Effects of Ethanol and Volatility on Exhaust Emissions: CRC E-67 Project

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Introduction

- Ethanol widely used to meet oxygenate and octane requirements
- Volatility and ethanol parameters are important inputs to the CARB Predictive Model and EPA Complex Model
- Data scarce on modern vehicles

E-67 Project

Objective: Expand the database of information available on the impacts of gasoline volatility parameters and ethanol content on exhaust emissions from recent model light-duty vehicles.

- Measure regulated emissions using standard FTP tests.
- Measure speciated emissions were measured on a subset of the test fuels.
- The test fuels varied in ethanol content, T50, and T90.

E-67 Project Design - Specifics

Vehicle Set: CA-Certified 2001-03 MY

Description of Test Vehicles

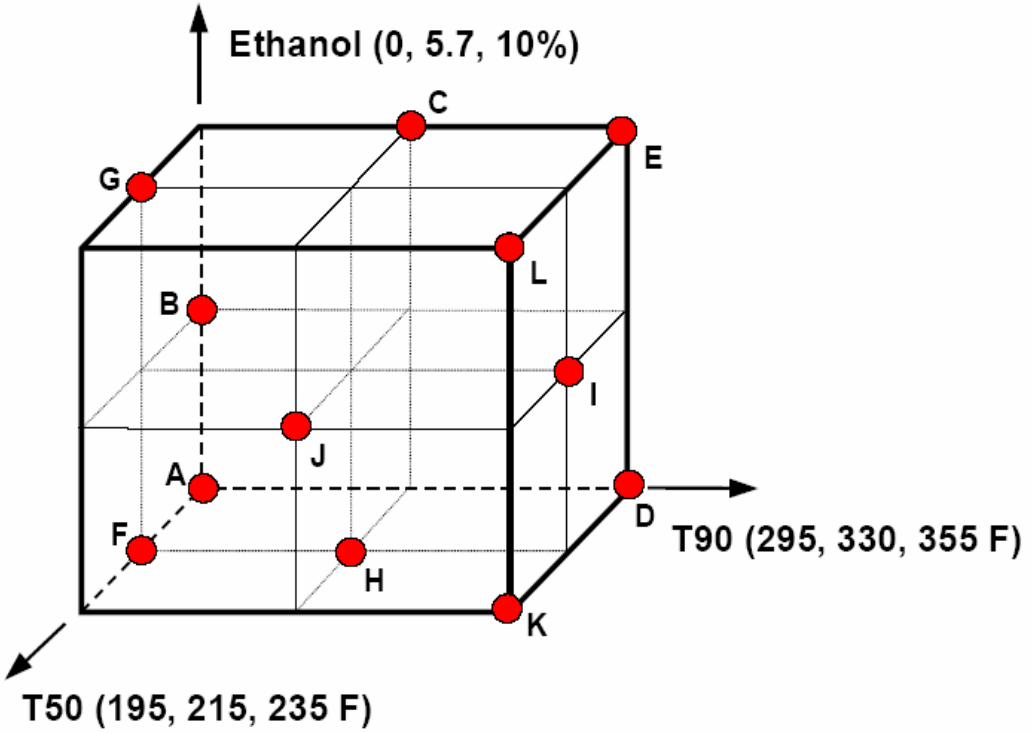
#	MY	OEM	Model	CA Cert	Type	Engine	Mileage	Engine Family
1	2002	Ford	Taurus	LEV	PC	3.0 L	19,414	1FMXV03.0VF4
2	2003	Chevrolet	Cavalier	LEV	PC	2.2 L	28,728	1GMXV02.2025
3	2003	Ford	F-150	LEV	LDT	4.6 L	13,856	3FMXT05.4PFB
4	2003	Dodge	Caravan	LEV	LDT	3.3 L	18,342	3CRXT03.32DR
5	2003	Ford	Explorer	LEV	LDT	4.0 L	16,445	3FMXT04.02FB
6	2003	Chevrolet	Trailblazer	LEV	LDT	4.2 L	13,141	3GMXT04.2185
7	2002	Toyota	Camry	ULEV	PC	2.4 L	14,731	1TYXV02.4JJA
8	2003	Buick	LeSabre	ULEV	PC	3.8 L	10,364	3GMXV03.8044
9	2001	VW	Jetta	ULEV	PC	2.0 L	28,761	1VWXV02.0223
10	2003	Ford	Windstar	ULEV	LDT	3.8 L	20,523	3FMXT03.82HA
11	2003	Chevrolet	Silverado	ULEV	LDT	5.3 L	10,298	3GMXT05.3176
12	2003	Honda	Accord	SULEV	PC	2.4 L	12,432	3HNXV02.4KCP

Vehicles equipped with catalysts aged to 100,000 miles for testing.

E-67 Project Design - Specifics

Fuel Set:

- 12 fuels with 3 levels of ethanol, T50 & T90.



General Fuel Properties

Property	Limits
RVP	7.5-7.8 psi
FBP	<437 ° F
RON	91-95
MON	83-87
(R+M)/2	87-91
Aromatics	23-27%
Benzene	0.9-1.0 wt. %
Olefins	8-12%
Sulfur	15-20 ppm

Fuels met D4814 and contained a detergent pkg

E-67 Project Design - Specifics

Test Protocol:

- Standard FTP testing (w/ multiple drain and fill fuel)
- Randomize fuel test order within each vehicle
- Test each fuel/vehicle combination twice
  - Auto/Oil outlier criteria used to determine need for third tests
- Measure organic gas speciation on fuels D, E, K & L

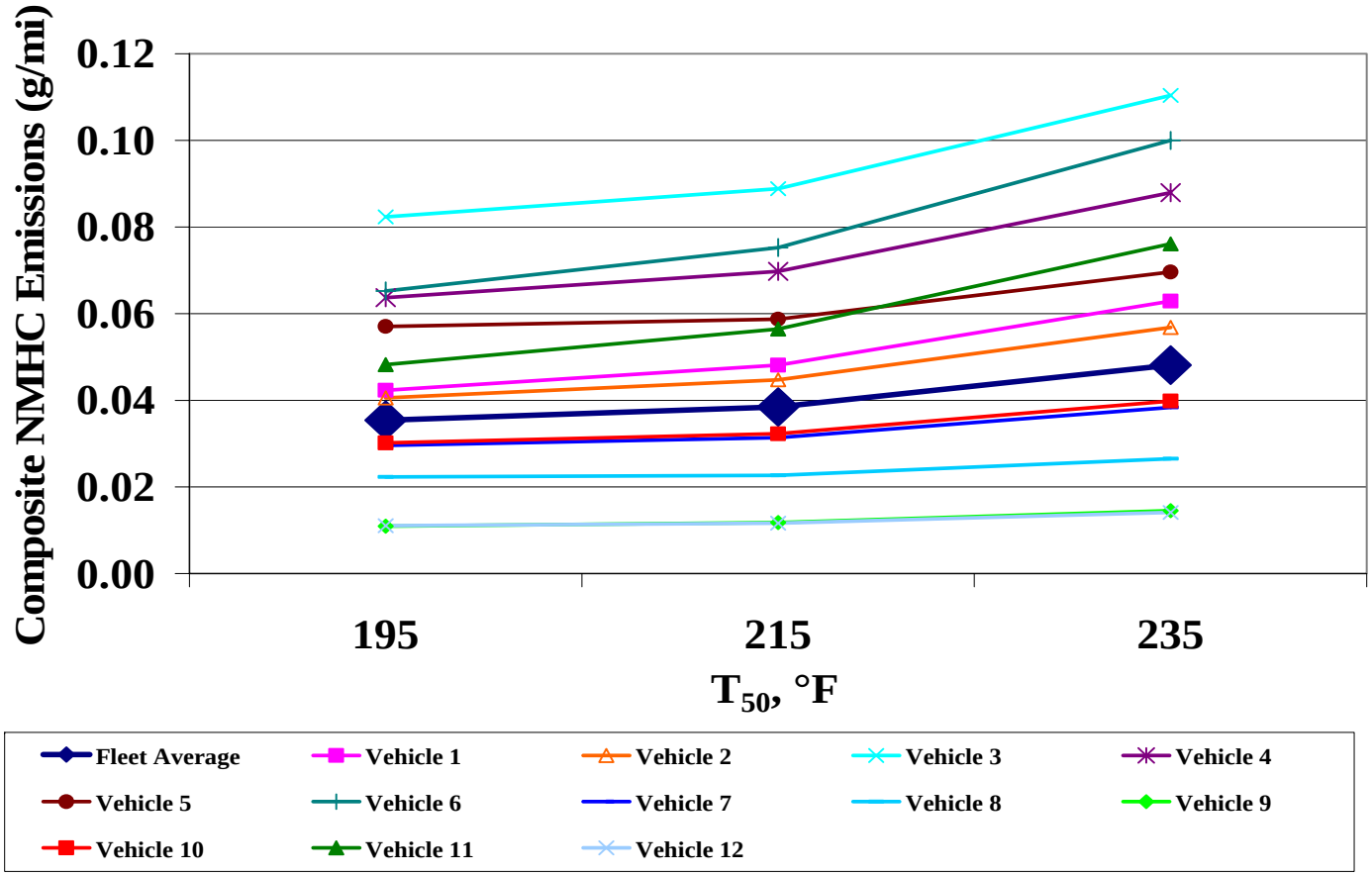
E-67 Statistical Analysis

- Emissions analyses were run using the Proc Mixed procedure in PC/SAS.
- The primary analysis estimated regression coefficients for the fuel effects, with the levels of EtOH, T50, and T90 used as continuous variables within the model.
- Analyses used the natural logs of the data for the regulated emissions, NMOG and toxics.
- Effects are statistically significant if $p<0.05$ and are marginally significant if $0.05<p<0.10$

E-67 Key Findings – NMHC

NMHC Increases with Increasing T50

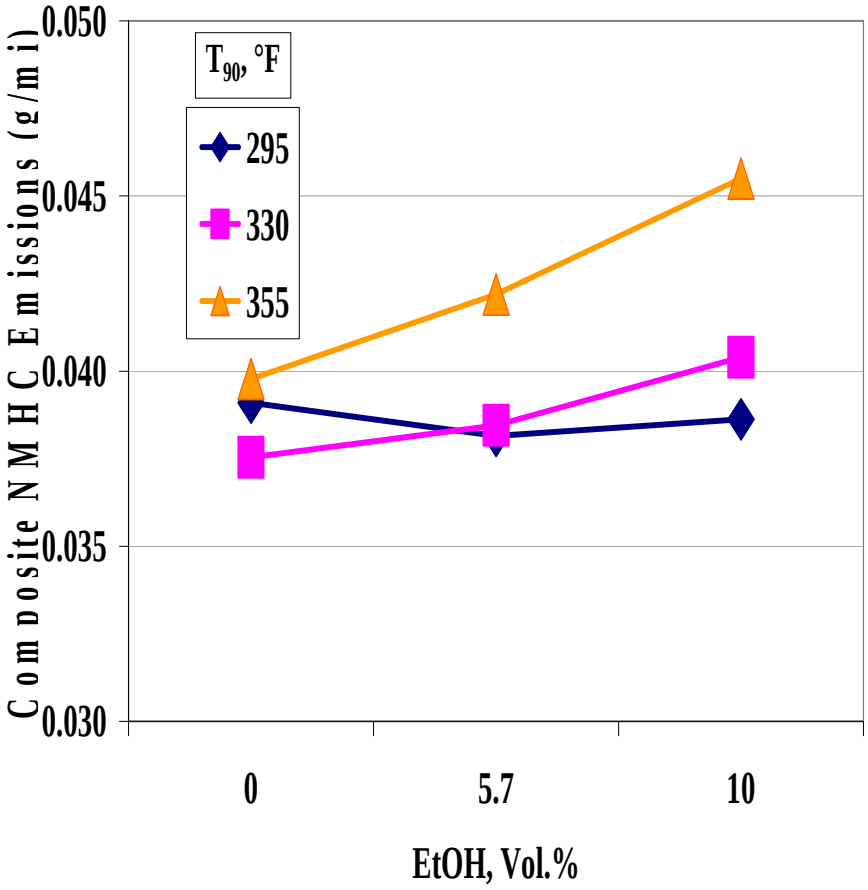
Composite NMHC by T50 - Fleet-Average and Individual Vehicles

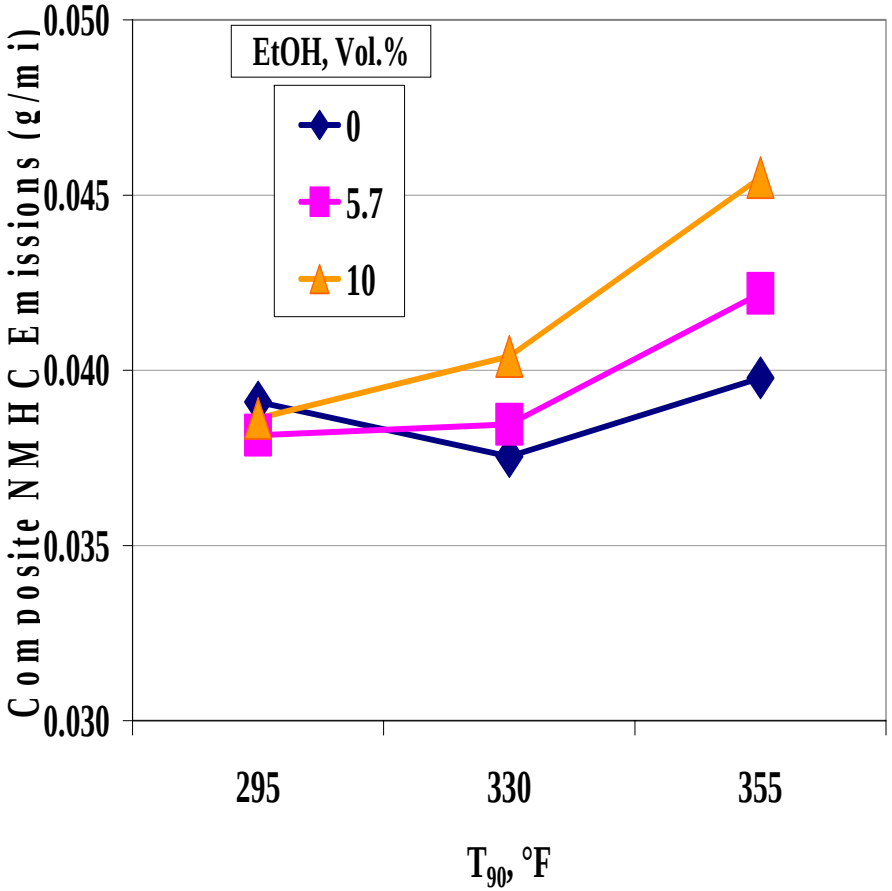


E-67 Key Findings – NMHC

Statistically Significant EtOH by T90 Interaction

Composite NMHC by EtOH x T90 - Fleet Average





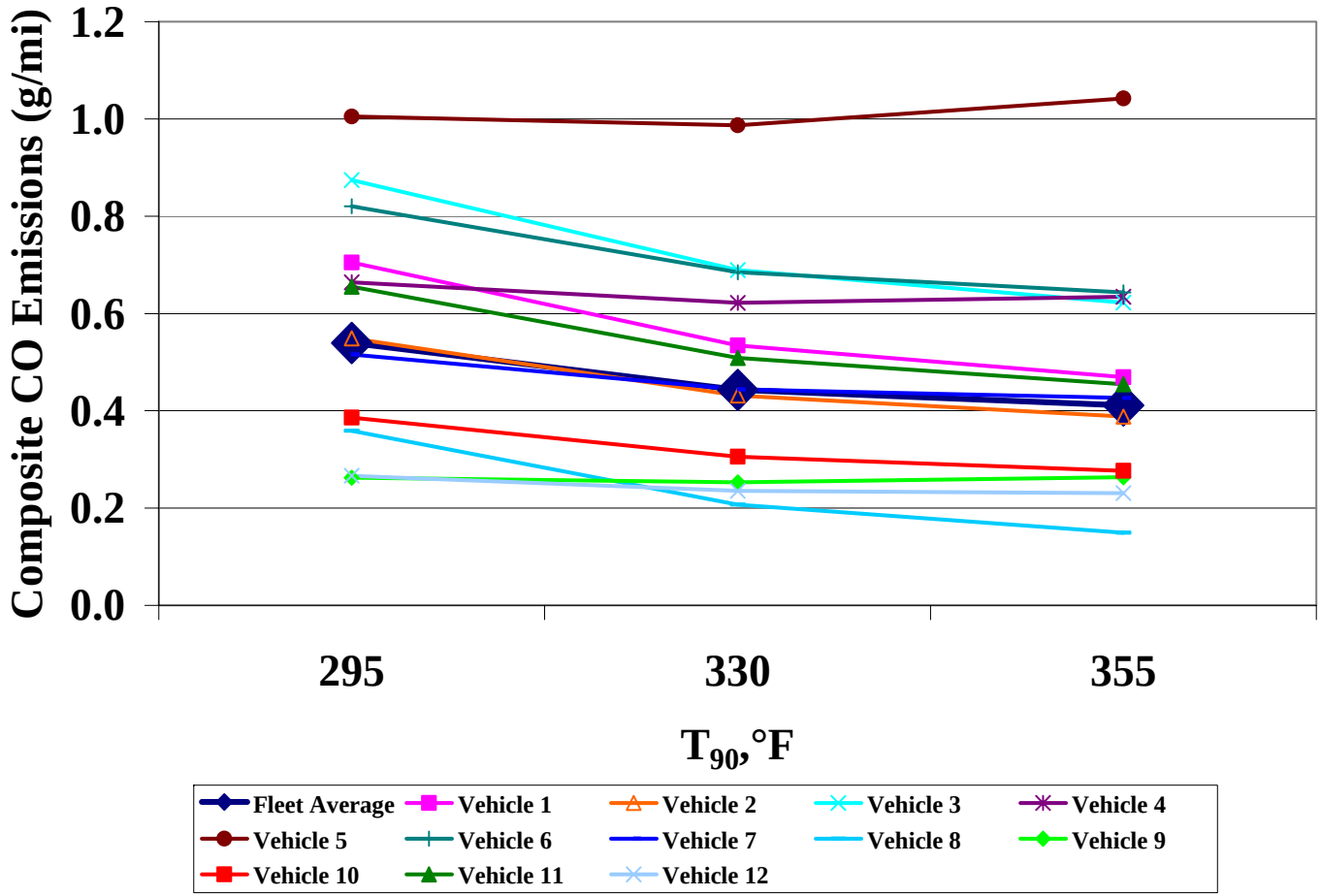
E-67 Key Findings - NMHC

- NMHC increased with increasing T50.
- The fleet-average percentage increases in NMHC in going from the low and mid-point level of T50 to the high T50 level were 36 and 25%, respectively.
- A significant interaction was found between ethanol and T90
  - NMHC increases with ethanol at mid- and high T90
  - NMHC increases with T90 at mid- and high ethanol levels

E-67 Key Findings – CO

CO decreased with increasing T90

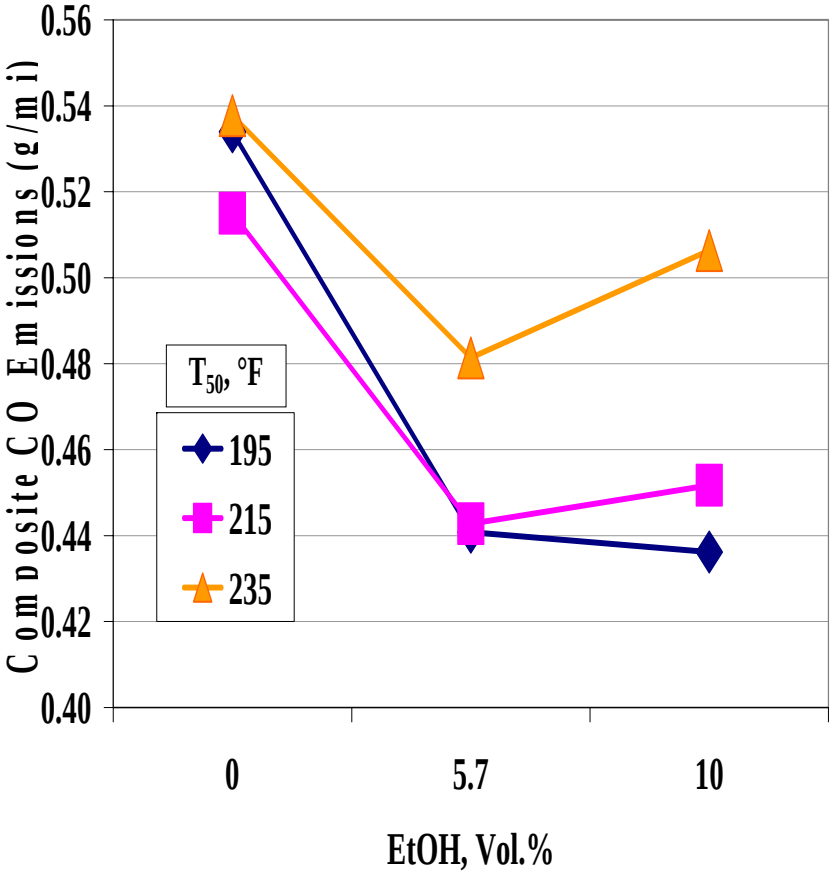
Composite CO by T90 - Fleet Average and Individual Vehicles

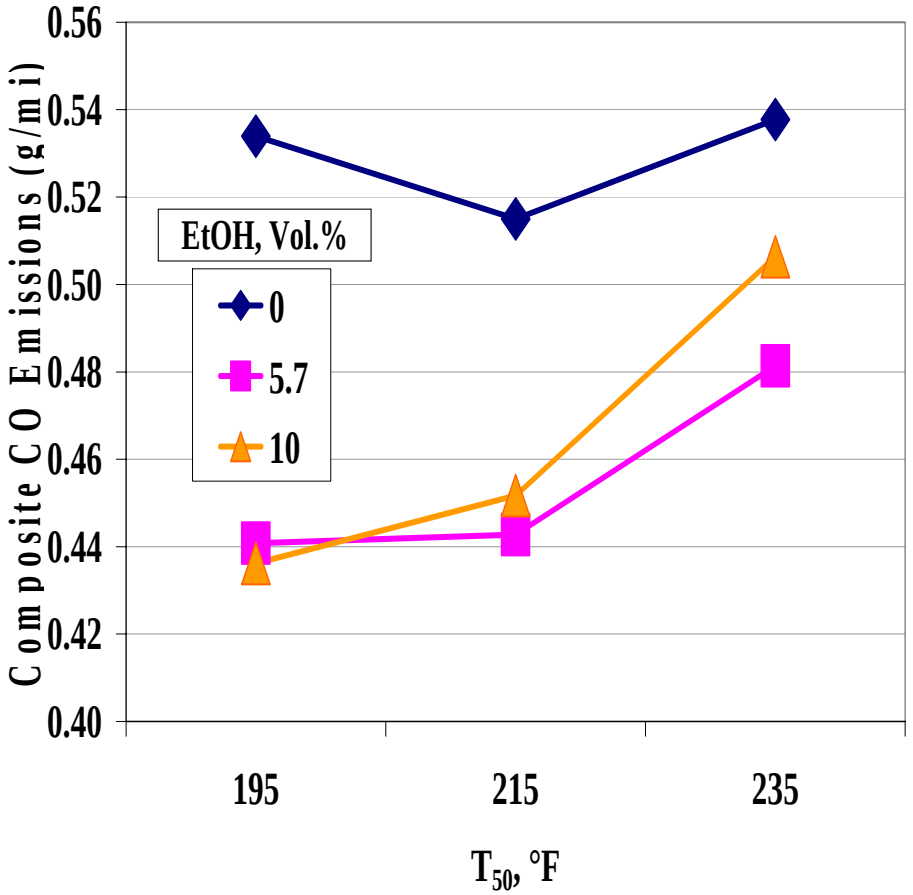


E-67 Key Findings – CO

Statistically Significant EtOH by T50 Interaction

Composite CO by EtOH x T50 - Fleet Average





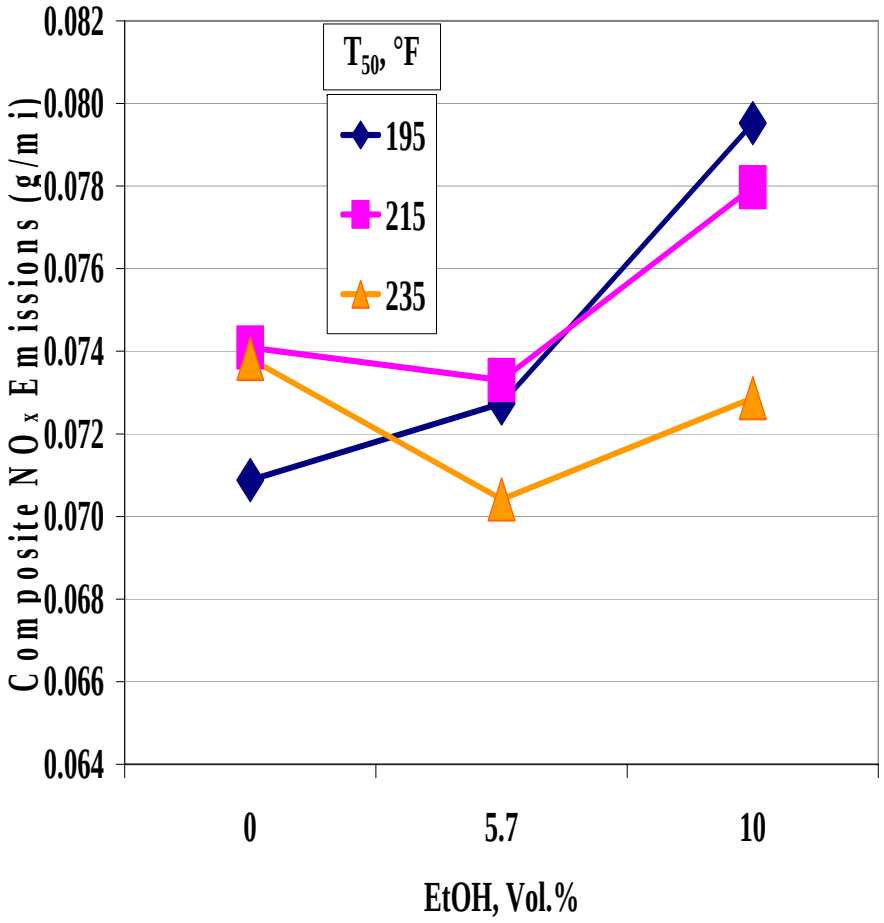
E-67 Key Findings - CO

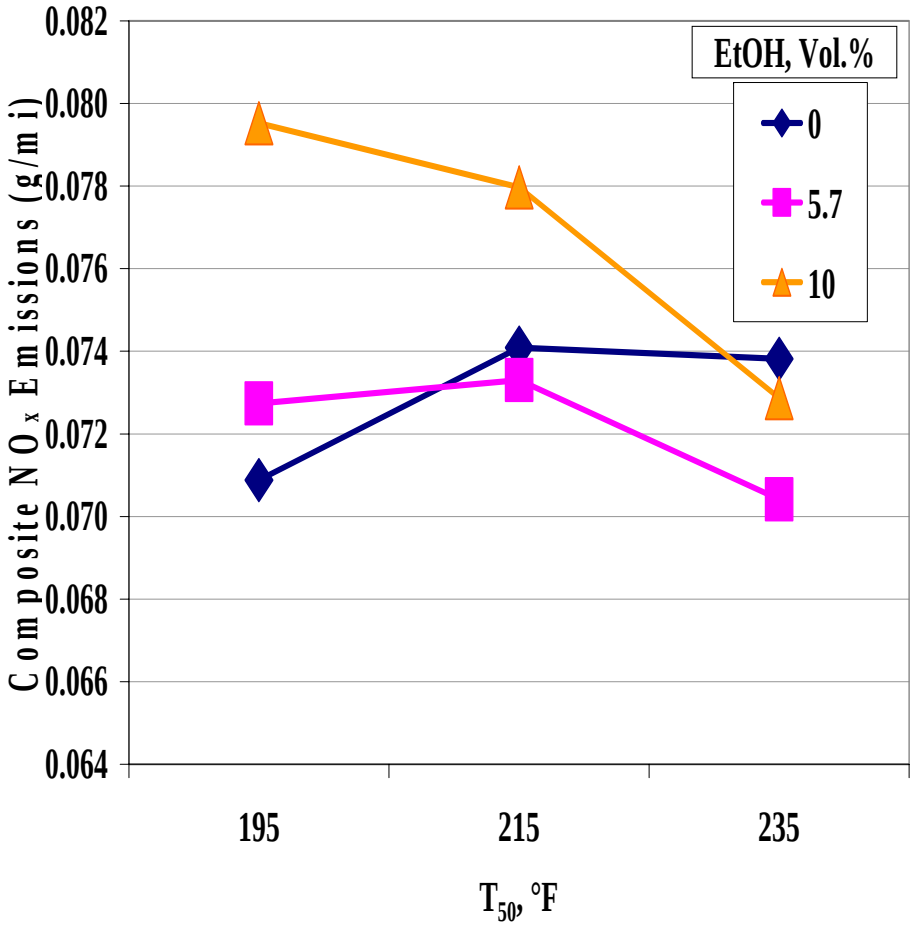
- CO decreased with increasing T90.
- The percentage decreases in going from the low and mid-point level for T90 to the high T90 level were 24% and 7%, respectively.
- A statistically significant interaction was found between ethanol and T50
  - CO decreased when ethanol was increased from 0% and 5.7%, but was unchanged or increased when ethanol was 10%
  - CO increased with T50 at 5.7% and 10% ethanol levels, but was unaffected when no ethanol was present

E-67 Key Findings – NOx

Statistically Significant EtOH by T50 Interaction

Composite NOx by EtOH x T50 - Fleet Average





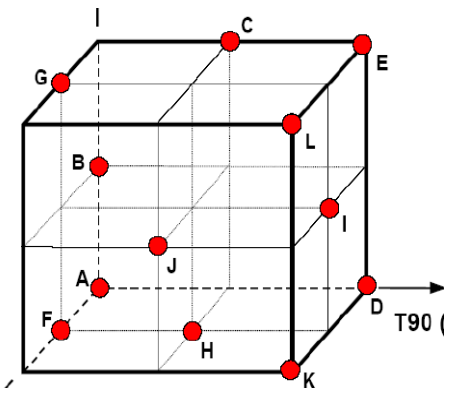
E-67 Key Findings - NOx

- A significant interaction was found between ethanol and T50.
- NOx increased with increasing ethanol at the low level of T50.
- At the mid-point level of T50, NOx was largely unaffected as ethanol was increased from the zero to the mid-point level, but increased as ethanol was increased to the high level.
- At the high level of T50, NOx is largely unaffected by ethanol.
- Alternatively, NOx decreased with increasing T50 at the high level of ethanol, but was largely unaffected by T50 at the zero and mid-point levels of ethanol.

E-67 Key Findings – NMOG & Toxics

Caveat:

- The effects of ethanol and T50 on NMOG and toxics described on the next slide were only observed for the subset of fuels having the high level of T90.
- The results of this study do not permit any conclusions as to what effects T50 or ethanol might have on NMOG or toxics emissions for fuels having low or mid-point T90 levels.



E-67 Key Findings – NMOG & Toxics

NMOG:

- Increased by 14% when ethanol was increased from zero to the high level.
- Increased by 35% when T50 was increased from the low to the high level.

Formaldehyde:

- Increased by 23% when T50 was increased from the low to the high level.

Acetaldehyde:

- Increased by 73% when ethanol was increased from zero to the high level.

Benzene:

- Increased by 18% when ethanol was increased from zero to the high level.
- Increased by 38% when T50 was increased from the low to the high level.

1,3-butadiene:

- Increased by 22% when ethanol was increased from zero to the high level.
- Increased by 56% when T50 was increased from the low to the high level.

CRC E-67

- The E-67 final report and the dataset are both available on the CRC website at:

http://www.crcao.org/

- Click on “Recent Reports and Study Results”