



Southwest  
Research  
Institute

**APBF-DEC**  
**MOTOR FUELS CONFERENCE**

# **Low Emissions Potential of EGR-SCR-DPF and Advanced Fuel Formulations-*A Progress Report***

**Department of Emissions Research  
Automotive Products and Emissions  
Research Division**

**October 2002**

# Participating Companies/Organizations

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## ***Automobile:***

Ford  
GM  
DaimlerChrysler  
Toyota

## ***Government:***

DOE  
NREL  
ORNL  
EPA  
CARB/SCAQMD

## ***Emission Control:***

MECA  
Johnson Matthey  
Delphi  
3M  
Engelhard  
Siemens  
Benteler  
ArvinMeritor  
Clean Diesel Tech.  
Corning  
Donaldson Co.  
OMG  
NGK  
Rhodia  
R. Bosch  
STT EMTEC  
Tenneco Automotive

## ***Energy/ Additives:***

API  
American Chemistry  
Council  
NPRA  
BP  
Ethyl  
ExxonMobil  
Marathon Ashland  
Pennzoil-Quaker State  
Lubrizol  
Shell Global Solutions  
Castrol  
ChevronTexaco  
Chevron Oronite  
Ciba  
Ergon  
Valvoline  
Motiva  
Infineum

## ***Engines:***

EMA  
Caterpillar  
Detroit Diesel  
Cummins  
John Deere  
Mack Trucks  
International Truck  
& Engine


## ***Technology:***

Battelle



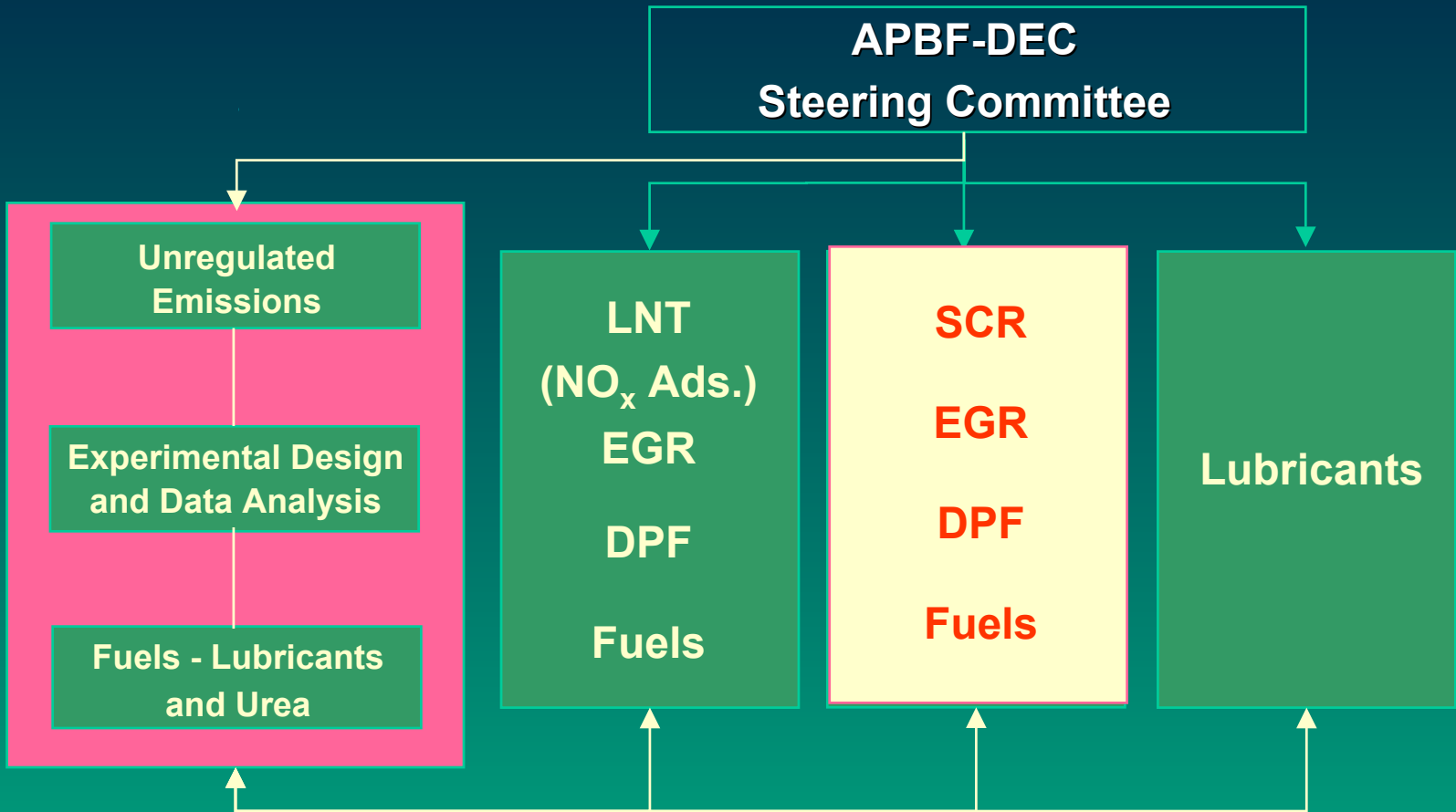
**APBF-DEC**

# *Outline*

- 
- ◆ Introduction
  - ◆ Objectives
  - ◆ Technical Approach
  - ◆ Test Setup
  - ◆ System Components
  - ◆ Results
  - ◆ Summary & Conclusions



# Introduction--APBF-DEC



*Adapted From NREL/W. Clark  
Presentation 9/26/01*



# *Outline*

◆ Introduction



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# *Objectives*

- ◆ **To Demonstrate Low Emissions Performance of Advanced Diesels+LPL EGR\*+Urea SCR+DPF (2 Different Systems)**
- ◆ **To Evaluate Sensitivities of The Control System Performance To Fuel Variables**
- ◆ **To Determine The Regulated And Unregulated Emissions W. &W/O Emission Controls**
- ◆ **To Examine The Emission Control System Durability**
- ◆ **To Sample Toxic Emissions For Analysis By Outside Lab**

**Emissions Goals: 2007 EPA NDE Standards**



*\* Low Pressure Loop EGR*

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|||  ◆ Technical Approach

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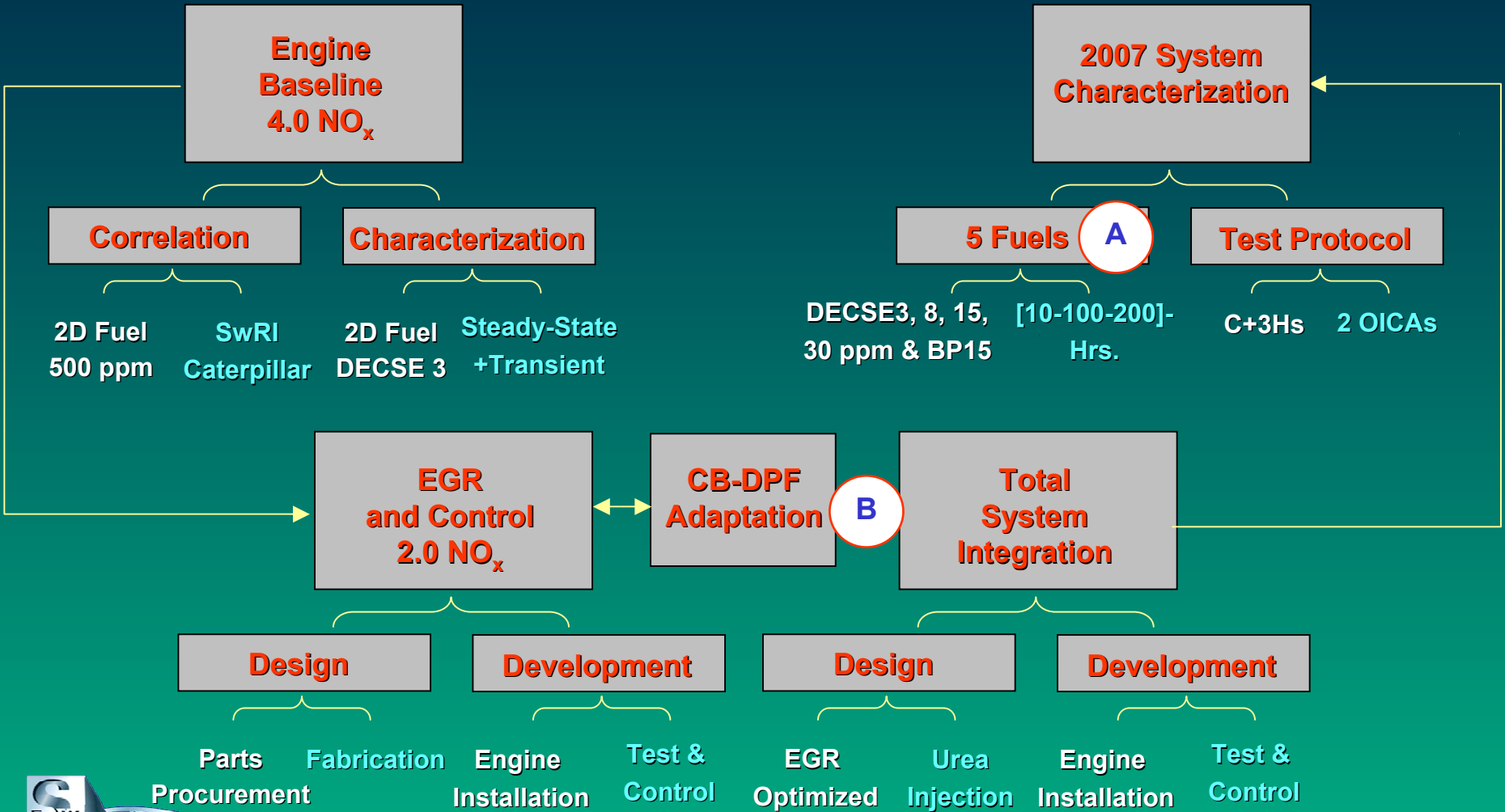
◆ System Components

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# Technical Approach--Development ( $\phi$ 1)



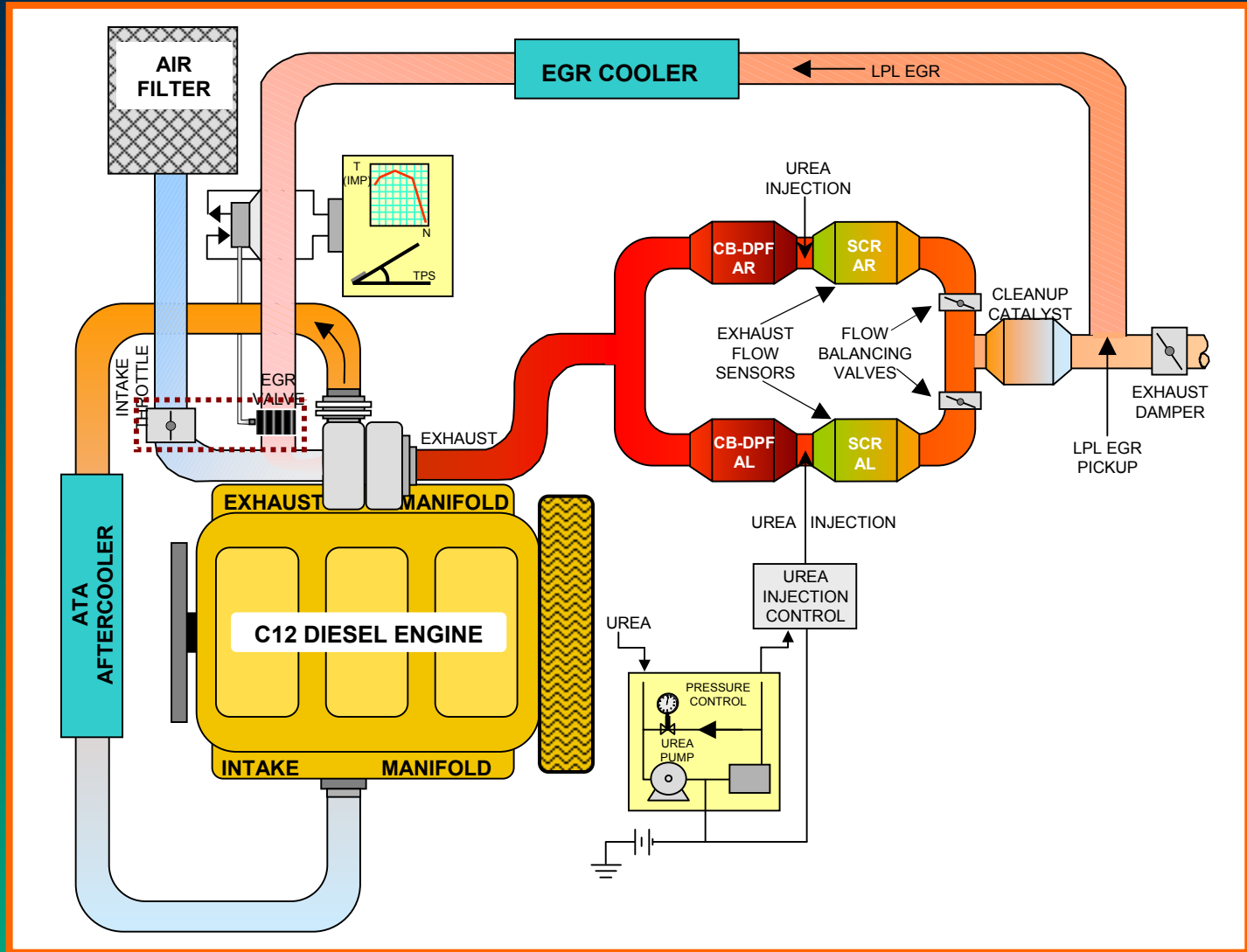


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# Test Setup



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# *System Components--Engine*



## **Engine Description** (on consignment to the project)

- Caterpillar C12
- 12.0 L/**430 hp**
- In-Line/6 Cylinders
- Turbocharged/Intercooled
- Rated Speed: 1800 rpm
- Peak Torque: 1650 lb-ft
- Peak Torque Speed: **1200 rpm**
- Emission Calibration: MY 2000



# *System Components--Fuels*

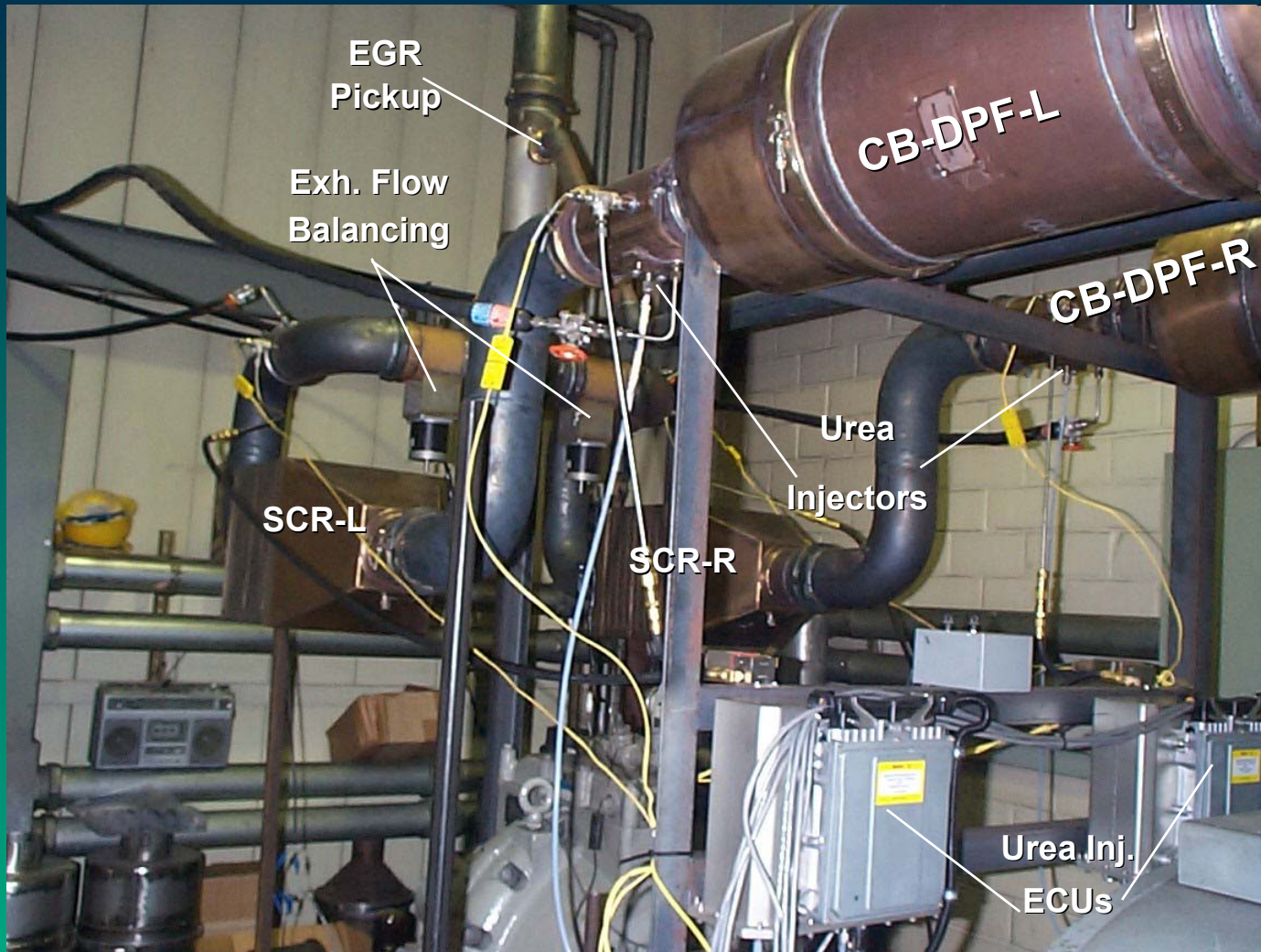
- ◆ **Fuel 1:** Baseline --3 ppm S
- ◆ **Fuel 2:** Durability/Emission Eval. --8 ppm S
- ◆ **Fuel 3:** Research/Emission Eval.--15 ppm S
- ◆ **Fuel 4:** BP 15
- ◆ **Fuel 5:** 30 ppm (Excursions)



# *System Components--EGR System*



# *Scope of Work--Post-Combustion Emission Controls*



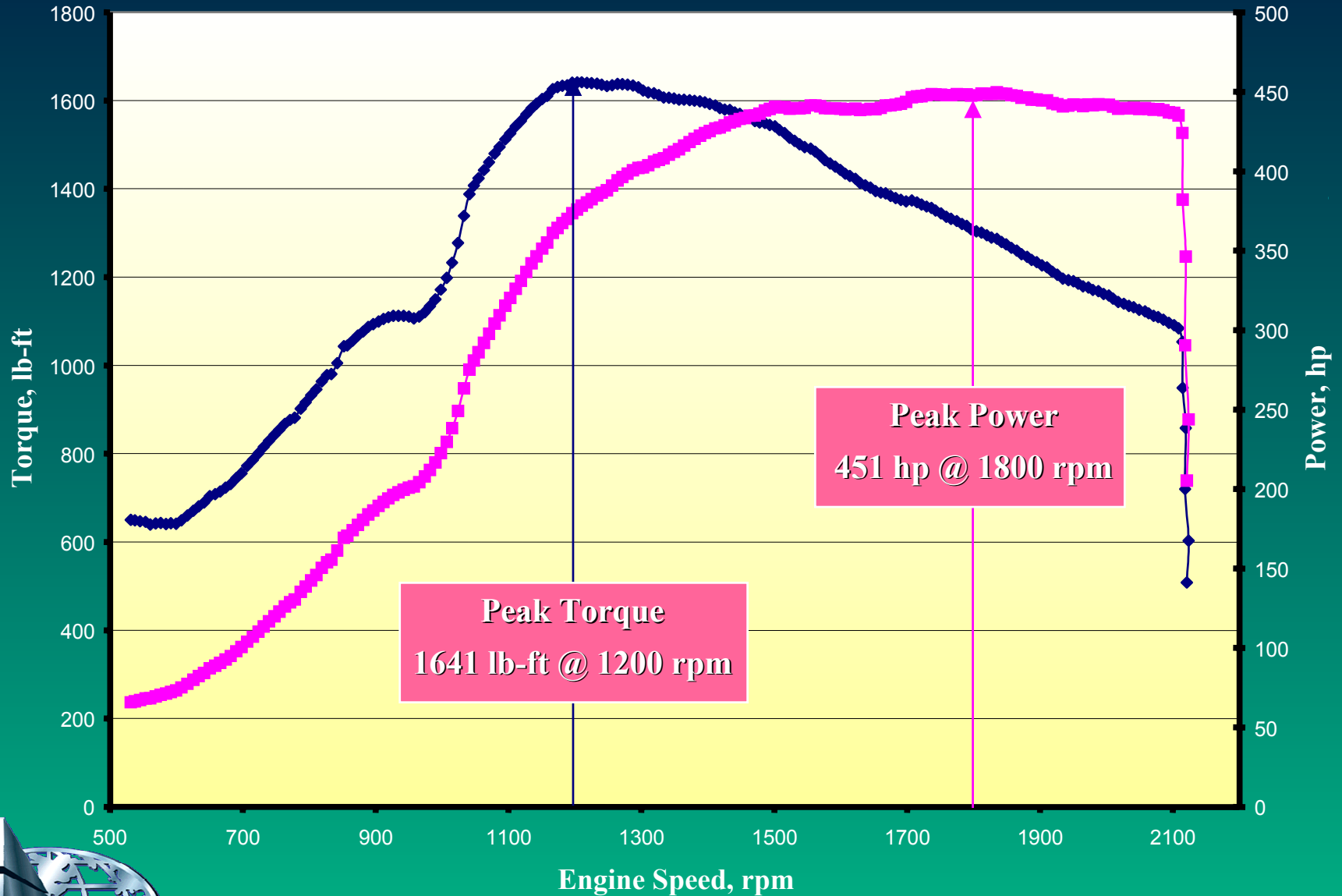
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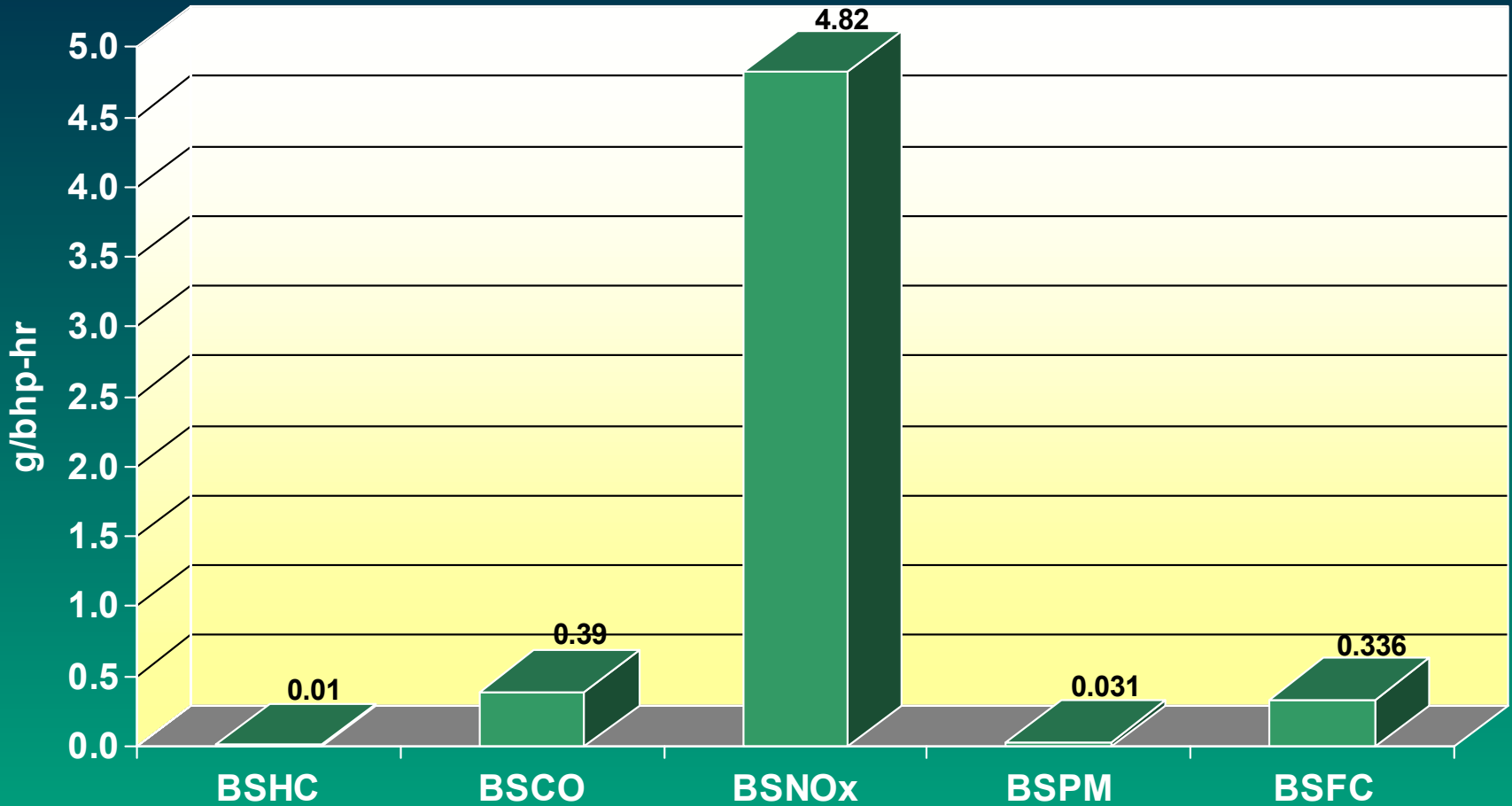




# Engine Performance

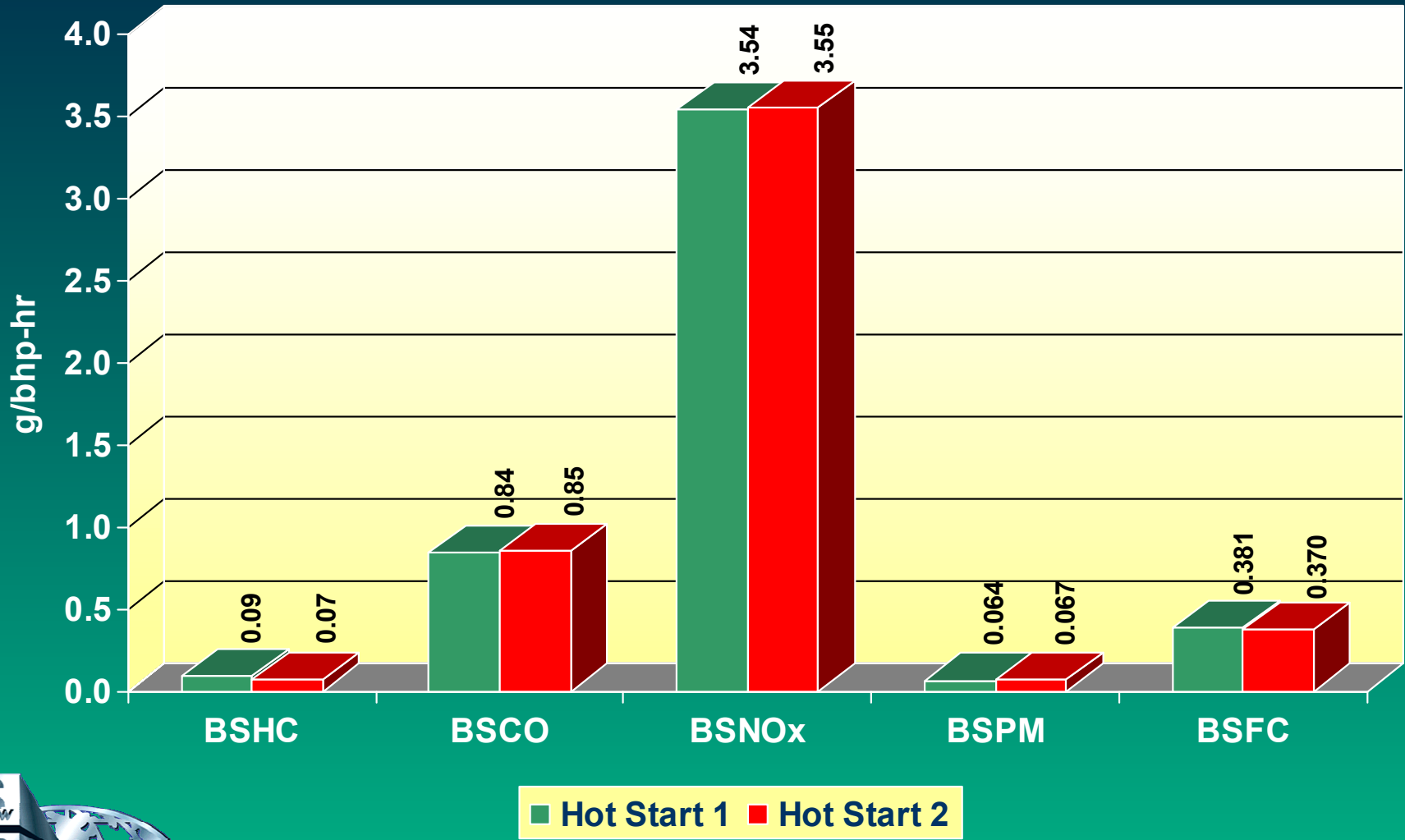


# Steady-State Emissions--350ppm Cert. 2D Fuel

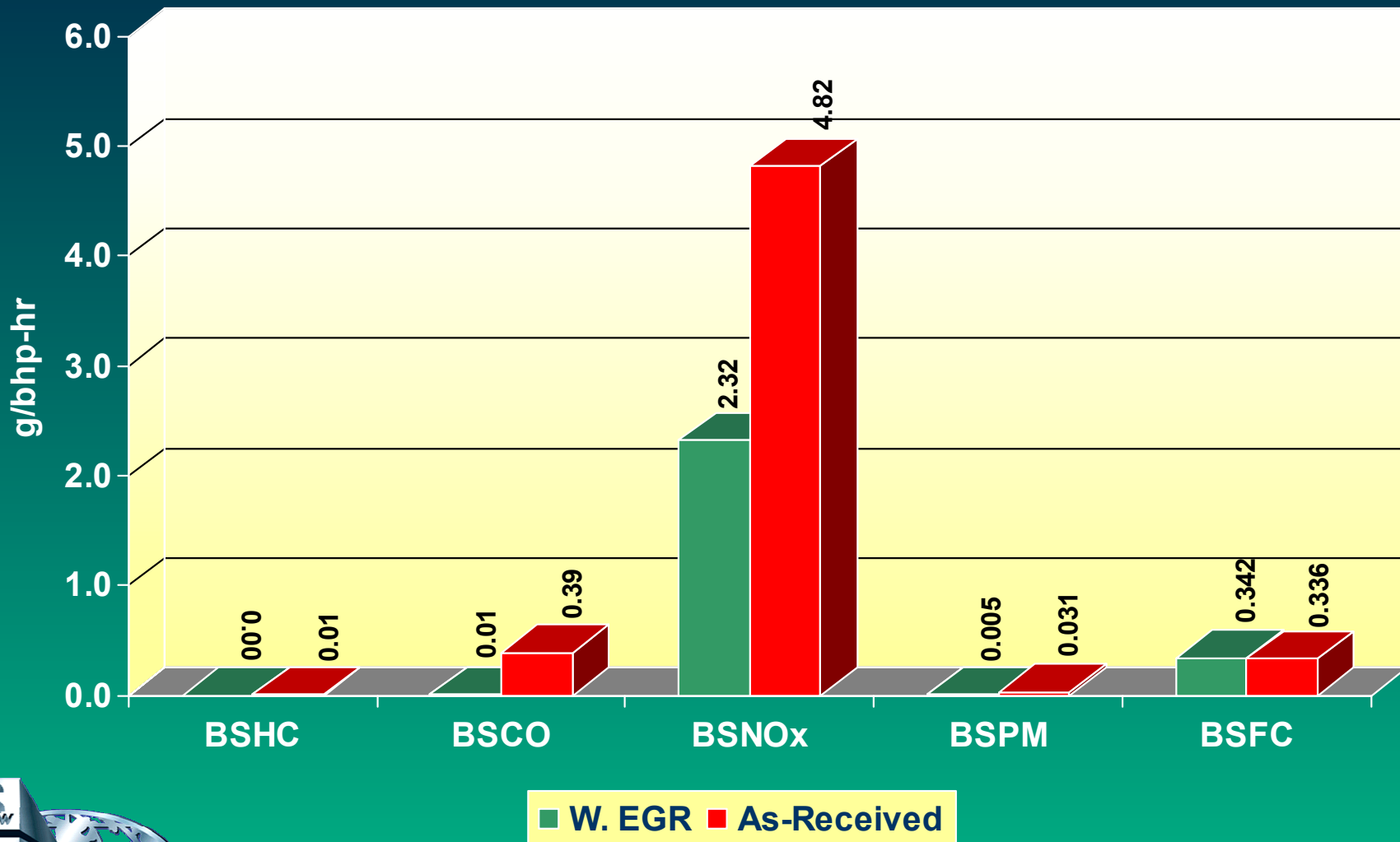


■ OICA 1

# *Transient Emissions -- 350ppm Cert. 2D Fuel -- Hot Starts*

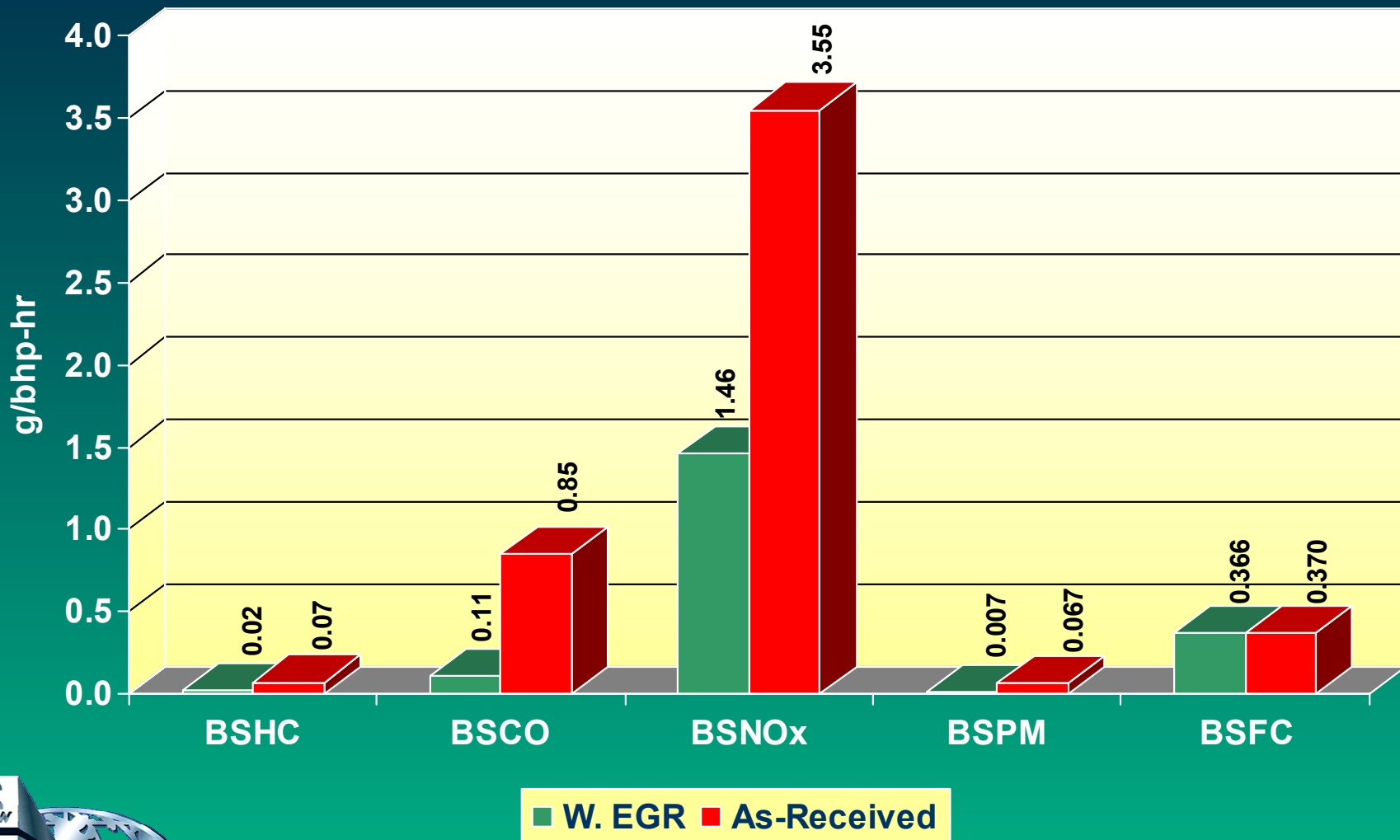


# *Steady-State Emissions Comparison--As-Received W. Cert. Fuel 350ppm S and W.EGR\*--DECSE 3ppm Fuel*



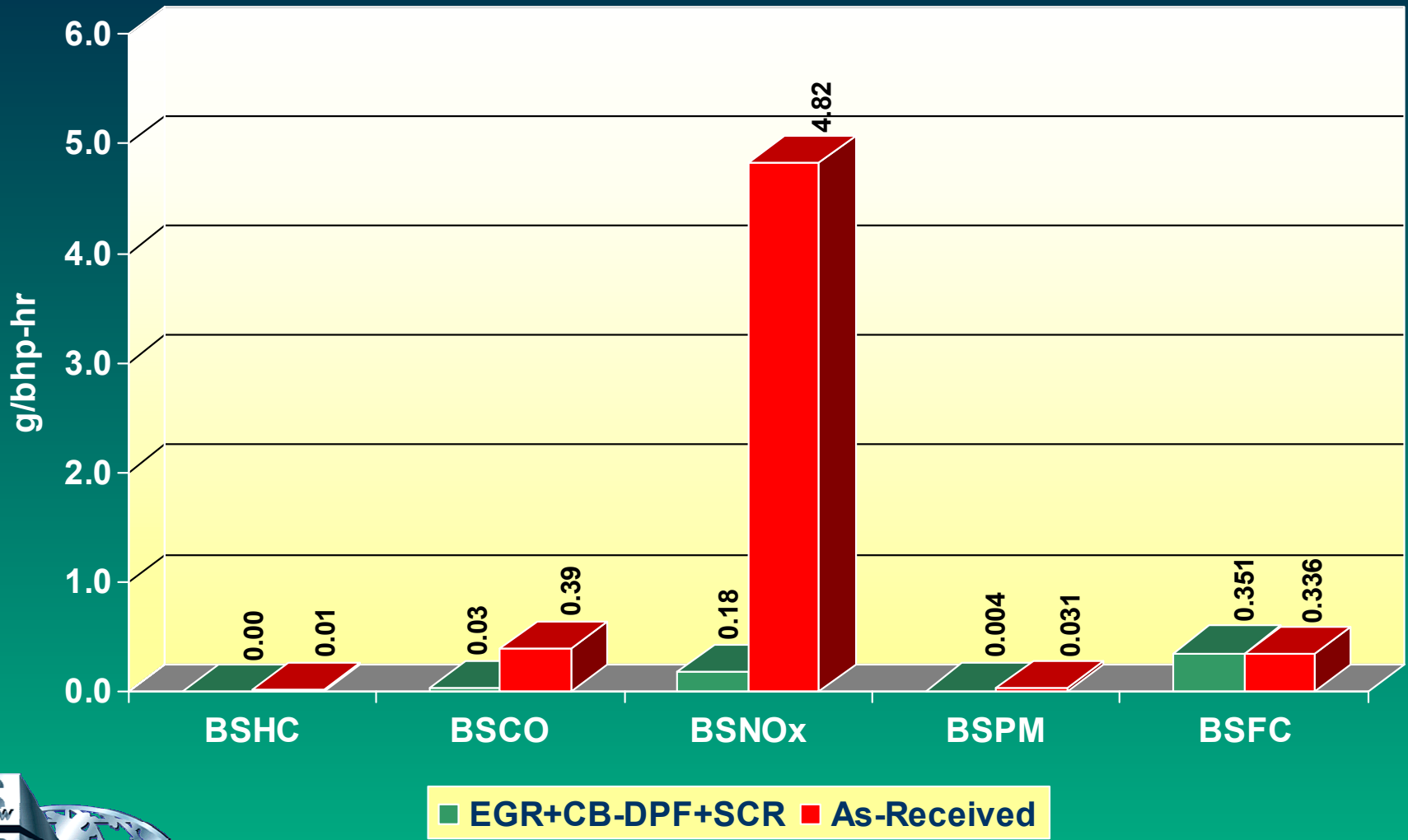
*EGR\* : Low Pressure Loop EGR With CB-DPF*

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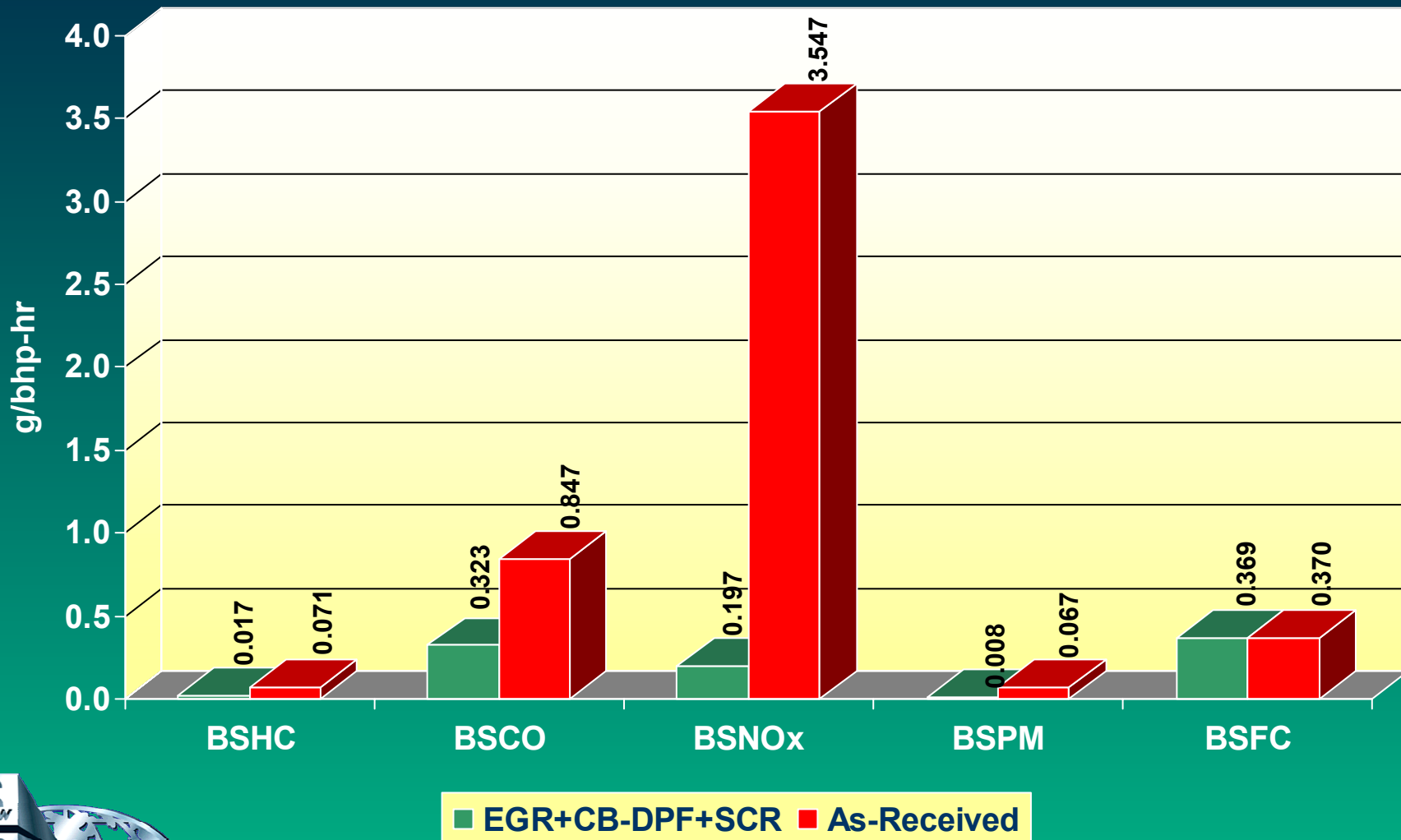
*EGR\* : Low Pressure Loop EGR With CB-DPF*

# Steady-State Emissions Comparison--As Received w. 350 ppm vs. EGR\*/CB-DPF/SCR--DECSE 3 ppm Fuel



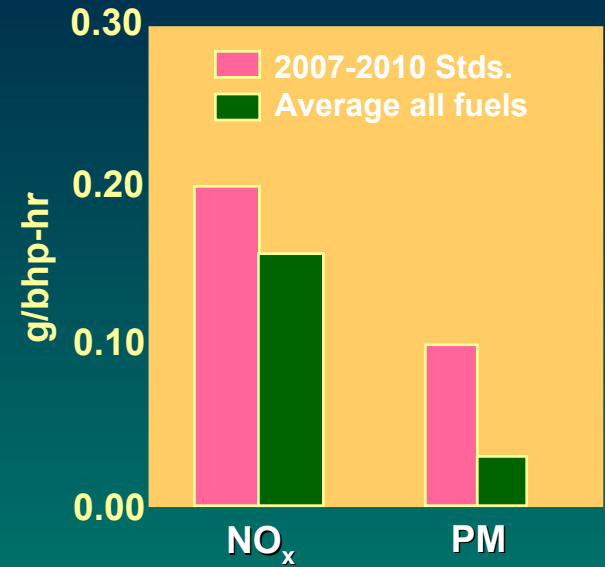
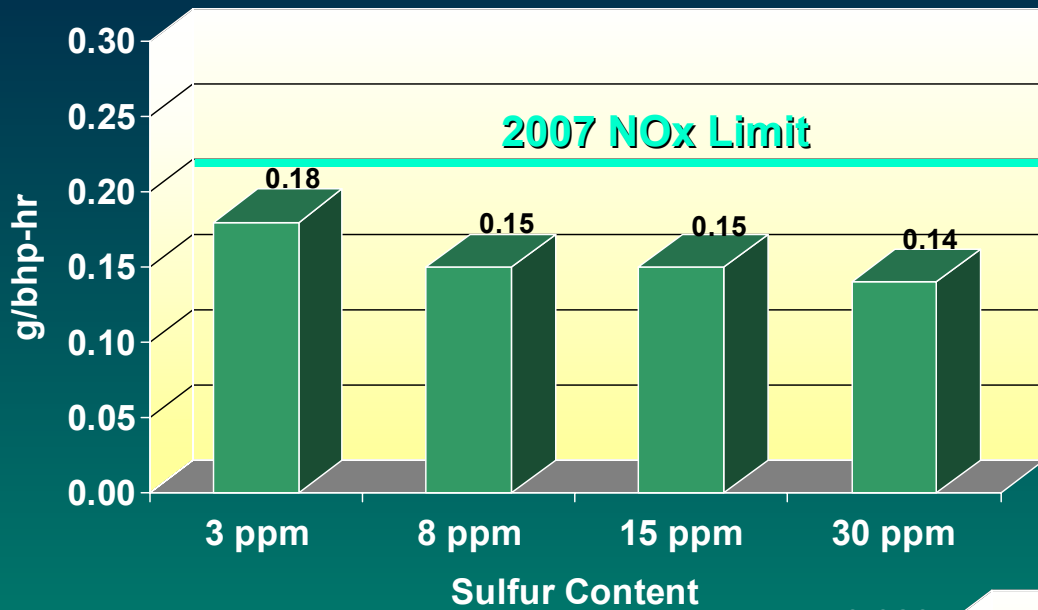
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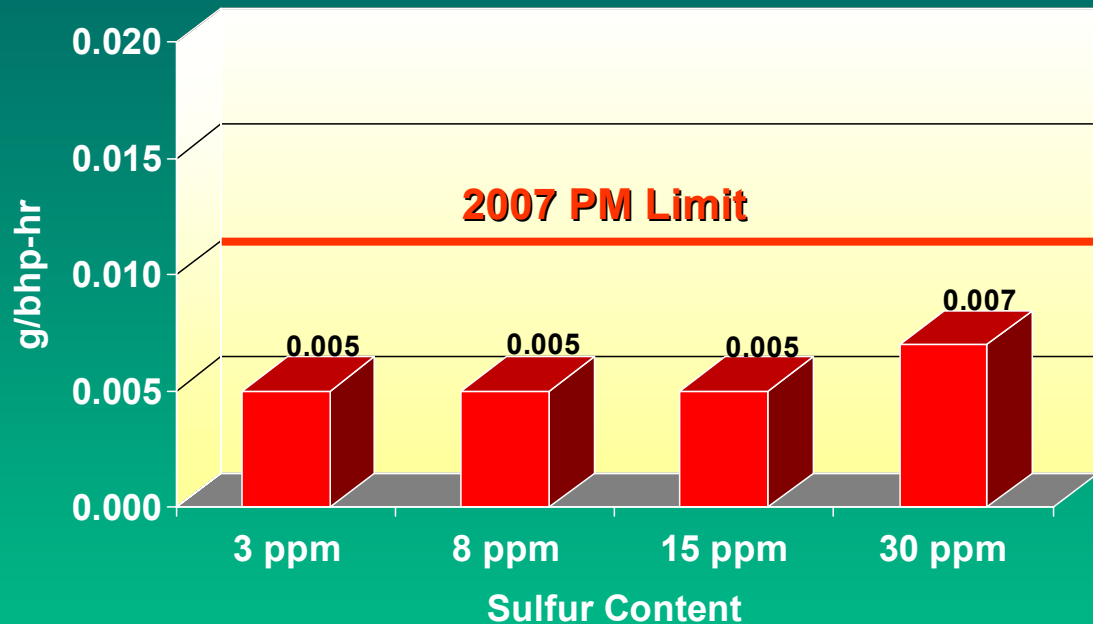


*EGR\* : Low Pressure Loop EGR With CB-DPF*

# Short-Term Sensitivity To Fuel Sulfur--Steady-State Composite Emissions -- Average of 2 OICA Tests

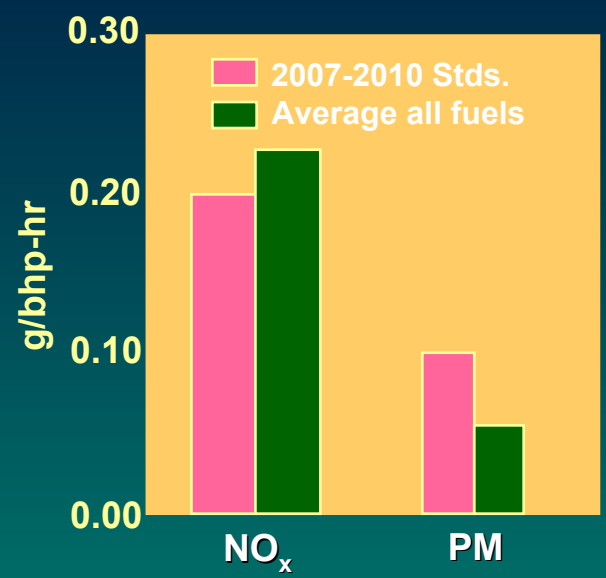
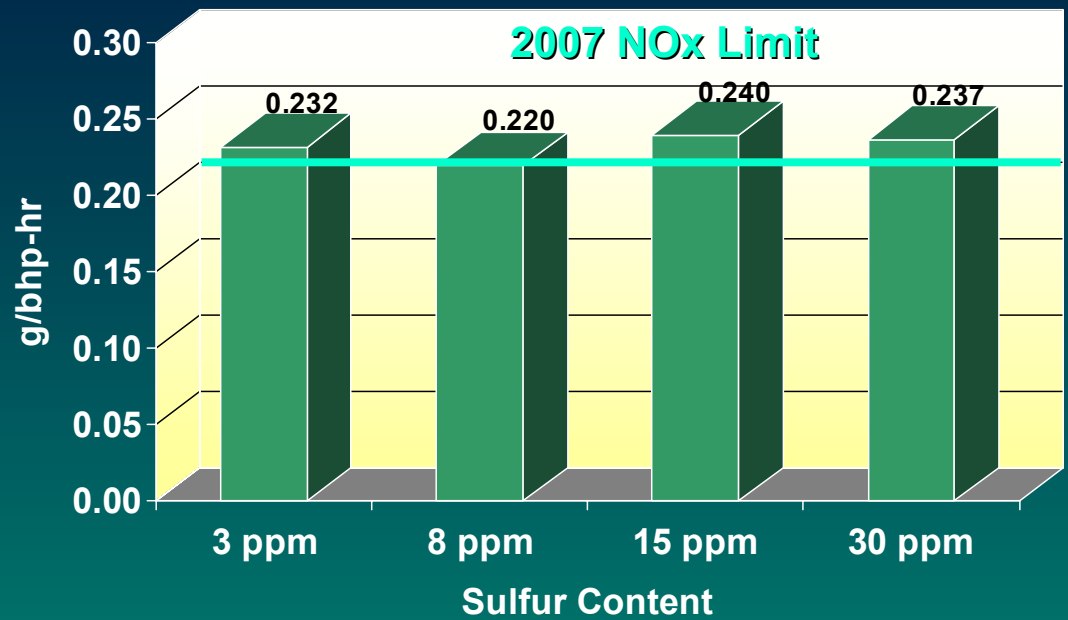


■ 250 hours of transients on aftertreatment system using all test fuels

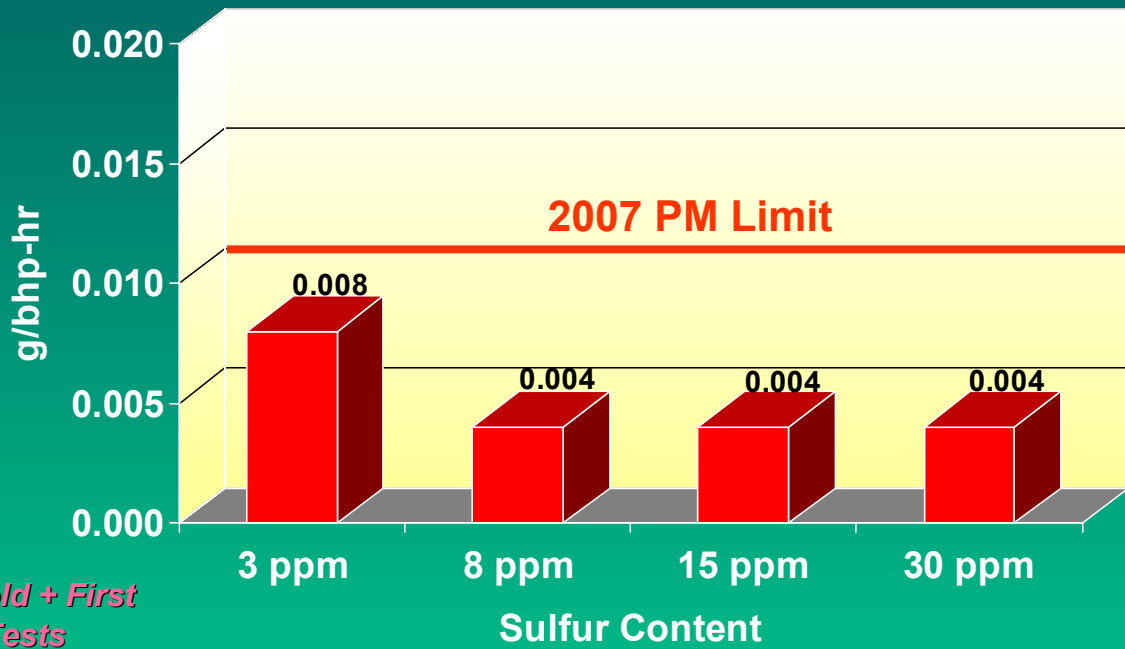




# Short-Term Sensitivity To Fuel Sulfur--Transient Composite Emissions\*



■ 250 hours of transients on aftertreatment system using all test fuels



\* Composite Based on Cold + First Hot-Start EPA Transient Tests

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# Summary and Conclusions

- ◆ The C-12 Caterpillar test engine had an EPA Transient NO<sub>x</sub>/PM emissions of 3.5/0.07 g/bhp-hr.
- ◆ The LPL EGR system was installed and calibrated to yield:
  - over 50% NO<sub>x</sub> reduction and,
  - about 90%PM reduction
- ◆ SCR System A was installed and urea injection was optimized for the OICA as well as the transient cycle.
- ◆ System A (including LPL EGR) yielded NO<sub>x</sub>/PM of 0.18/0.004 g/bhp-hr in the OICA test.
- ◆ System A calibration for the EPA transient test cycle yielded composite results of 0.22 to 0.24 g/bhp-hr NO<sub>x</sub> and 0.004 to 0.008 g/bhp-hr PM.
- ◆ The next step for System A is 6,000 hours of durability.



