# Diesel Fuel Sulfur Effects on the Performance of Diesel Oxidation Catalysts


**Shawn D. Whitacre**

Cummins, Inc.

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Diesel Engine Emissions Reduction Workshop

# Introduction

- Research focus:
  - Impact of sulfur on:
    - ☑ Catalyst performance
      - Short term catalyst durability
- This presentation summarizes results from fresh catalyst performance evaluations

- WVU contracted to conduct DOC and Lean NOx catalyst testing for **DECSE** program.

(experimental details discussed previously)

# Diesel Oxidation Catalyst (DOC)

- DOCs can be very effective in control of hydrocarbon (HC) and carbon monoxide (CO) emissions.
- Presently used for PM control in some buses (to meet 0.05 g/bhp hr standard)
- Will likely be used in combination with other NOx and PM control systems to meet future standards
  - HC control in NOx adsorber system
  - Ammonia slip in SCR system

# DOC Specifications

| Engine | Pt Loading (g PT/ft3) | Substrate Size (cm) | Volume (L) |
|---|---|---|---|
| ISM370 Cummins | 2 | 19.1 (OD) x 15.9 | 4.50 |
| T444E International | >50 | 17.8 x 11.8 | 2.92 |

400 cpsi cell density
Catalysts sized to handle 1/2 exhaust flow

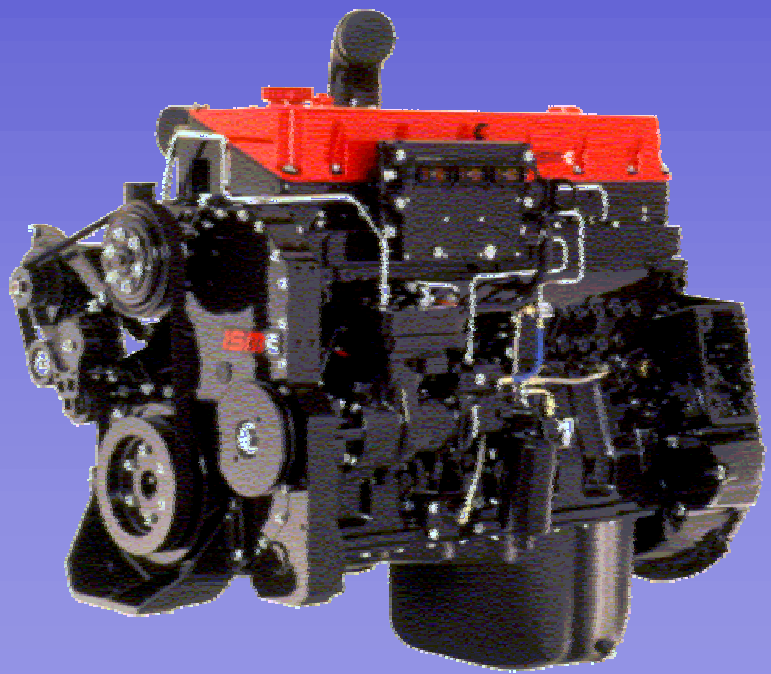
# DECSE Test Fuels

- Sulfur content: 3-, 30-, 150-, and 350-ppm S
- The 3-ppm base fuel is doped with a mixture of sulfur compounds:
  - dibenzothiophene (59.4%w)
  - benzothiophene (25.9%w)
  - di-t-butyl disulfide (5.7%w)
  - ethyl phenyl sulfide (8.9%w)
- Other properties:
  - 29%m aromatics  (10%m PNAs)
  - 45 cetane number

# Sulfate Make

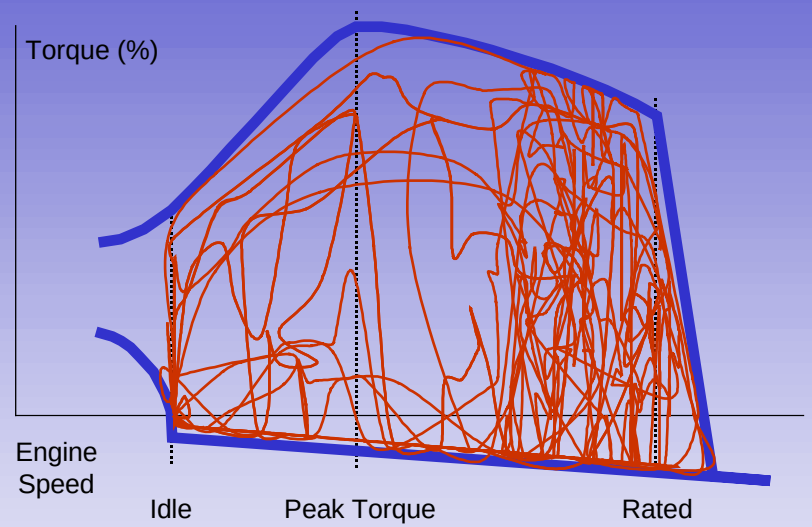
- DOCs are loaded with precious metal catalyst to facilitate oxidation of HC, CO, and PM
  - catalyst selection determined by exhaust temperature profile
  - $SO_2$ ---> $SO_3$ conversion is elevated by precious metal, especially at high temperature
  - at high temperatures, precious metal typically minimized to limit sulfate formation

# Cummins ISM370 Results

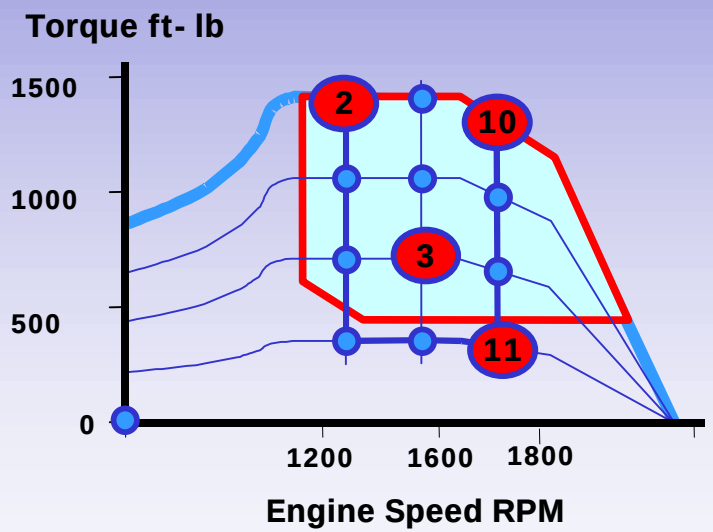


# Evaluation Protocol - ISM370

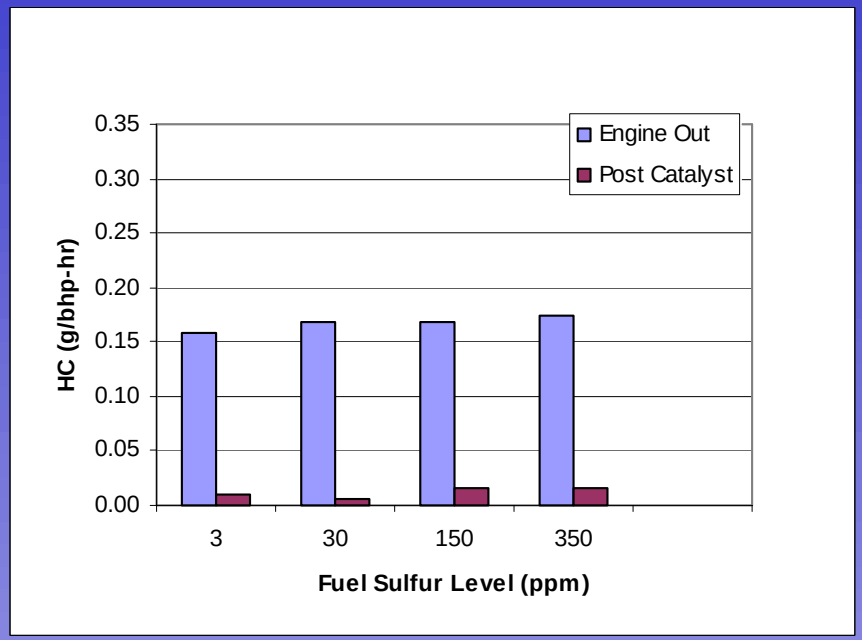
## HD Transient Federal Test Procedure



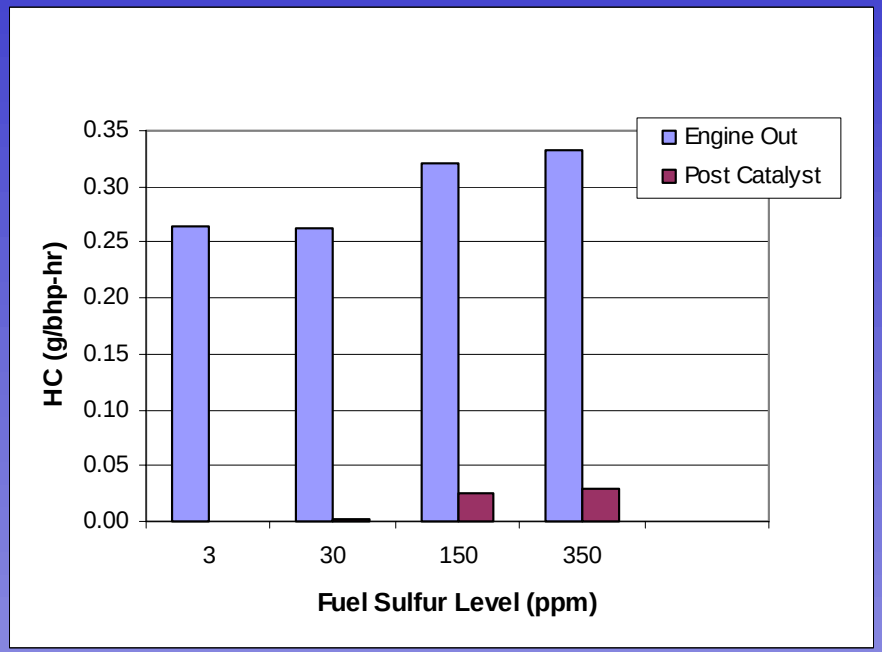

## 4-mode Steady-State



# Hydrocarbon Emissions



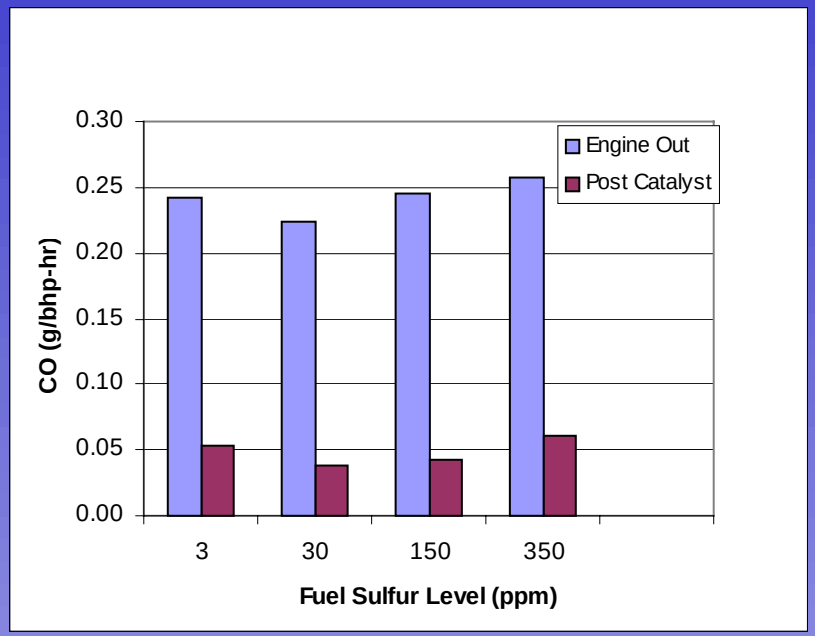

OICA 4-mode composite



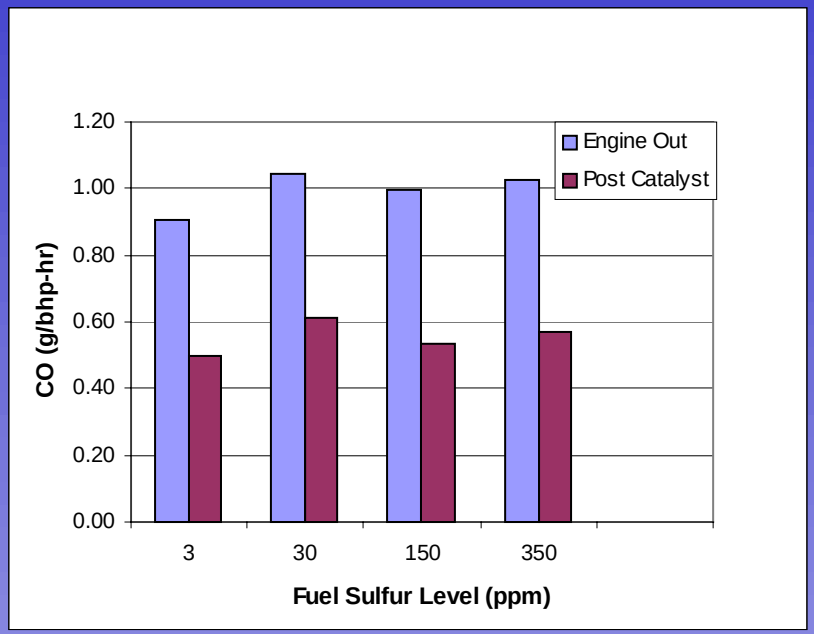

Transient FTP

## Cummins ISM370

# Carbon Monoxide Emissions




OICA 4-mode composite

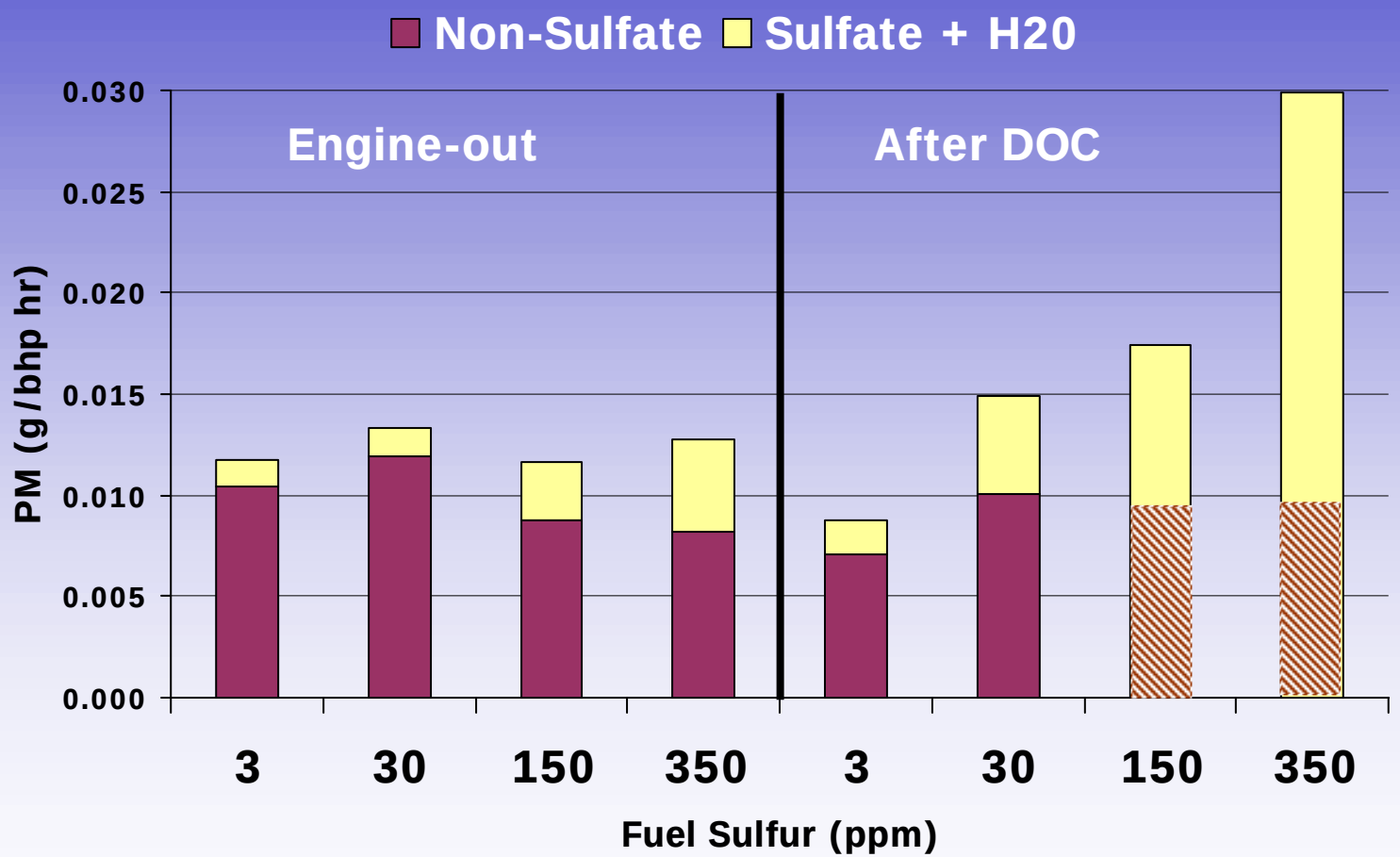



Transient FTP

## Cummins ISM370

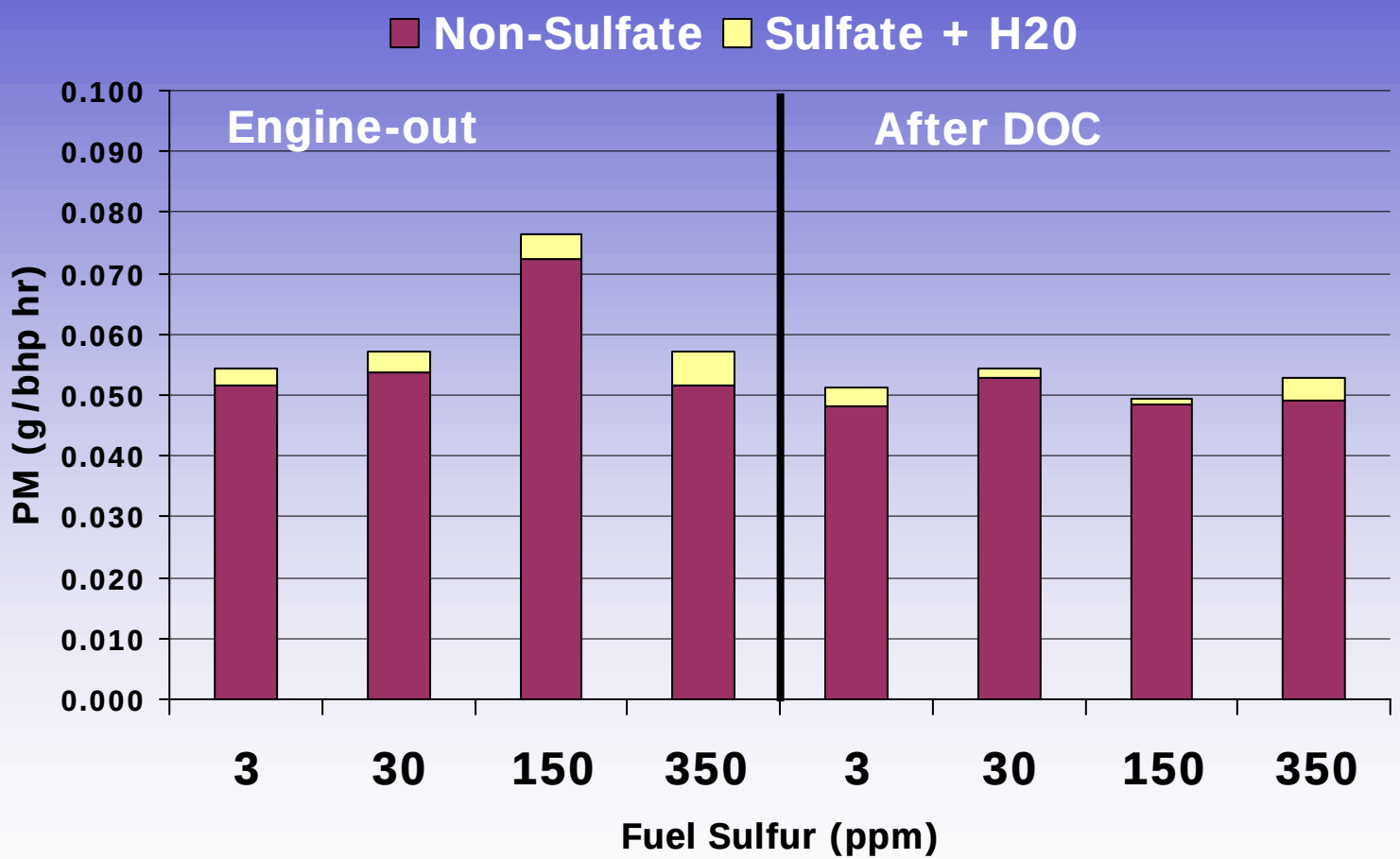
# Peak Torque PM - ISM370

OICA Mode 2 - 518°C (964°F) catalyst inlet temperature



# FTP PM Emissions - ISM370

Catalyst inlet temperature range = 124°C to 352°C Avg: 239°C



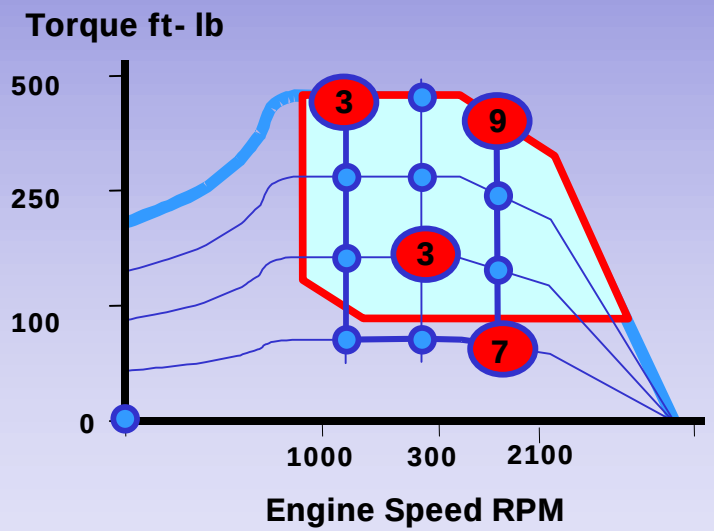
# Cummins ISM370 Summary

- DOC Performance
  - HC reduction:
    - 95%+ with low sulfur fuels over both cycles
    - reduction efficiency declines 3-10% with high S fuel
  - CO reduction
    - 80%+ reduction over steady-state modes
    - 40-50% reduction over transient test
    - not impacted by fuel sulfur level
  - PM
    - no apparent PM reduction
    - strong sulfur dependence, especially at elevated exhaust temperature

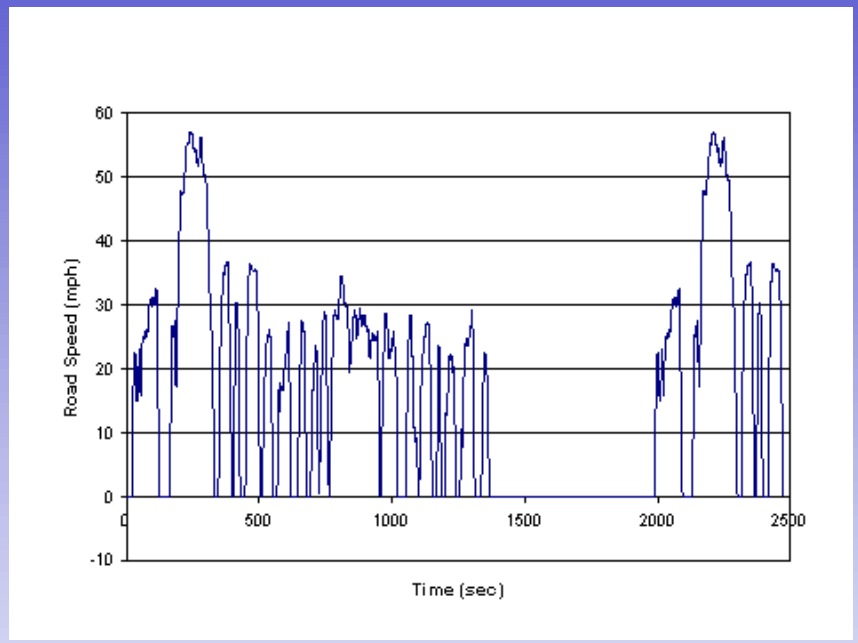
# International T444E Results

# Evaluation Protocol - T444E

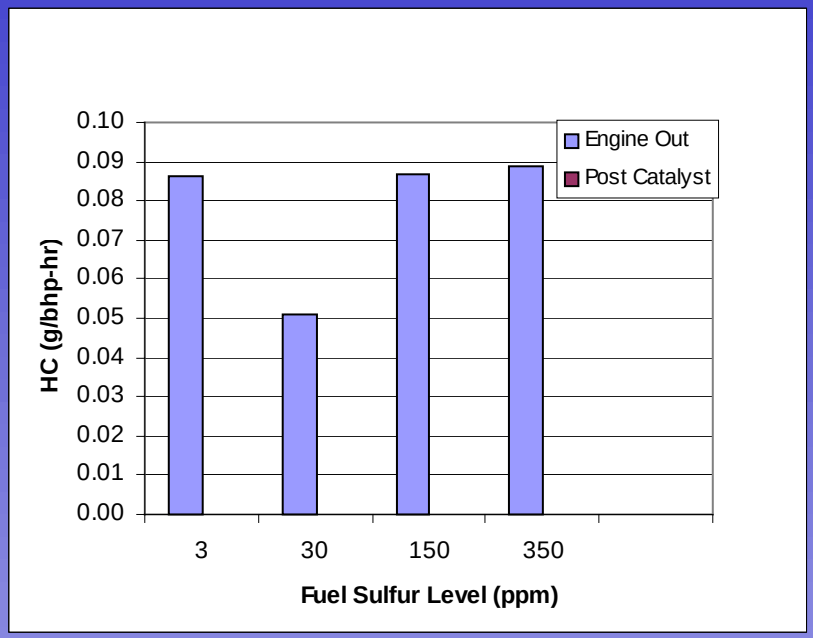
## Navistar 9-mode



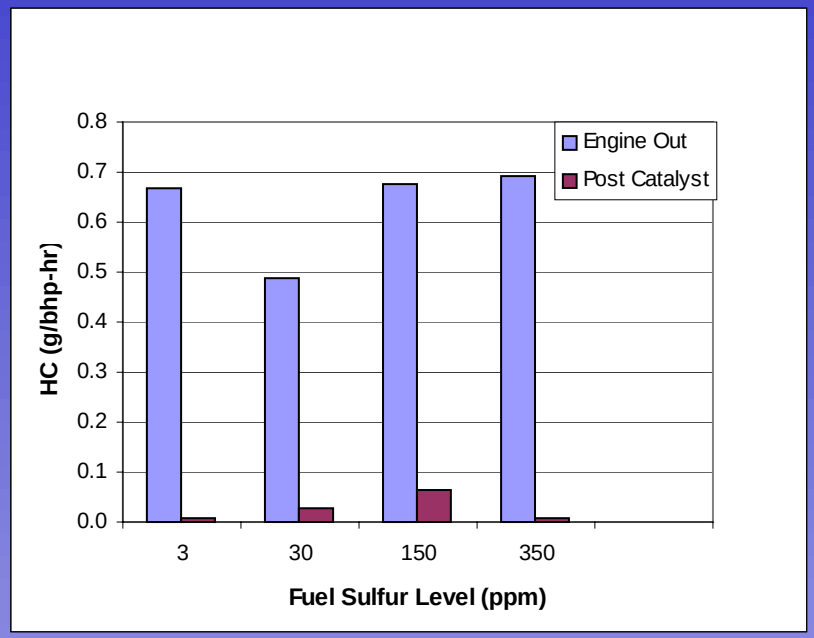

## FTP-75 Mimicry



# Hydrocarbon Emissions



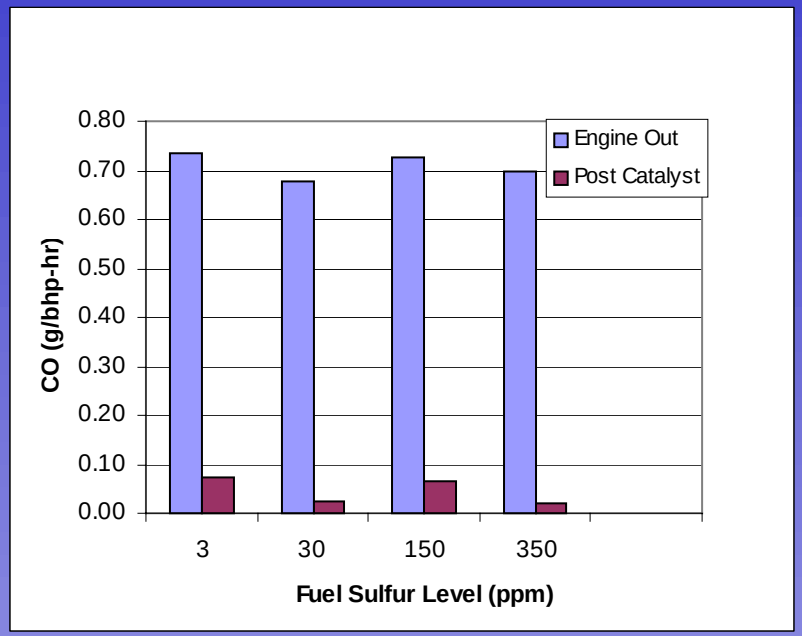

NAV 4-mode composite



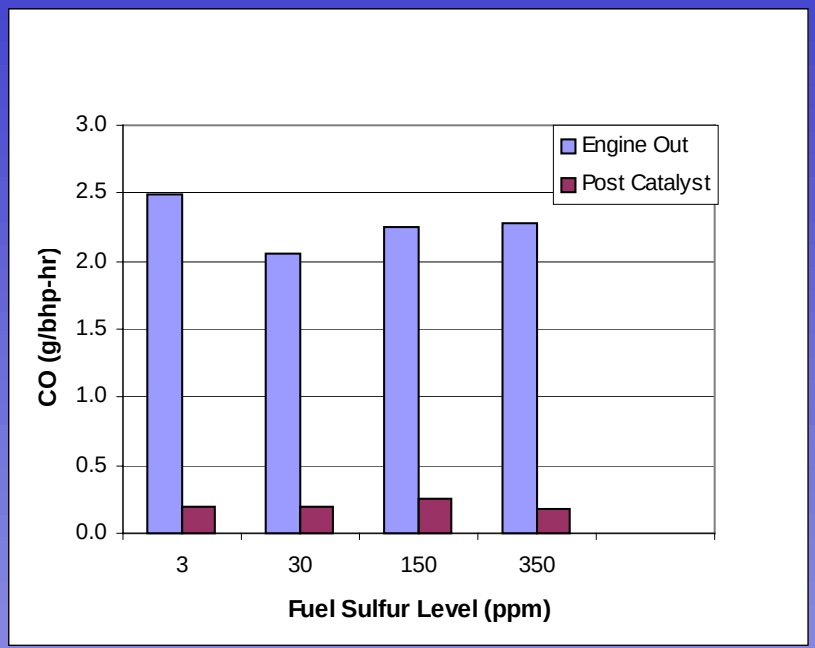

FTP75 Mimicry

## International T444E

# Carbon Monoxide Emissions




NAV 4-mode composite

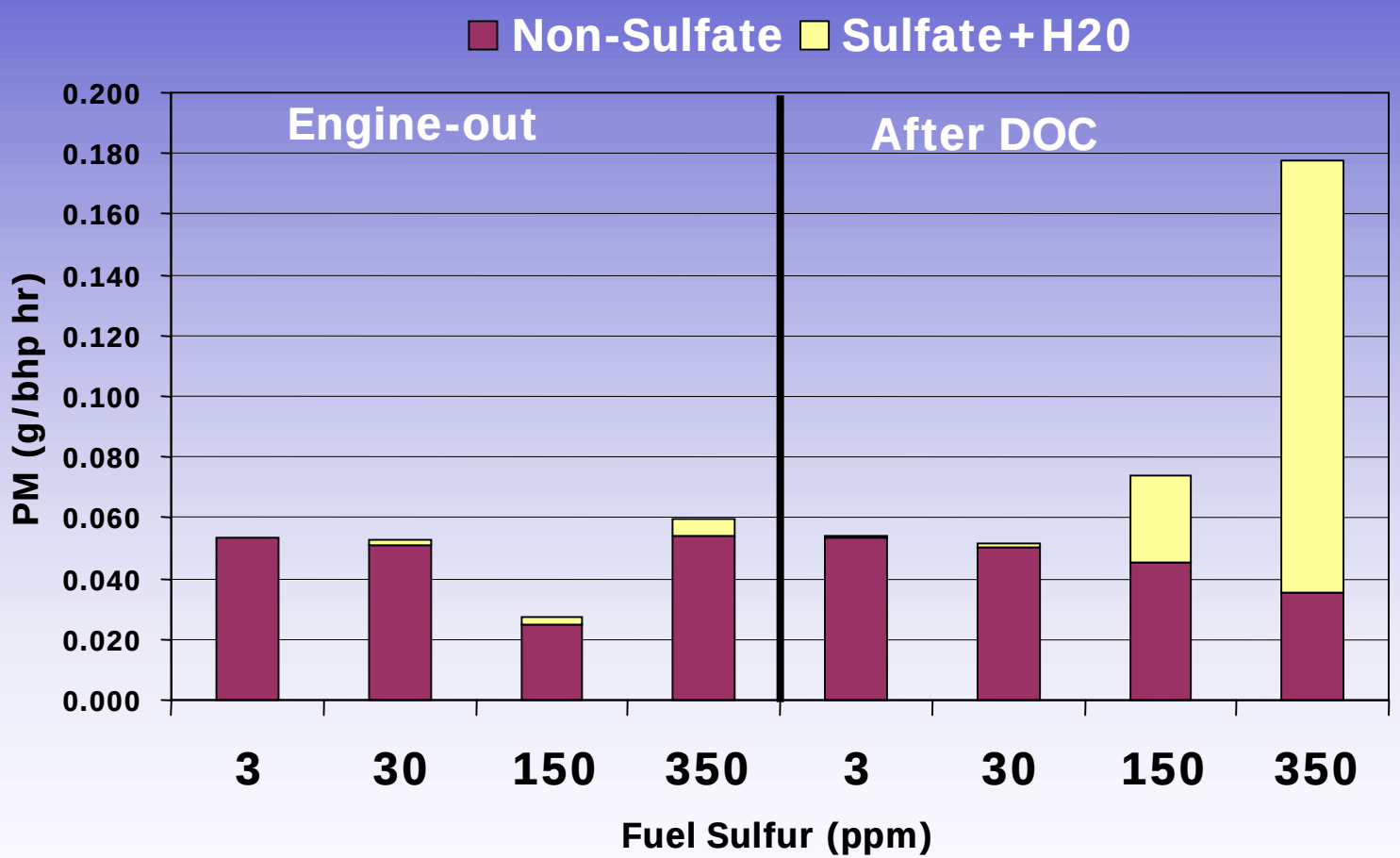



FTP75 Mimicry

## International T444E

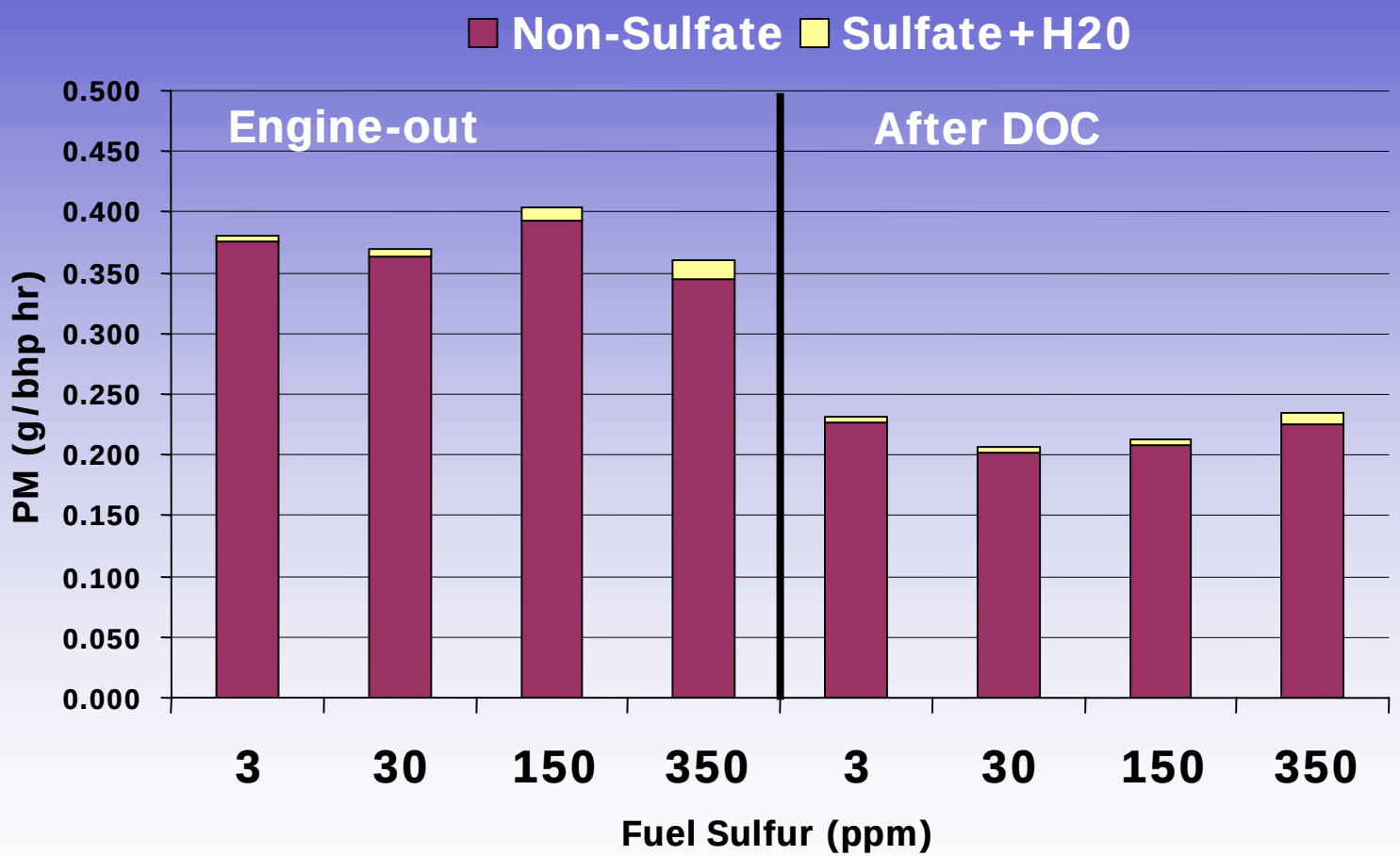
# Peak Torque PM - T444E

NAV 9 Mode 9 - 434°C (813°F) catalyst inlet temperature



# FTP75 PM Emissions - T444E

Catalyst Inlet Temperature: 105°C to 229°C Avg: 172°C



# International T444E Results

- DOC Performance
  - HC reduction:
    - 99%+ efficiency under steady state conditions
    - 90%+ efficiency over transient test
    - No fuel sulfur impact
  - CO reduction
    - 90%+ reduction in steady-state and transient tests
    - No fuel sulfur impact
  - PM
    - Sulfate contributes large fraction of total PM with 150-, and 350-ppm S fuels
    - Effective for PM reduction over transient

# Conclusions

- Both DOC formulations are very effective for HC and CO emission reduction
- Higher sulfur fuels negatively impact PM emissions, especially under high load conditions
  - precious metal required to ensure robust low temperature performance, but.....
  - sulfur is barrier to DOC application in systems designed to meet future low PM standards

# Acknowledgements


- Special thanks to:
  - West Virginia University
    - Scott Wayne, Nigel Clark, Mridul Gautam, Don Lyons, Ralph Nine, and several others
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