Federal Diesel Research Study

February 4, 2010
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California Environmental Protection Agency

Air Resources Board

Overall Program Plan

- Test matrix includes 3 fuels
  - CARB ULSD
  - Federal A
  - Federal B
- Testing of 3 engines
  - 2007 MBE4000
  - 2006 Cummins ISM
  - 1991 DDC 60
- Chassis dyno testing
  - 10 trucks including 3 CARB vehicles
  - Testing focuses on CARB 50 mph Cruise cycle

Engine Testing Status

- Testing on 2007 MBE4000 “completed”
  - Results discussed *in September 2009*
- Testing on 2006 Cummins ISM “completed”
  - Results discussed *in presentation*
- Testing on 1991 DDC 60 “in progress”
  - Preliminary results discussed *in presentation*
- Draft Memorandum on engine testing completed by *February 2010*

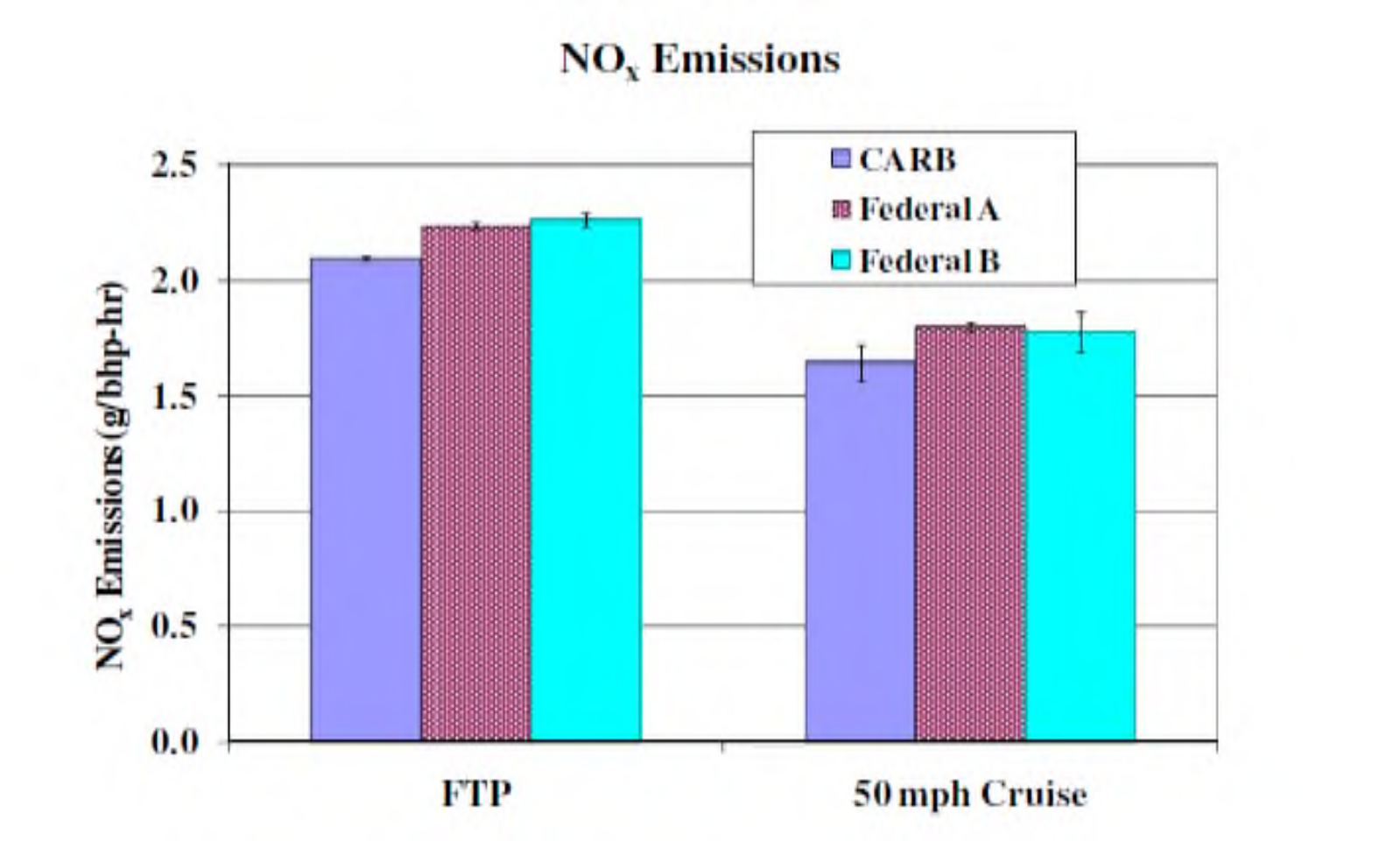
Engine Parameters

- 2007 MBE4000
  - Equipped with OEM DPF
  - In-line 6, 4-stroke, 12.8 L, Turbo, EGR
  - 410 hp @ 1900 rpm
- 2006 Cummins ISM 370
  - In-line 6, 4-stroke, 10.8 L, Turbo, EGR
  - 370 hp / 1450 ft-lbs @ 1200 rpm
- 1991 Detroit Diesel Series 60
  - In-line 6, 4-stroke, 11.1 L,Turbo with after cooler
  - 350 hp @ 1800 rpm

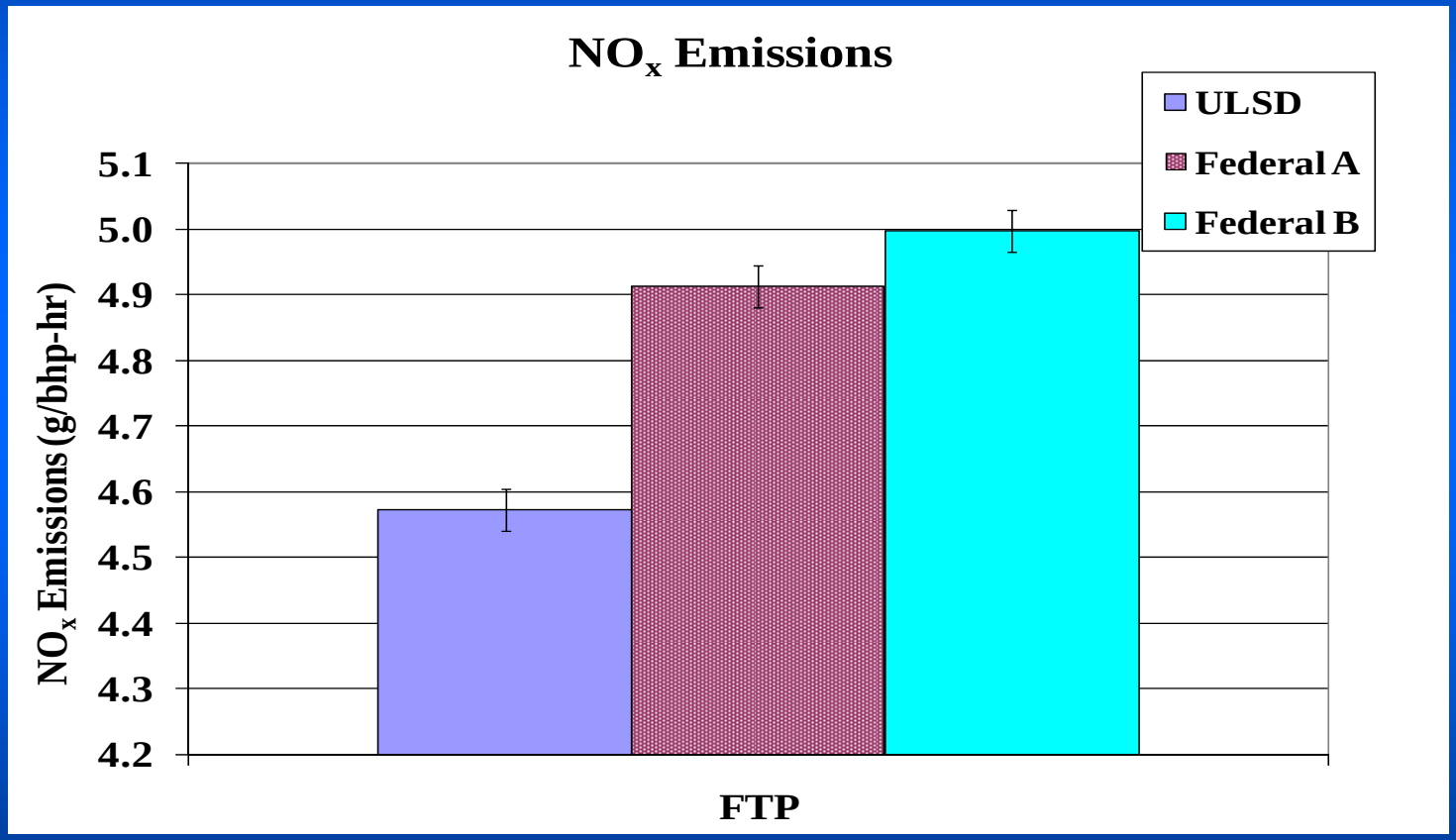
Prelim. ISM/DDC Results

- Higher NO_x for both Federal diesels on both engines
- Higher PM for both Federal diesels over the FTP, but not over the 50 mph cruise on 2006 Cummins Engine
- No consistent trends for THC over 2006 Cummins; higher emissions for Federal diesels for 1991 DDC
- Higher CO for both Federal diesels on both engines
- Slightly higher CO_2 for both Federal diesels on both engines
- Some trends of lower brake specific fuel consumption for the Federal B on both engines
- Higher emissions for Federal B compared to Federal A for most of the pollutants on both engines

NO_x Results 2006 Cummins ISM



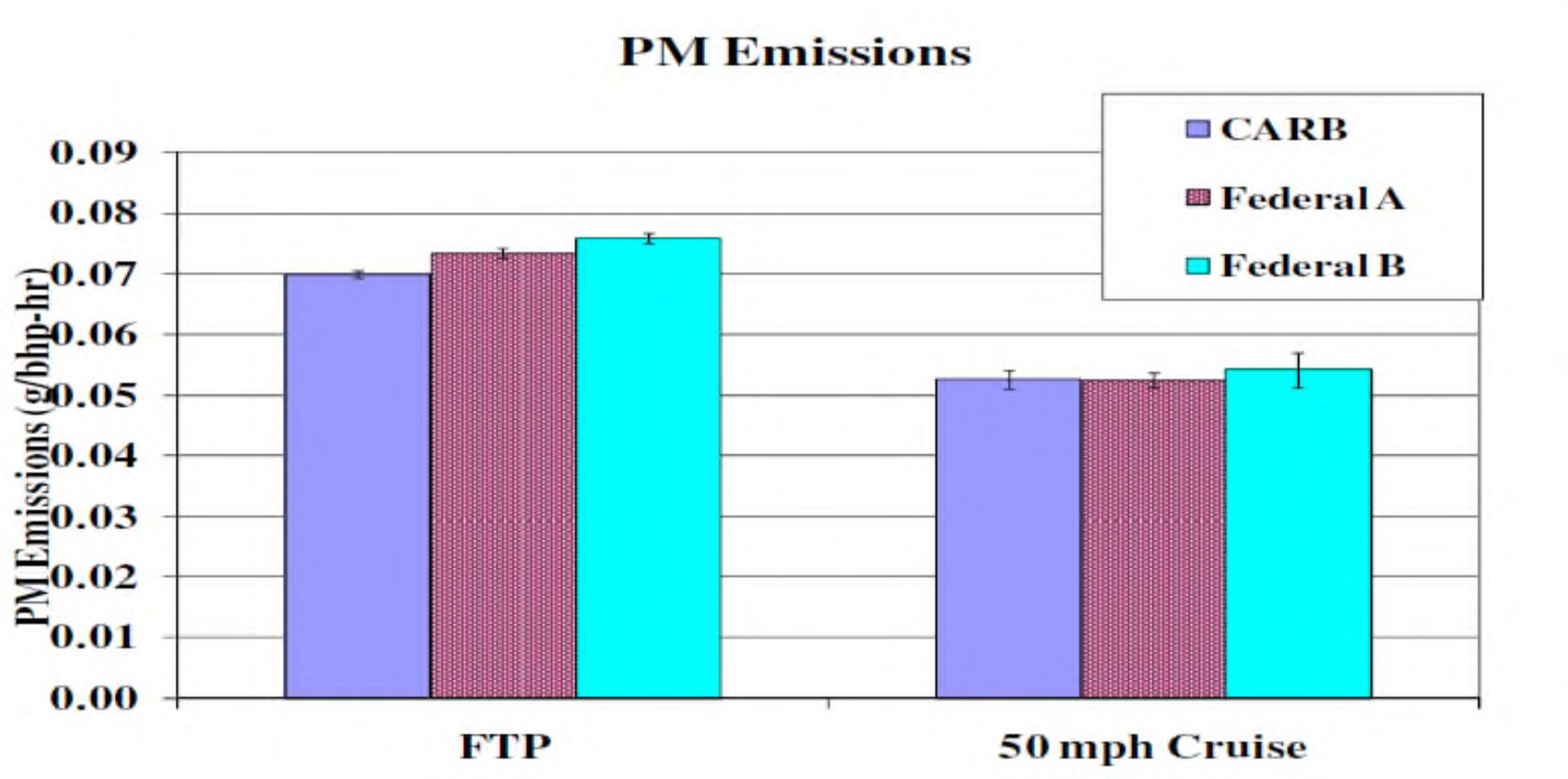
Prelim NO_x Results 1991 DDC 60



NO_x Engine Results

		2007 MBE4000		2006 Cummins ISM		1991 DDC 60	
	CARB vs.	% Difference	P-values	% Difference	P-values	% Difference	P-values
FTP	Federal A	-	-	6.7%	0.000	7.5%	0.000
	Federal B	7.3%	0.000	7.9%	0.000	9.3%	0.000
50 mph Cruise	Federal A	-	-	10%	0.001		
	Federal B	4.7%	0.000	8.1%	0.020		

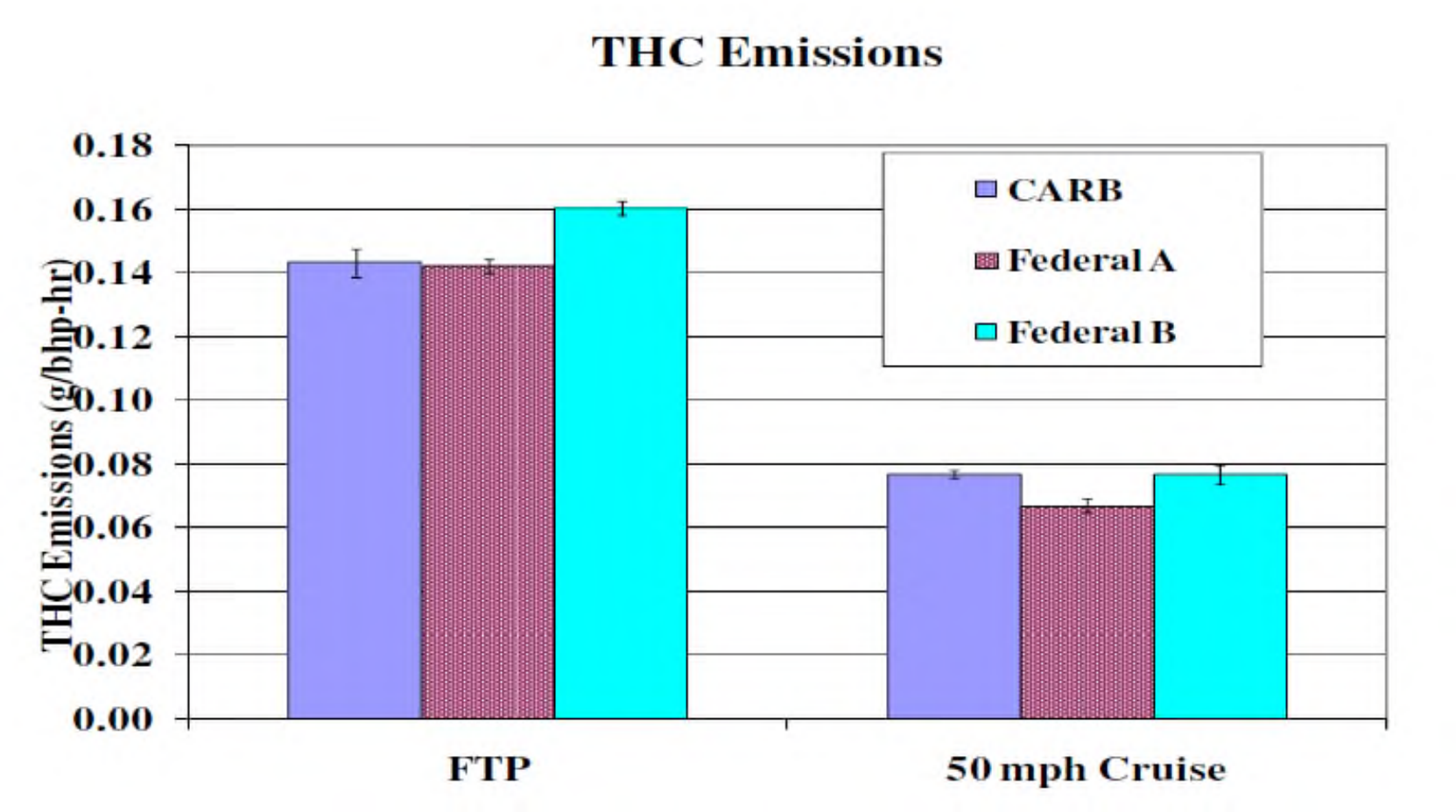
PM Results 2006 Cummins ISM



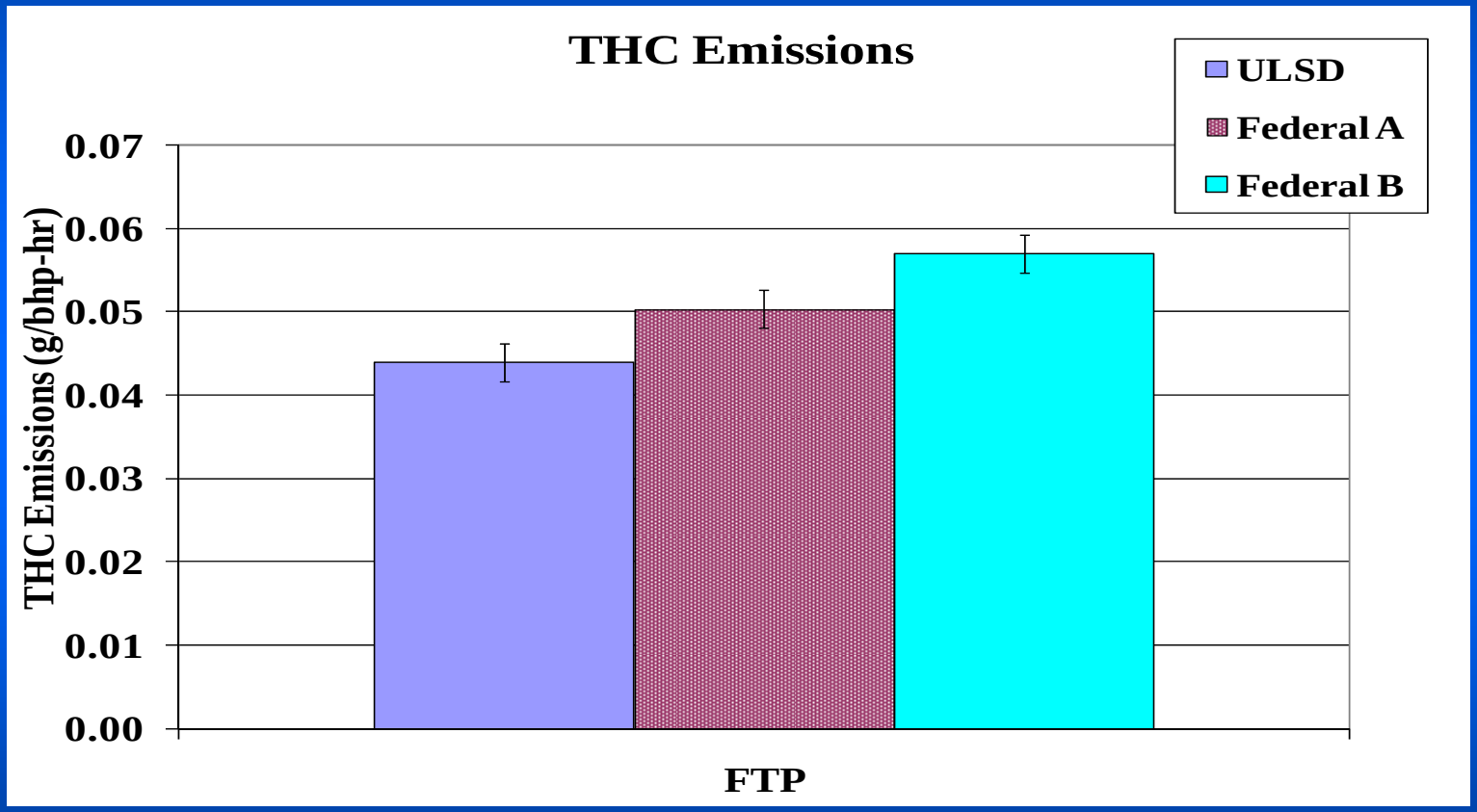
PM Engine Results

		2007 MBE4000		2006 Cummins ISM		1991 DDC 60	
	CARB vs.	% Difference	P-values	% Difference	P-values	% Difference	P-values
FTP	Federal A	-	-	5%	0.000		
	Federal B	53%	0.752	8%	0.000		
50 mph Cruise	Federal A	-	-	0%	0.831		
	Federal B	109%	0.297	3%	0.278		

THC Results 2006 Cummins ISM



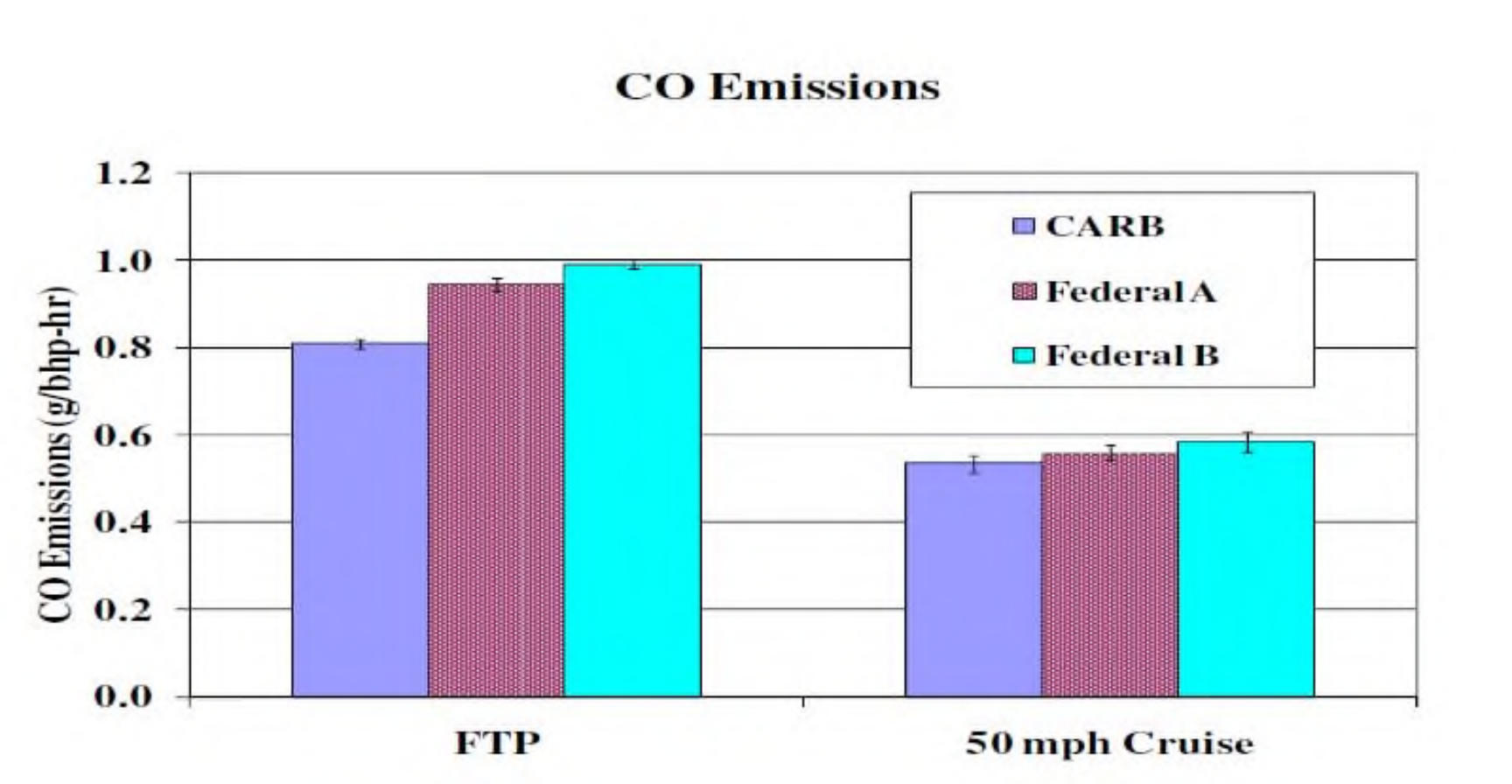
Prelim. THC Results 1991 DDC



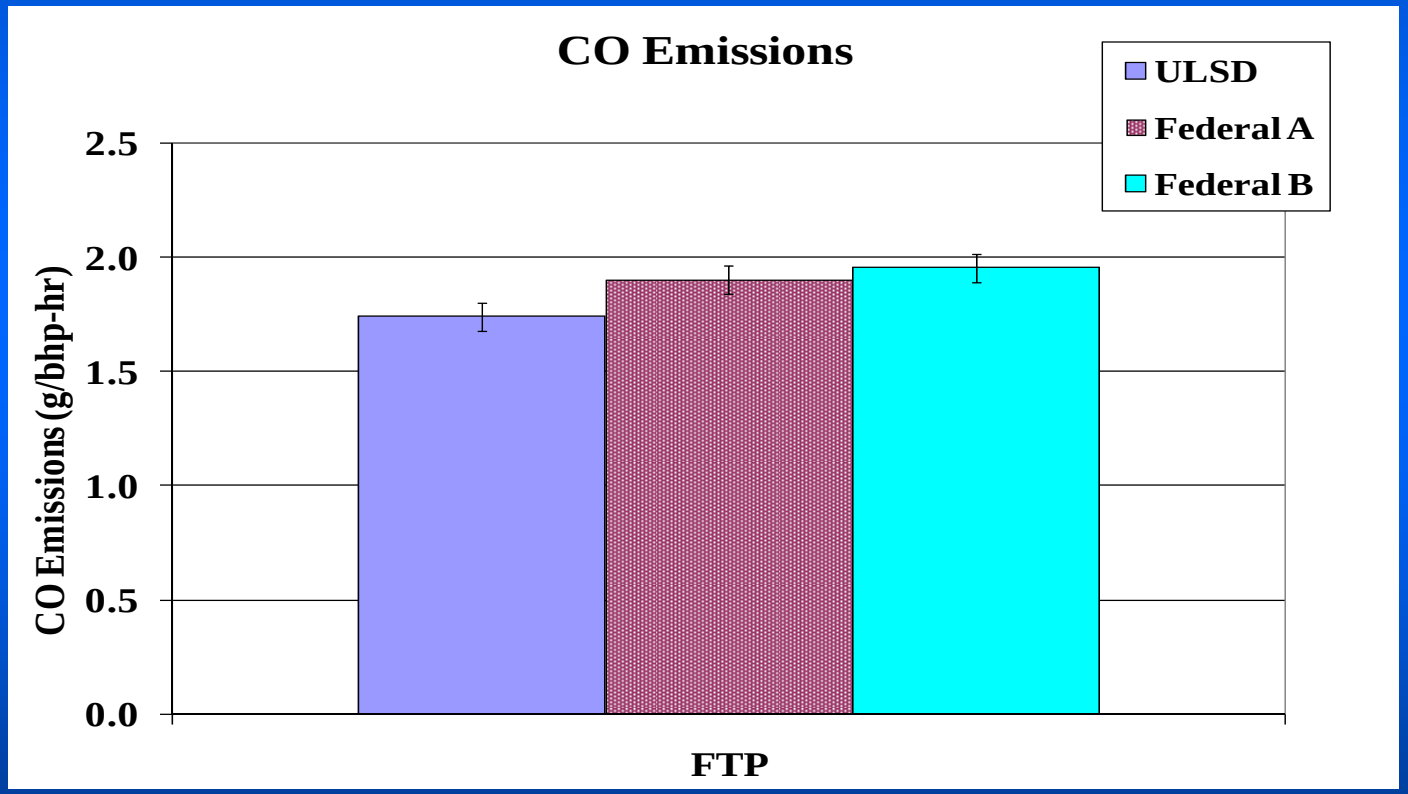
THC Engine Results

		2007 MBE4000		2006 Cummins ISM		1991 DDC 60	
	CARB vs.	% Difference	P-values	% Difference	P-values	% Difference	P-values
FTP	Federal A	-	-	-0.7%	0.633	14.4%	0.000
	Federal B	27%	0.135	12.0%	0.000	29.5%	0.000
50 mph Cruise	Federal A	-	-	-13%	0.000		
	Federal B	-14%	0.270	0%	0.904		

CO Results 2006 Cummins ISM



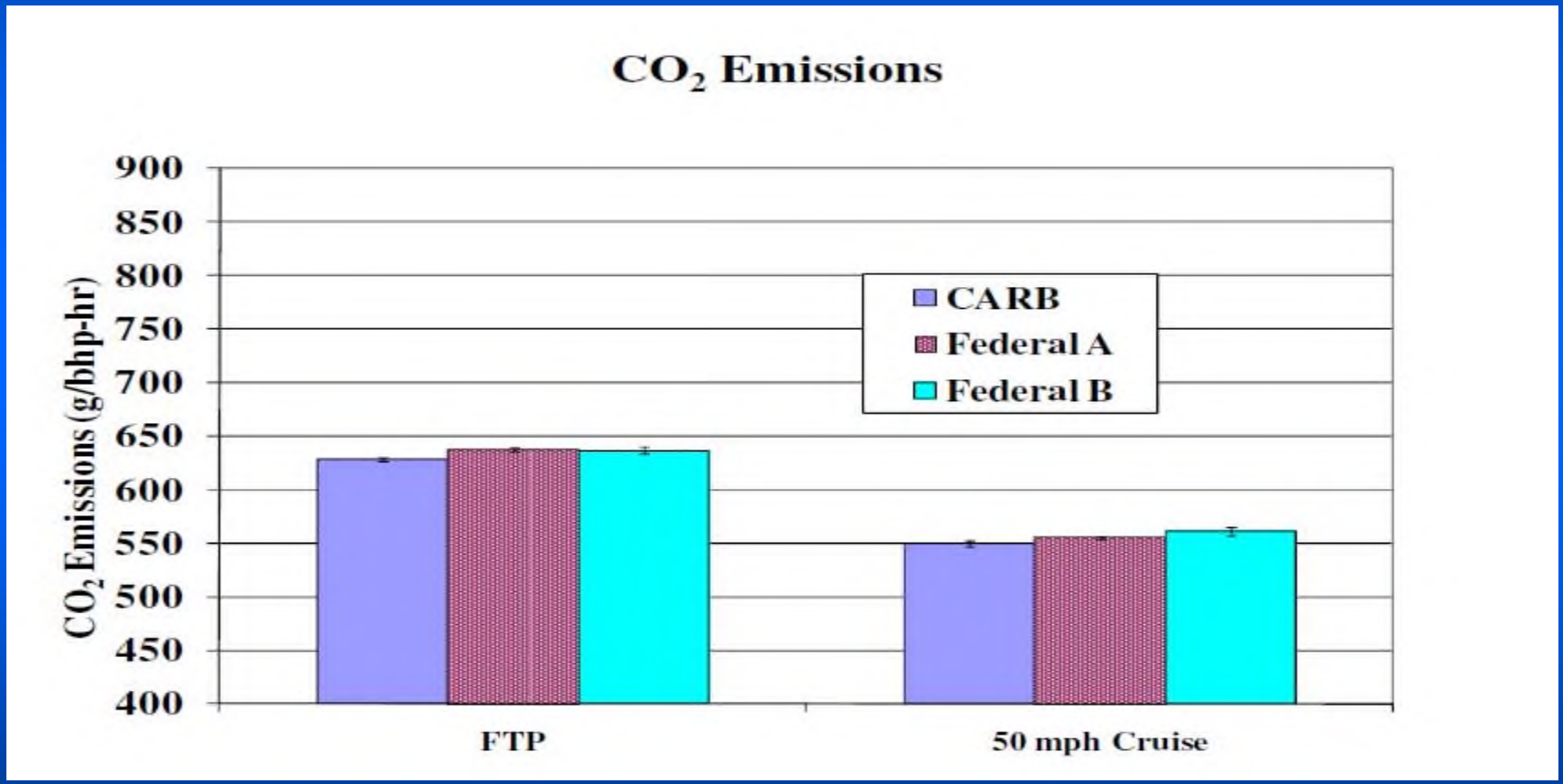
Prelim. CO Results 1991 DDC 60



CO Engine Results

		2007 MBE4000		2006 Cummins ISM		1991 DDC 60	
	CARB vs.	% Difference	P-values	% Difference	P-values	% Difference	P-values
FTP	Federal A	-	-	16.8%	0.000	9.1%	0.000
	Federal B	51%	0.000	22.5%	0.000	12.2%	0.000
50 mph Cruise	Federal A	-	-	5%	0.041		
	Federal B	31%	0.024	9%	0.002		

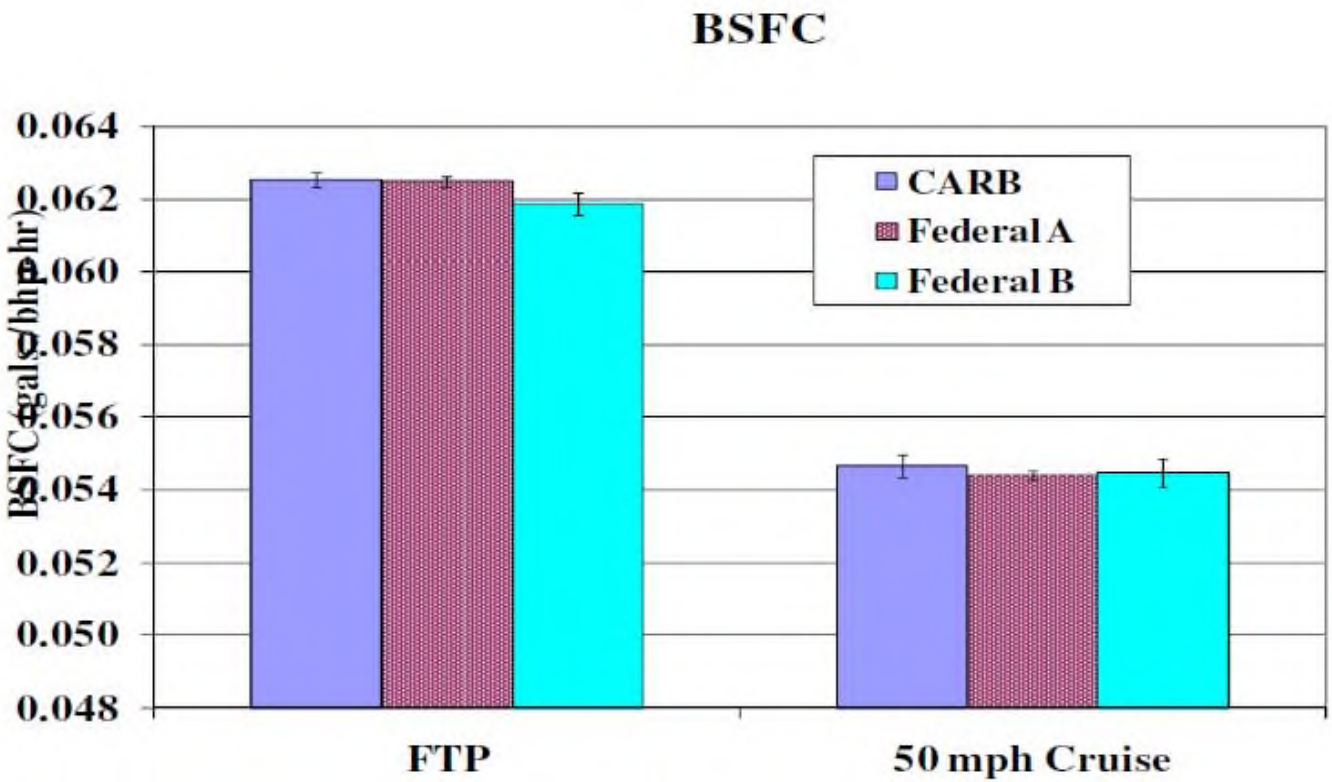
CO_2 Results 2006 Cummins ISM



CO_2 Engine Results

		2007 MBE4000		2006 Cummins ISM		1991 DDC 60	
	CARB vs.	% Difference	P-values	% Difference	P-values	% Difference	P-values
FTP	Federal A	-	-	1%	0.000	2%	0.003
	Federal B	1.4%	0.000	1.3%	0.000	1.2%	0.013
50 mph Cruise	Federal A	-	-	1%	0.004		
	Federal B	2.0%	0.000	2.0%	0.000		

BSFC Results 2006 Cummins ISM



BSFC Engine Results

		2007 MBE4000		2006 Cummins ISM		1991 DDC 60	
	CARB vs.	% Difference	P-values	% Difference	P-values	% Difference	P-values
FTP	Federal A	-	-	0%	0.667	0%	0.524
	Federal B	-0.9%	0.000	-1.0%	0.002	-1.2%	0.014
50 mph Cruise	Federal A	-	-	0%	0.080		
	Federal B	-0.4%	0.255	-0.4%	0.348		

Chassis Dyno Status

- Chassis dyno testing in 1st Quarter of 2010
  - Construction completed *mid/late-February*
  - Installation & Commissioning by *mid-March*
- 10 test vehicles
  - Trucks with 2007 MBE4000 and 2006 Cummins
  - CE-CERT's in-house truck with 2000 Caterpillar engine
  - Port indicated they could provide additional vehicles

Updated Test Plan

- Changed the number of tests per day
- Provided vehicle matrix
- Provided test weights

Chassis Dyno Test Matrix

Test Day	Morning Schedule (assumes 6 replicates)	Afternoon Schedule (assumes 6 replicates)
ARB HHDDT Cruise Test Cycle		
Day 1	CCC AAA	AAA BBB
Day 2	BBB CCC	CCC AAA
Day 3	AAA BBB	BBB CCC

C = CARB diesel fuel, A = Federal A diesel fuel, B = Federal B diesel fuel

Chassis Dyno Vehicle Test Matrix

1991-1993	1 vehicle
1994-1997	1 vehicle
1998-2002	2 vehicle (UCRs 2000 Caterpillar C-15 + 1 retrofit)
2002-2006	3 vehicles (one will be 2006 Cummins ISM + 1 retrofit)
2007-2010	2 vehicles (one will be 2007 MBE4000)
2010+	1 vehicle

Test Weights

- Three trucks utilized for Biodiesel

- 2006 Cummins Engine → 58,744 lbs

- 2000 Caterpillar Engine → 66,000 lbs

- 2007 MBE 4000 → 57,490 lbs

- Remaining trucks using

- CE-CERT's Mobile Emissions Laboratory (MEL) ~ 65,000 lbs