

# AD HOC AUTO/ENERGY CIDI R&D PROGRAM



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**MOTOR FUELS: EFFECTS ON ENERGY  
EFFICIENCY & EMISSIONS IN THE  
TRANSPORTATION SECTOR MEETING**

**DOE**

Washington, D.C.  
October 9-10, 2002



# PROGRAM MANAGEMENT

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## **AD HOC CIDI R&D WORKING GROUP**

**FUNCTION:** to provide overall program management & support including:

- Assure consistency between the program projects
- Define appropriate information flow among participants in all projects & others including trade associations
- Ensure that the overall program is properly managed



# PROGRAM MANAGEMENT

## Phase I

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### **AD HOC CIDI R&D WORKING GROUP**

#### **MEMBERSHIP:**

Co-Chairs:

Tom Asmus (DaimlerChrysler)

Jack Segal (ARCO)

Other Members:

Ford Representative (Brad Bates)

GM Representative (Jim Spearot)

BP Amoco Representative (Tom Bond)

Exxon Representative (Jim Stokes)

Mobil Representative (Jim Katzer)

Jim Wallace & Associates LLC

Team Leader of DOE's OAAT (Steve Chalk)

Co-leaders of each project teams



# CIDI R&D PROGRAM-Phase I

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**GENERAL:** The Program was Auto/Energy Industry led with major input and financial support from DOE

## **Phase I consisted of four projects:**

- CIDI Diesel Fuel Test Program
- PM Analysis Project
- Oxygenate Analysis Project
- Lube Oil Analysis Project



# **Phase I Diesel Fuel Test Program**

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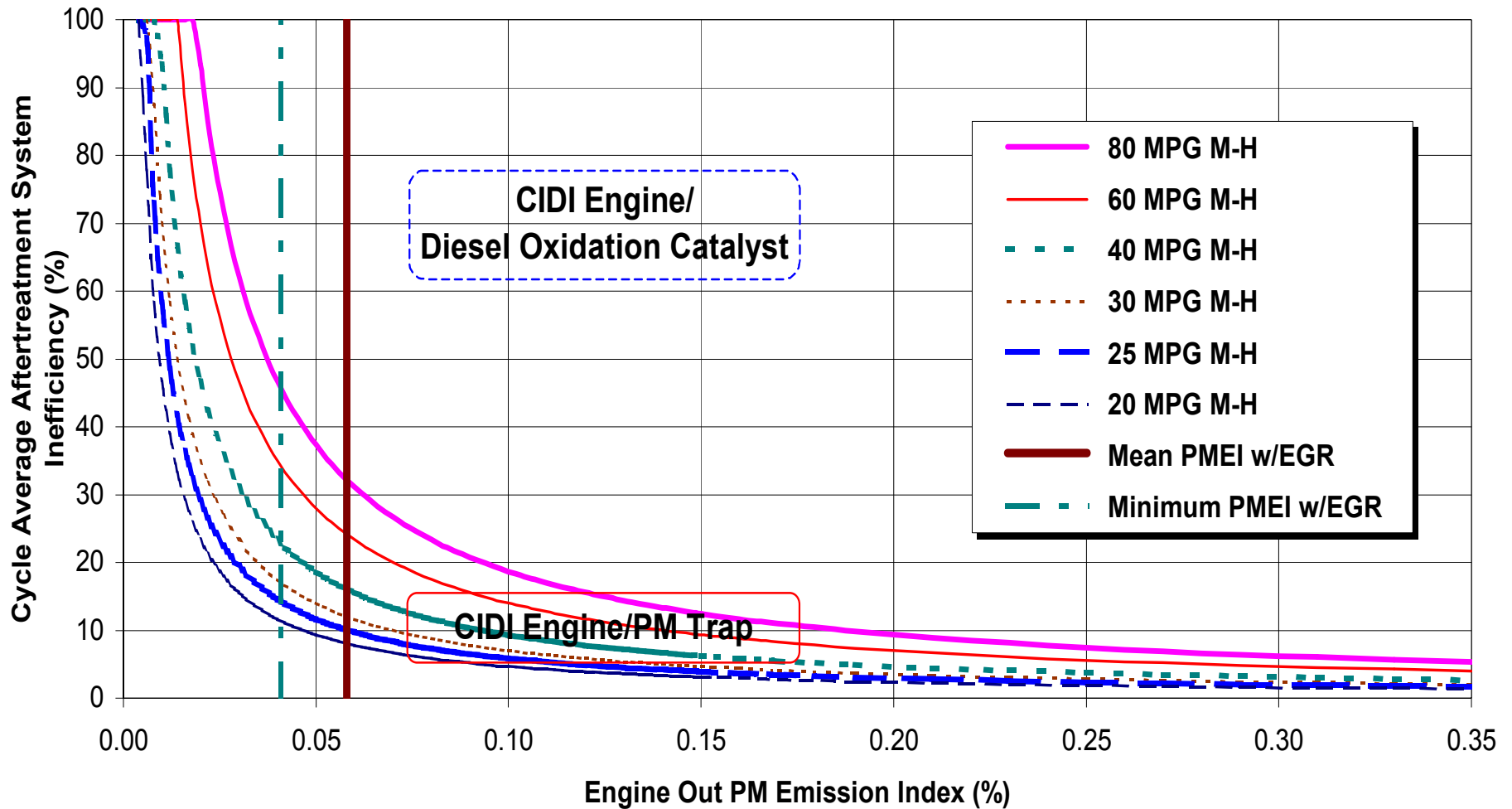
## **Objective**

- Determine the sensitivity of engine-out NO<sub>x</sub> and particulate matter to changes in diesel fuel formulation in light-duty CIDI engines.

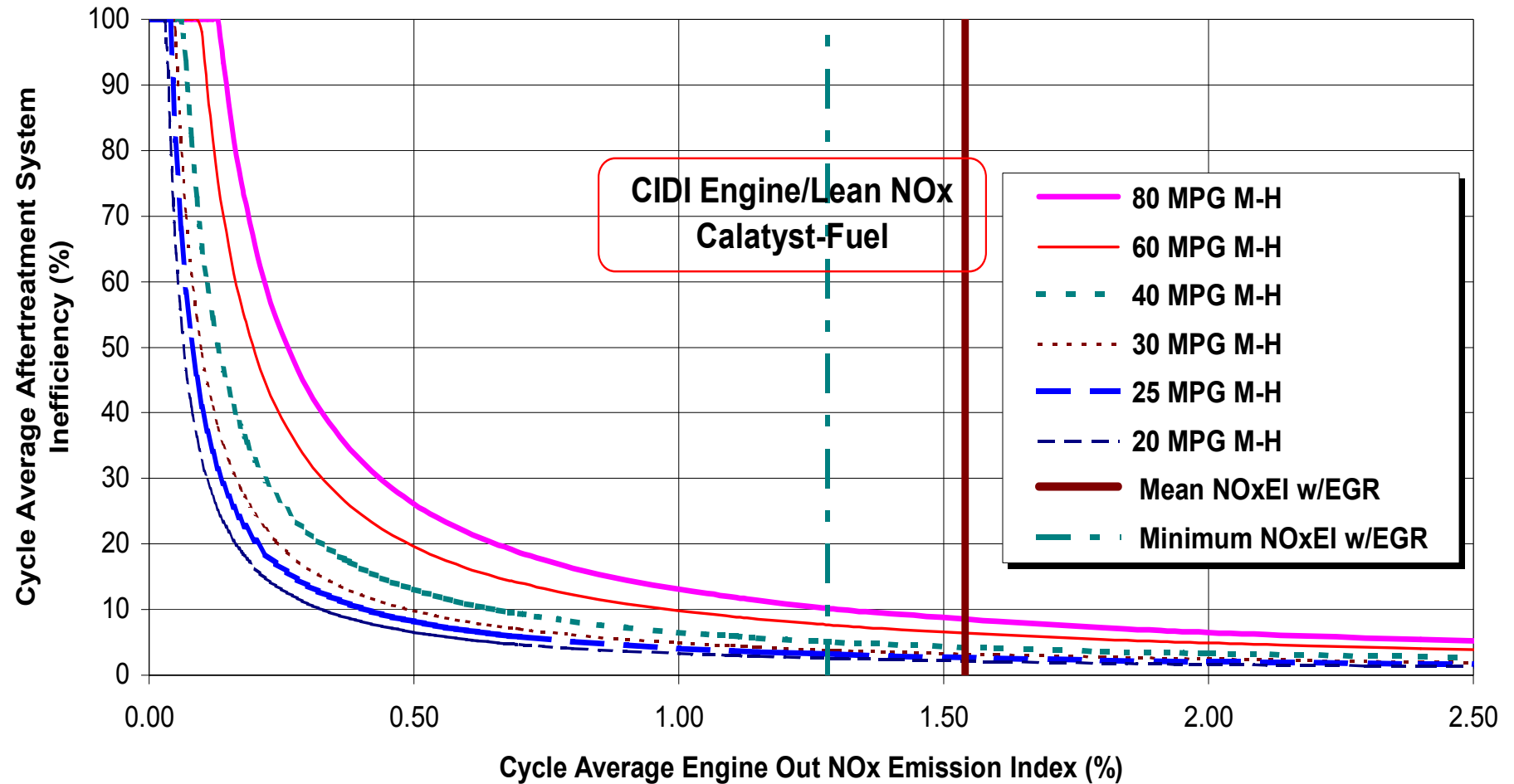
## **Conclusions**

- Fuel properties can significantly affect diesel combustion and exhaust emissions by altering the ignition delay and relative proportion of premixed and diffusion burning.
- Even under the most optimistic circumstances, fuel reformulation alone is not sufficient to reach Tier 2 tailpipe emissions standards.
- An overall systems approach considering engine design, emission control devices, controls, calibration strategy and fuel properties will be needed to address future tailpipe emissions standards.

# Phase I Diesel Fuel Test Program



# Phase I Diesel Fuel Test Program





# CIDI TEST PROJECT TEAM

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Tom Kenney (Co-Lead)	Ford
Jack Segal (Co-Lead)	ARCO
Chuck LeTavec	ARCO-BP
John Eckstrom	BP
Les Wolf	BP
Salo Korn	DaimlerChrysler
Tim Gardner	Ford
Scott Low	Ford
Jim Hilden	GM
Pat Szymkowicz	GM
Gib Jersey	ExxonMobil
John Garbak	DOE
Ed Owens	SwRI®





# Phase I Diesel Fuel Test Program

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## **Publications**

- SAE Paper 2001-01-0151 "Overall Results: Phase I Ad Hoc Diesel Fuel Test Program" by Ad Hoc members, March 2001.
- SAE Paper 2001-01-0148 "Effects of Advanced Fuels on the Particulate and NOx Emissions from an Optimized Light-Duty CIDI Engine" by GMR, March 2001.
- SAE Paper 2001-01-0149 "Evaluation of Some Advanced Diesel fuels for Low Emissions and Improved Fuel Economy" by Ford, March 2001.
- SAE Paper 2001-01-0150 "An Advanced Diesel Fuel Test Program at DaimlerChrysler" by DaimlerChrysler, March 2001.



# Particulate Matter Analysis - Phase I

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## **Objectives**

- Investigate the role of dimethoxy methane as an oxygenated diesel fuel additive on the engine-out exhaust emissions of potentially toxicologically relevant compounds.
- Determine the polycyclic aromatic hydrocarbon (PAH) content of organic solvent extracts of exhaust particulate matter; gaseous exhaust PAH; other toxic air pollutants collected from a diesel engine using various fuel compositions and engine operating conditions.

## **Conclusions**

- All fuel tests were tested in triplicate over five modes with pilot injection off and LPP=7° ATDC operation. Pilot fuel injection effect evaluated for all fuels in triplicate over two modes and two pilot fuel injection strategies.
- Statistically significant fuel effects on exhaust emissions were identified.
- Oxygenate-containing fuel and Fischer-Tropsch fuel produced the lowest overall toxic air pollutant and PAH exhaust emissions.



# Particulate Matter Analysis - Phase I

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## **Publications**

- SAE Paper 2001-01-3627, "Dimethoxy Methane in Diesel Fuel: Part 1. The Effect of Fuels and Engine Operating Modes on Emissions of Toxic Air Pollutants and Gas/Solid Phase PAH," Ad Hoc members, October 2001.
- SAE Paper 2001-01-3628, "Dimethoxy Methane in Diesel Fuel: Part 2. The Effect of Fuels on Emissions of Toxic Air Pollutants and Gas/Solid Phase PAH Using a Composite of Engine Operating Modes," Ad Hoc members, October 2001.
- SAE Paper 2001-01-3629, "Dimethoxy Methane in Diesel Fuel: Part 3. The Effect of Pilot Injection, Fuels and Engine Operating Modes on Emissions of Toxic Air Pollutants and Gas/Solid Phase PAH," Ad Hoc members, October 2001.



# PM ANALYSIS PROJECT TEAM

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Jim Ball (Industry Co-Lead)

Charlie Lapin (Industry Co-Lead)

John Garbak

Eleanor Liney

John Gamble

Diane Hall

Rick Wynn

Gib Jersey

Doug Yost

Ed Frame

Ed Owens

Jim Wallace

Tim Belian

Mike Leister

Randy Petty

Ford

ARCO

DOE

Equilon

Exxon

BP

Citgo

Mobil

SwRI®

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SwRI®

Jim Wallace & Assoc. LLC

CRC

Marathon Ashland

Equilon



# Oxygenates for Advanced Petroleum-Based Diesel Fuels

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## **Objective**

- Identify at least two oxygenates for use in advanced diesel fuel formulations based on physico-chemical properties, exhaust emissions, and other factors.

## **Conclusions**

- Seventy-one (71) oxygenate candidates were screened.
- Eight (8) were evaluated for engine out exhaust emissions.
- Two (2) were recommended for future testing: tri-propylene glycol monomethyl ether and di-butyl maleate.

## **Publications**

- SAE Paper 2001-01-3631, "Oxygenates for Advanced Petroleum-Based Fuels: Part 1. Screening and Selection Methodology for the Oxygenates," Ad Hoc members, September 2001.
- SAE Paper 2001-01-3632, "Oxygenates for Advanced Petroleum-Based Fuels: Part 2. The Effect of Oxygenate Blending Compounds on Exhaust Emissions," Ad Hoc members, September 2001.



# OXYGENATE ANALYSIS PROJECT

## TEAM

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Bill Piel (Industry Co-Lead)

Tom Asmus (Industry Co-Lead)

Eleanor Liney

Jack Segal

Gib Jersey

Les Wolf

L.I. Yeh

John Garbak

Mani Natarajan

Rick Wynn

Dave Naegeli

Ed Frame

Stan Moulton

Doug Yost

Manuel Gonzalez

Consultant

DaimlerChrysler

Equilon

ARCO

Mobil

BP Amoco

Exxon

DOE

Marathon Ashland

Citgo

SwRI®

SwRI®

SwRI®

SwRI®

PDVSA



# OXYGENATE ANALYSIS PROJECT TEAM (continued)

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Chuck Mueller

Jim Wallace

Tim Belian

Mike Leister

Randy Petty

Chuck LeTavec

Dave Layton

Sandia

Jim Wallace & Assoc. LLC

CRC

Marathon Ashland

Equilon

ARCO

Lawrence Livermore NL



# Impact of Lube Oil on Advanced Diesel Engine Emissions

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## **Objective**

- Quantify the crankcase oil contribution to engine out PM and other exhaust emissions.

## **Conclusions**

- At operating conditions representative of low speed cruise with a slight acceleration, the use of a synthetic SAE 15W50 engine oil resulted in an 18% reduction in PM as compared to SAE 5W30 oils; however, average NOx emissions increased by 33%.
- At these conditions, synthetic and mineral SAE 5W30 oils produced statistically similar PM; the volatile organic fraction of PM was 30% less with the synthetic SAE 5W30 oil.

## **Publication**

- SAE Paper 2001-01-1901, "Impact of Lubricant Oil on Regulated Emissions of a Light-Duty Mercedes-Benz OM611 CIDI-Engine," Ad Hoc members, May 2001.





# LUBE OIL ANALYSIS PROJECT TEAM

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Spyros Tsereregounis (Industry Co-Lead)	GM
Andy Jackson (Industry Co-Lead)	Mobil
Jack Johnston	Exxon
Augie Birke	Equilon
Jack Segal	ARCO
John Garbak	DOE
Jim Hoffman	Marathon Ashland
Rick Wynn	Citgo
Kent Froelund	SwRI®
Ed Owens	SwRI®
Ed Frame	SwRI®
Jim Wallace	Jim Wallace & Assoc. LLC
Tim Belian	CRC
Mike Leister	Marathon Ashland
Randy Petty	Equilon



# AD HOC CIDI R&D PHASE I COMPLETION

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- Project results reported out at October, 2000 working group meeting
- Eleven (11) peer reviewed SAE papers have been published. Ten papers were from the four Phase I projects, and one paper was from a Phase II project.



# PROGRAM MANAGEMENT

## Phase II

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### **AD HOC CIDI R&D WORKING GROUP MEMBERSHIP:**

Co-Chairs: Tom Kenney (Ford)  
Tom Bond (BP)

Other Members: GM Representative (Jim Spearot)  
ExxonMobil Representative (Jim Katzer)  
Shell Representative (Mark Gainsborough)  
Marathon Ashland (Mani Natarajan)  
PDVSA Representative (Manuel Gonzalez)  
Conoco Phillips Representative (Bob Pahl)  
Jim Wallace & Associates LLC  
Team Leader of DOE's OFCVT (Steve Gougen)  
Co-leaders of each project team



# **CIDI R&D PROGRAM Phase II**

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PHASE II CONSISTS OF THREE PROJECTS:

- Low NO<sub>x</sub> Engine Operation Project
- CIDI Testing Project – Phase II
- PM Analysis Project – Phase II



# Low NOx Engine Operation

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## **Objective**

- Determine engine control parameters that lower engine out NOx emissions with oxygenated and alternate CIDI fuels

## **Conclusions**

- Fuels evaluated have the same EGR and combustion timing window for low NOx operation; NOx emission index lowered 45%
- With current test engine potential of fuel oxygen was not realized
  - Driveability concerns limits EGR use
  - Improved turbocharger may widen EGR envelope
- Combustion timing retard was limited by allowable fuel consumption penalty

## **Publications**

- SAE Paper 2002-01-2884, "Impact of Engine Operating Conditions on Low-NOx Emissions in a Light-Duty CIDI Engine using Advanced Fuels," Ad Hoc members, October 2002.



# LOW NO<sub>x</sub> PROJECT TEAM

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Tom Kenney (Industry Co-lead)

Manuel Gonzalez (Industry Co-lead)

Ken Wright

Gib Jersey

Jim Ball

Jim Spearot

Dave Hilden

Mani Natarajan

King Eng

Jim Wallace

Ed Frame

Doug Yost

Wendy Clark

John Garbak

Ford

PDVSA

Conoco Phillips

ExxonMobil

Ford

GM

GM

Marathon Ashland

Shell Global Solutions

Jim Wallace & Assoc. LLC

SwRI®

SwRI®

NREL

DOE



# CIDI CORE TESTING PROJECT -- PHASE II

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## Objective

- Demonstrate the tailpipe emissions potential of advanced fuels in modern diesel engine vehicles with state-of-the-art controls and PM/NOx aftertreatment systems, targeting Tier 2, Bin 5.

## Status

- Ford has built and is calibrating a Focus, having a catalyzed DFP and Urea SCR aftertreatment system.
- GM is selecting a candidate vehicle for their test program and expects to use lean NOx trap based aftertreatment system
- Test fuels have been ordered

## Expected Completion Date

- Ford expects to report test results in Q2, 2003
- GM is targeting their program to be completed by the end of 2003



# CIDI CORE TESTING PROJECT – PHASE II -- TEAM

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Tom Kenney (Project Co-Lead)	Ford
Jim Spearot (Project Co-Lead)	GM
Frank Gerry	BP
Chuck LeTavec	BP
Adam Schubert	BP
Les Wolf	BP
Ken Wright	Conoco Phillips
Mani Natarajan	Marathon Ashland
Jim Wallace	Jim Wallace & Assoc. LLC
Jim Katzer	Exxon Mobil
Ed Frame	SwRI
King Eng	Shell
Manuel Gonzalez	PDVSA
Dave Hilden	GM





# Particulate Matter Analysis - Phase II

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## **Objective**

- Examine the effect of oxygenated compounds in diesel fuel on the emissions of particulate matter, oxides of nitrogen, and fuel economy when emission control devices are used.
- Understand the influences of fuels and emission-control devices on exhaust emissions of a subset of potentially toxicologically relevant compounds with an engine operated to minimize NO<sub>x</sub> emissions.

## **Status**

- Low NO<sub>x</sub> operating points defined
- Currently in Progress



# PM ANALYSIS – PHASE II

## PROJECT TEAM

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Jim Ball (Industry Co-lead)

Mani Natarajan (Industry Co-lead)

Les Wolf

Ken Wright

Jim Katzer

Dave Hilden

Jim Spearot

Manuel Gonzalez

King Eng

Doug Yost

Ed Frame

Wendy Clark

Steve Gougen

Ford

Marathon Ashland

BP

Conoco Phillips

ExxonMobil

GM

GM

PDVSA

Shell Global Solutions

SwRI®

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# PM ANALYSIS – PHASE II

## PROJECT TEAM (continued)

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Dale McKinnon

Tim Johnson

Jim Wallace

MECA

Corning

Jim Wallace & Associates LLC



# CIDI R&D PROGRAM-PHASE III

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- Planning for Phase III underway
- Final decisions on Phase III expected February, 2003