Study of Fuel Property Effects
Using Future Low Emissions Heavy Duty Truck Engine Hardware

Sharon Li, Brian Bolton, Nabil Hakim

Diesel fuel properties such as cetane number, aromatic content and density have been known to substantially influence heavy-duty truck engine emissions. The influence of these fuel properties on an advanced technology Detroit Diesel 21st Century Truck engine is presented.

DETROIT DIESEL CORPORATION

Study of Fuel Property Effects Using Future Low Emissions Heavy-Duty Truck Engine Hardware

Xiaobin (Sharon) Li, Brian Bolton, Nabil Hakim

Detroit Diesel Corporation

August 24, 2000

Outline

- Background
- Test Fuels
- Challenges and Solutions
- Results
  - Equal Power
  - Equal Calibration
- Conclusions

Background

- **Fuel properties have had substantial impact on engine emissions**
- **Fuel impact varies with engine technology**
- **An assessment of fuel impact on *future low emission designs* was needed as part of an EMA-EPA-API study effort**

Advanced Fuels Test Strategy at DDC

- **Use advanced technology truck engine hardware generating ~ 2002 emissions**
- **Run carefully designed and controlled transient FTP tests and selected steady state tests**
- **Run a minimum of 3 designed mineral diesel fuels plus a Fischer-Tropsch (round-robin selected) fuel**

Outline

- Background
- **Test Fuels**
- Challenges and Solutions
- Results
  - Equal Power
  - Equal Calibration
- Conclusions

Test Fuels

- Three conventional diesel fuels designed to vary density, cetane number, and aromatic contents
- A Fischer-Tropsch fuel representing the “best-available” diesel fuel
- Repeat checks using the standard DF2 Cert fuel

Fuel Properties

- **Three fuels with matched sulfur content and matched T90**
  - **Represents variation among "conventional diesel fuel"**
- **The Fischer-Tropsch fuel**
  - **Represents the extremes of diesel fuel properties**

Fuels	Cetane Number	Aromatics (%mass)	Sulfur (ppm)	Density (g/cm^3)	T90 (°F)
05Y60012A (12A)	51.4	12.9	331	0.8304	586
05Y60012B (12B)	42.0	33.1	332	0.8605	586
05Y60012C (12C)	46.9	32.3	325	0.8481	592
05Y60011 (11)	73.0	0.4	< 5	0.7700	639

Outline

- Background
- Test Fuels
- **Challenges and Solutions**
- Results
  - Equal Power
  - Equal Calibration
- Conclusions

Challenges & Solutions
- Test Repeatability

- **Test repeatability is critical**
  - **Prototype engine may sustain performance shifts**
  - **Fuel supply is limited**
  - **Fuel effects can be small**

- **Test Methodology Development**
  - **Must have a well developed test procedures**
  - **Carry out repeated runs of reference fuels**
  - **Run statistical checks**

Challenges & Solutions
- Basis of Comparing Fuel Effects

- **Basis of comparing fuel effects is a variable**
  - **Density and heating value differences change fuel injection and combustion**
  - **Fueling control interacts with advanced technology hardware and control strategies**

- **Fuel effects can be tested on different bases**
  - **Same power**
  - **Same calibration**
  - **Same power and calibration**

FTP Test Data Repeatability

- **Excellent repeatability on NOx and BSFC**
- **Good repeatability on PM**

	Standard Deviation/Mean			
Fuels	**NOx**	**PM**	**CO_2**	**BSFC**
In-House	0.8%	3.1%	0.6%	0.3%
12C	0.7%	2.0%	0.5%	0.2%
11	0.2%	5.2%	0.3%	0.4%

Fuel Properties and Symbols

Fuels	Cetane Number	Aromatics (%mass)	Density (g/cm^3)	Symbol
12B (Heavy, High Arom)	42.0	33.1	0.8605	▲
12C (Reference)	46.9	32.3	0.8481	○ ●
12A (Light, Low Arom)	51.4	12.9	0.8304	■
11 (Fischer-Tropsch)	73.0	0.4	0.7700	✳

Outline

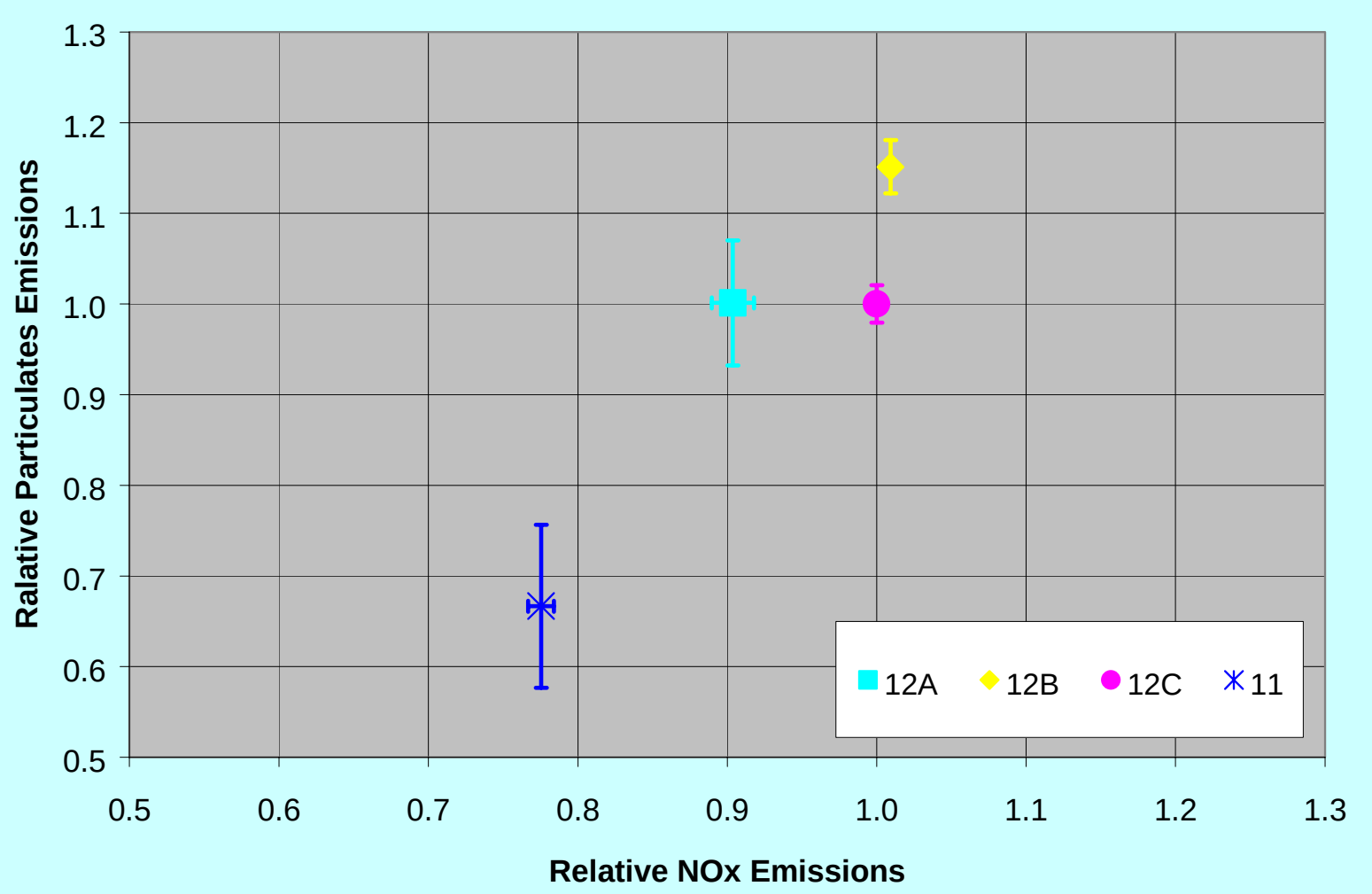
- Background
- Test Fuels
- Challenges and Solutions
- **Results**
  - **Equal Power**
  - **Equal Calibration**
- Conclusions

Comparison on Equal Power Basis

- **Use the torque curve generated using reference fuel (12C) for all fuels**
- **Engine calibration adjusted to keep other parameters similar**

Fuel Effects on Equal Power Basis

(FTP NOx and PM Emissions)



Fuel Effects on Equal Power Basis

Emission and Performance Statistical Results

Fuels	NOx	PM	CO	CO_2	HC	BSFC	NOx+HC
Relative Reduction (%)							
12C	0	0	0	0	0	0	0
12A	9.6	-0.1	-18.2	0.4	-9.3	-0.3	8.3
12B	-0.9	-15.1	-6.5	-1.2	-19.5	-0.3	-2.2
11	22.5	33.3	-17.0	2.9	-8.8	0.9	20.3
Level of Significance							
12A	100.0	3.3	100.0	82.3	60.4	81.4	100.0
12B	95.0	100.0	100.0	99.6	94.2	92.0	98.7
11	100.0	100.0	100.0	100.0	72.0	100.0	100.0

Fuel Effects on Equal Power Basis
(Summary)

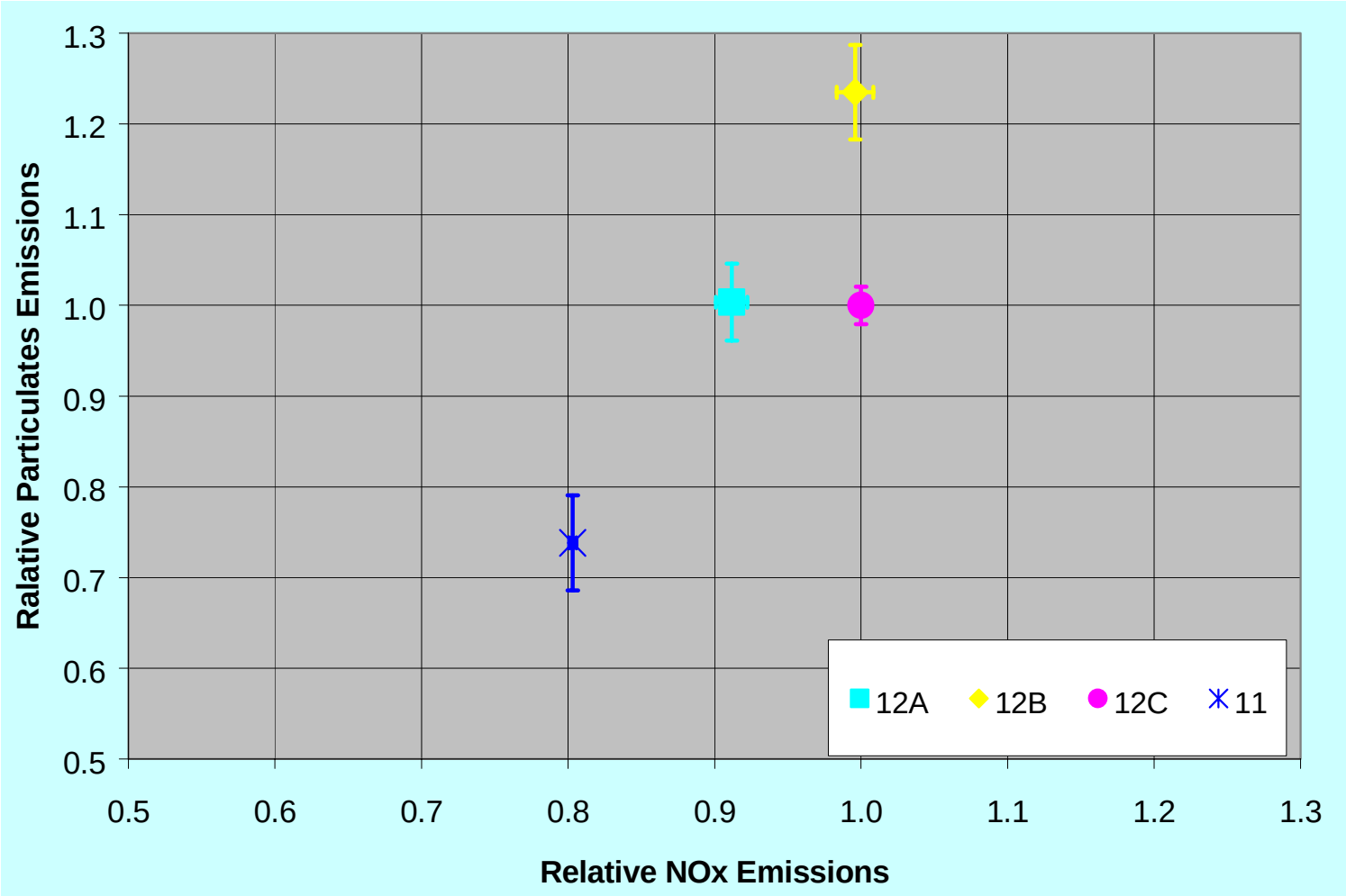
- NOx and PM decreased when cetane number increased, along with aromatic content and density decrease
- Substantial decrease in NOx and PM is obtained with clean F-T fuel
- A slight improvement in BSFC with F-T fuel

Comparison on Equal Calibration

- **Same engine calibration used for all fuels**
- **Different torque curves resulted for different fuels**
- **The torque curve for F-T fuel was ~ 8% lower than reference fuel.**

Fuel Effects on Equal Calibration

(FTP NOx and PM Emissions)



Fuel Effects on Equal Calibration

Emission and Performance Statistical Results

Fuels	NOx	PM	CO	CO_2	HC	BSFC	NOx+HC
Relative Reduction (%)							
12C	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12A	8.8	-0.4	-17.2	0.3	-17.5	-0.6	7.0
12B	0.4	-23.5	-14.3	-1.8	3.3	-0.6	0.6
11	19.7	26.2	-63.6	0.9	7.8	-1.8	18.8
Level of Significance							
12A	100.0	14.3	100.0	63.4	90.5	99.9	100.0
12B	51.9	100.0	100.0	100.0	28.0	99.8	54.5
11	100.0	100.0	99.9	99.8	31.4	100.0	100.0

Outline

- Background
- Test Fuels
- Challenges and Solutions
- Results
  - Equal Power
  - Equal Calibration
- **Conclusions**

Conclusions
- Fuel Effects on Engine Emissions

- **For future low emission engine, fuel properties have significant impact on both NOx and PM**

- **Reductions of 23% NOx and 33% PM obtained when running a Fischer-Tropsch fuel**