  - Power assembly improvements
  - Improved CCV systems (high-efficiency filtration)
  - Driven by:
    - Tier 3 standards PM standards
    - Preparation for high-hour catalyst durability for Tier 4
- PM controls for Tier 4
  - Low sulfur fuel (<15 ppm)
  - Catalytic PM controls

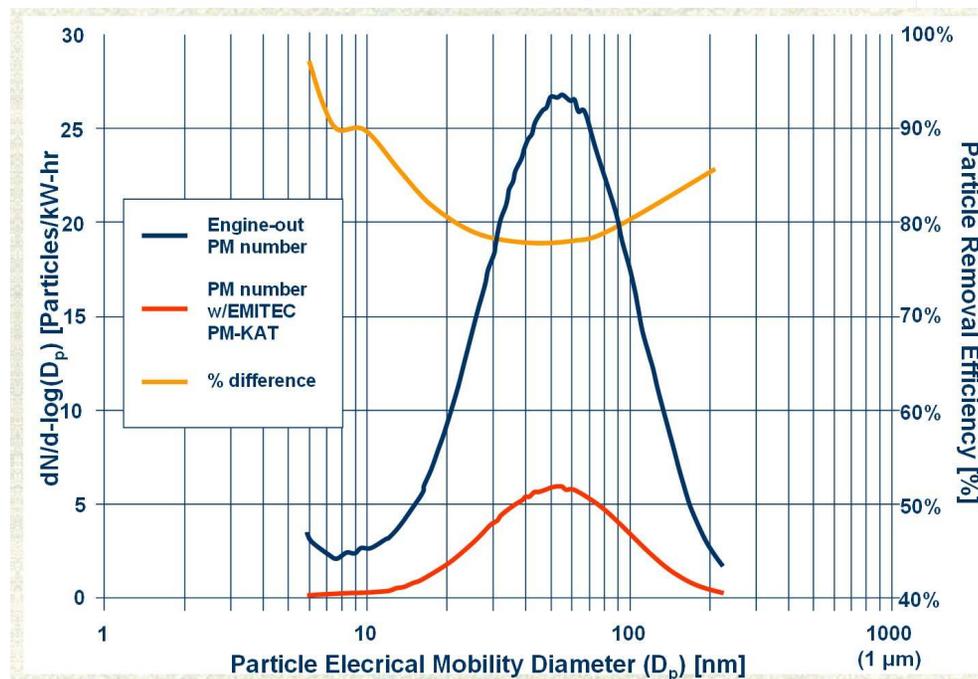
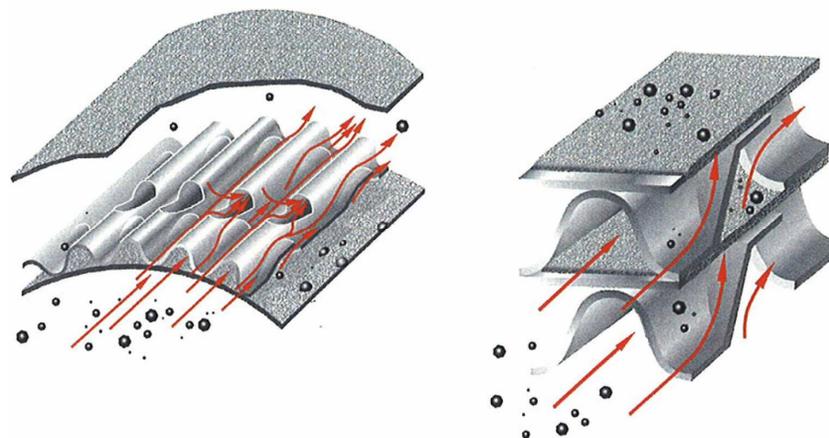
# Wall-flow PM Trap



exhaust flow

# Partial-flow PM Traps (Emitec Metalit Trap)

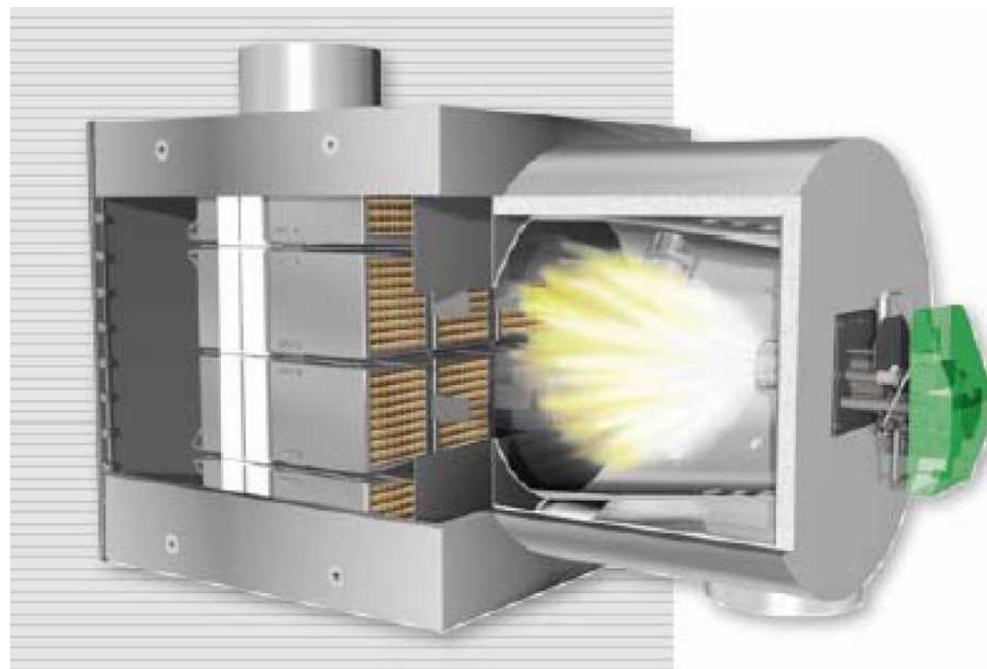
- OEM MAN Euro IV heavy-duty diesel trucks application
  - Metalit trap for PM control
  - EGR + injection timing retard for NO<sub>x</sub> control
- Uses flow restrictions rather than plugs to force flow through the porous sintered metal wall
  - Accumulated ash migrates through channels





# Hug PM Trap + Burner for Forced Regeneration

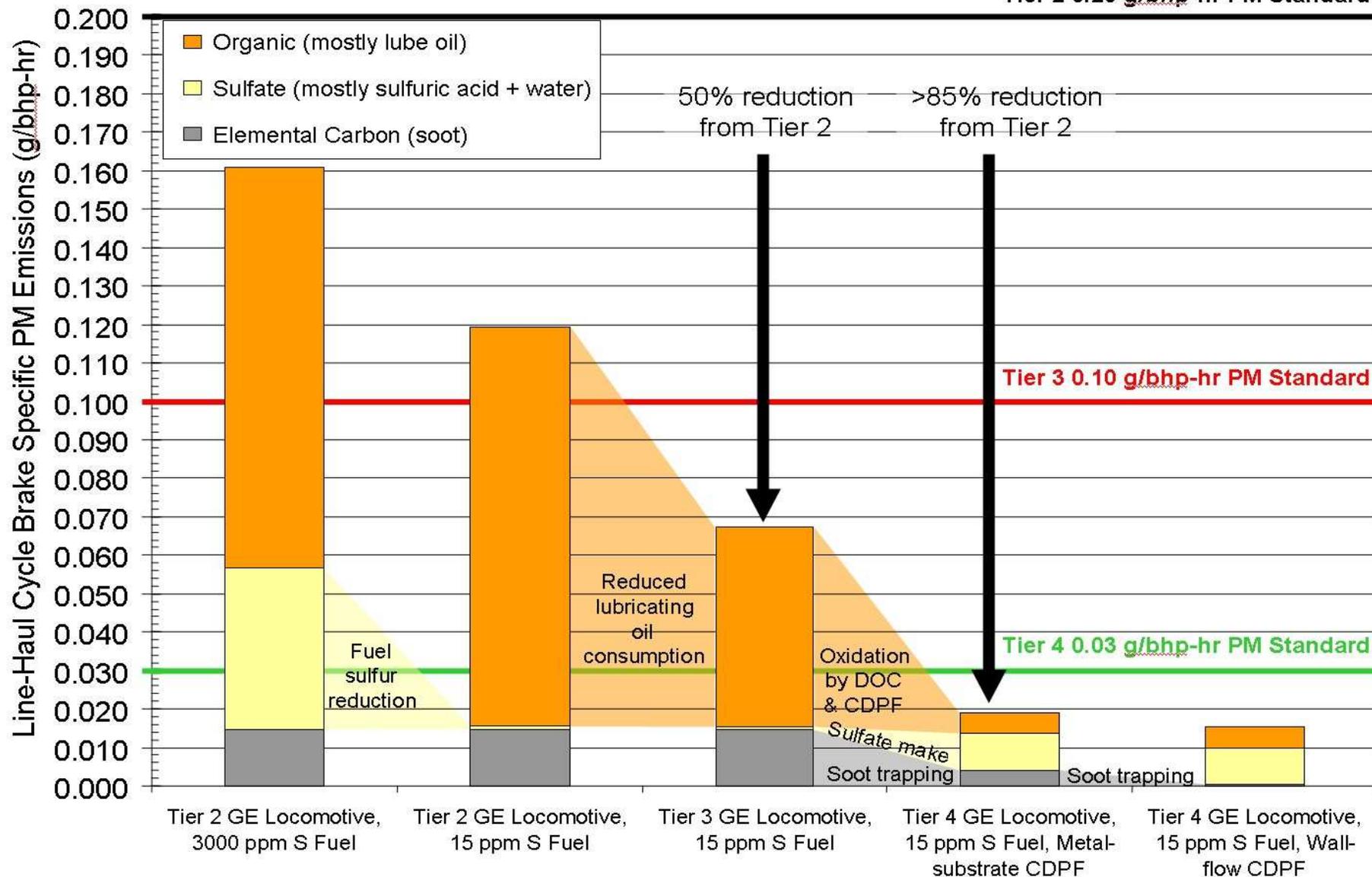
- Silicon carbide monolith units with alternating blocked channels
- Relatively open structure of porous wall eventually allows passage of accumulated ash
  - Reduced ash maintenance when compared to current 2007 U.S. truck silicon carbide trap systems
- Relies on diffusional particle capture (depth filtration) for removal of elemental carbon PM
- Would need to be combined with a catalytic coating and/or upstream DOC for passive regeneration and oxidation of organic PM





# Tier 4 PM Control

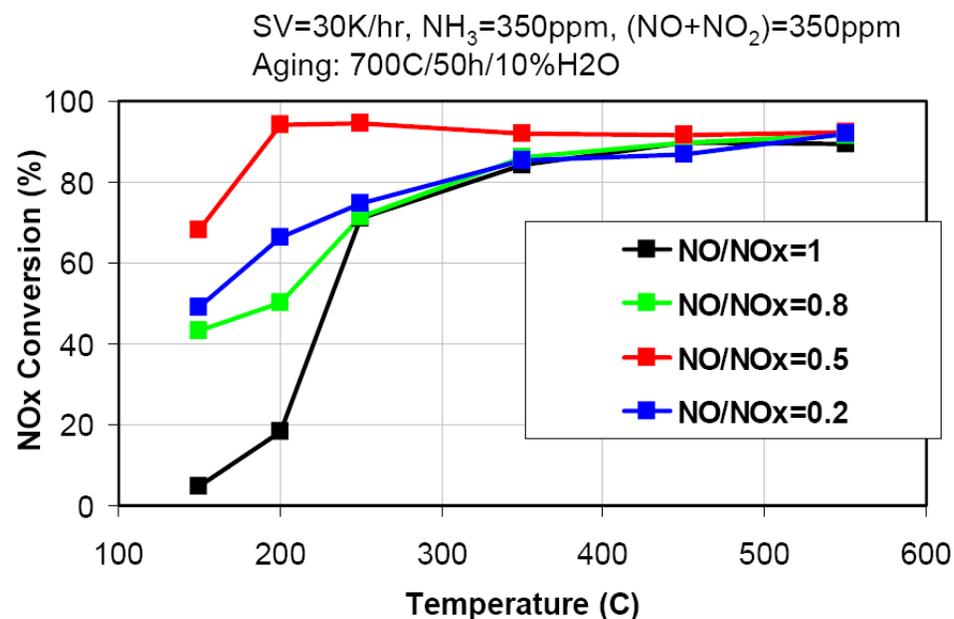
Tier 2 0.20 g/bhp-hr PM Standard





# Compact Fe-Zeolite SCR

- Developed for 2010 U.S. HD Trucks
- Improved high temperature durability
  - Thermally stable to 750 – 800°C
- Extension of technology originally developed for fuel oil and natural gas stationary turbine applications
  - 90+% NO<sub>x</sub> efficiency at very high hours of operation
- NO to NO<sub>2</sub> oxidation promotes low-temperature activity and allows a reduction in SCR catalyst volume





# Systems Integration

- DOC
  - 0.8 X engine displacement
  - Exhaust-manifold or post-turbine mounting
  - Generation of NO<sub>2</sub> for passive soot regeneration and improved low-temperature NO<sub>x</sub> control of the SCR system
  - Oxidation of organic PM species
- PM Filter
  - 1.7 X engine displacement
  - Mounted post-turbine (downstream of DOC)
- Urea dosing & static mixer
- SCR catalyst & ammonia slip catalyst
  - 2.5 X engine displacement
- Sensors for closed-loop control



## Implications for Locomotive Lubricants

- Change to low SAPS oils similar to CJ-4 specification for heavy-duty trucks
  - Work needed within LMOA to develop new locomotive specification for use with Tier 4 catalytic NOx and PM controls
- We need to determine acceptable ash loading rate and maintenance procedures for PM controls



## For further Information:

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# Layout of Hug “Mobiclean” System for 1.5 MW Locomotive

