Auto Industry Comments on California RFG Phase 3

CARB Workshop, Sacramento, CA
November 15, 1999

Alliance of Automobile Manufacturers and the Association of International Automobile Manufacturers

Cleaner Burning Gasoline

- Ca RFG2 has been one of most successful air quality programs ever undertaken
- Reduced sulfur widely acknowledged as key factor
- DI role underappreciated

CBG Success and DI

- 50% of VOC reductions attributable to DI reduction
- 15% of toxic reductions attributable to DI reduction
- Before 1996: 66% gasoline had DI (corrected) >1200 (4 year sample weighted average)
- Since 1996: 10% gasoline had DI (corrected) >1200 (4 year sample weighted average)

Situation

- California needs more reductions
- Fuel remains best hope for improved air quality
- Autos' proposal offers 50 tpd for just pennies
- Next opportunity to act is Dec. 9

Overview of Presentations

- Proposed RFG3 vs. Autos' recommendation
- Alliance test program update
- Volatility concerns
- Advanced vehicle technologies
- Emission/air quality benefits
- Fuel cost and supply issues
- Closing remarks

ARB Adopted LEV II Standards

- "State and federal air quality standards continue to be exceeded in regions throughout California"

- SIP called for adoption of technology-based emission control strategies for light-duty vehicles beginning in 2004 MY

  - Emission reductions of 25 tpd ROG+NOX by 2010 in South Coast
  - Additional technology measures, mobile source "Black Box", needs of 75 tpd
  - LEV II "make(s) progress on the Black Box"
  - **Void of 43 tpd in Black Box remain**

- "Emission reductions are needed statewide."

- "The exhaust standards proposed in this rulemaking present a significant challenge to automobile manufacturers over the next ten years." ARB Staff Report: Initial Statement of Reasons, November 5, 1998

ARB Should NOT Sacrifice Air Quality Needs for Flexibility

LEV II

- Reduced LD Tailpipe Standards
- Reduced MD Tailpipe Standards
- Reduced Evaporative Standards
- Zero Evaporative for PZEV
- Trucks to Car Standards
- Extend useful life
- Eliminate TLEV category

Emissions

2010 LEV II SCAB Reduction of 57 tpd
with technology forcing regulation

Phase 3 Gasoline Caps

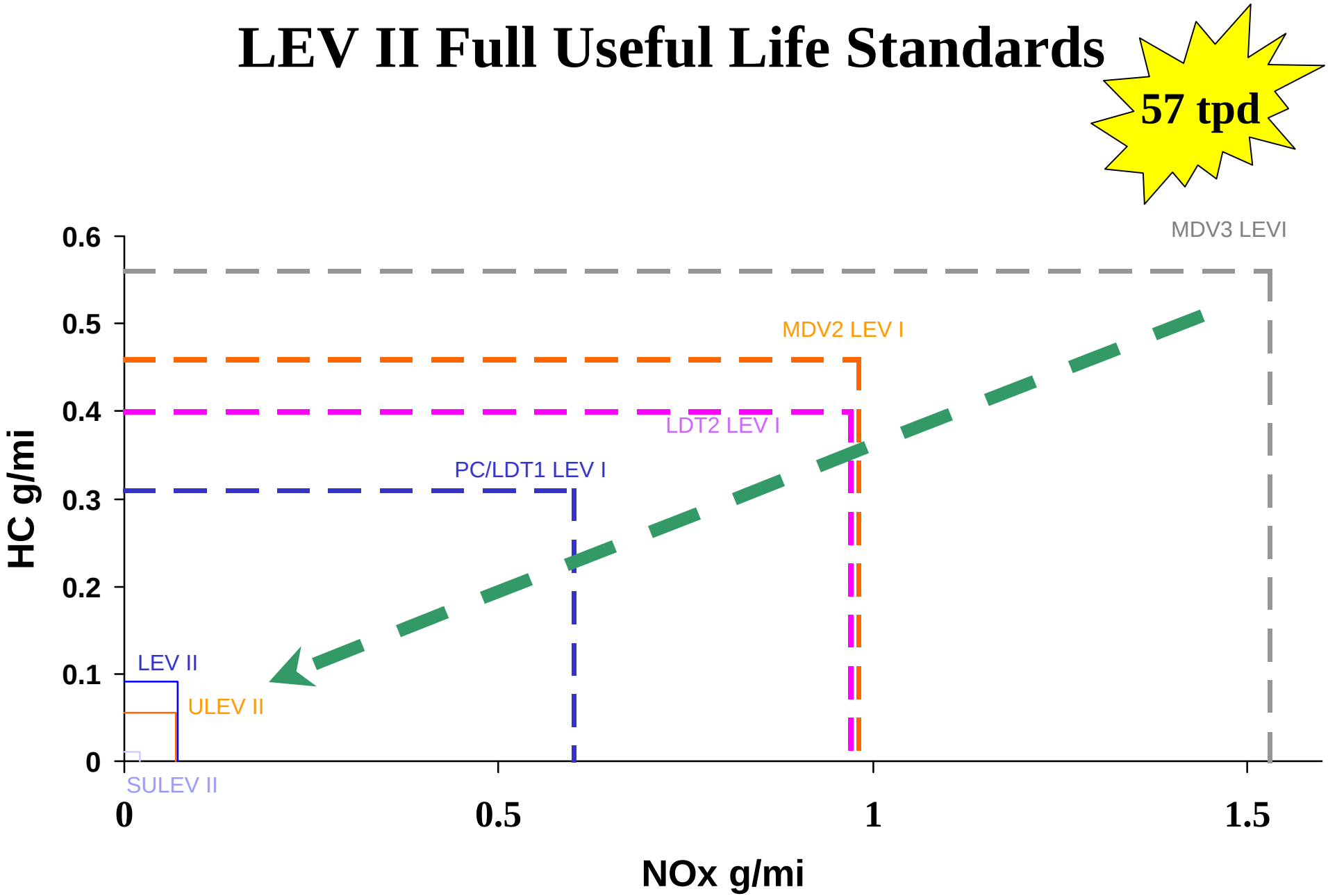
- Reduced Sulfur 80-60/30 ppm
- Reduced Benzene 1.2-1.1%
- Increased Aromatics 30-35%
- Increased T50 220-225° F
- Increased T90 330-335° F
- Increase RVP Range 6.4-7.2 psi
- Increase O_2 Range 0-3.7%

2005 Phase 3 Statewide Reduction of 19 tpd* with relaxation from many 1998 in-use fuel averages

EMFAC7G Inventory Model
LEV II Benefit ARB, Phase 3 AIR Analysis

* Excluding co-mingling effect

LEV II Full Useful Life Standards



ARB Phase 3 Proposal vs Alliance Proposal

Property	Existing Phase 2			ARB Proposed Ph3			1998	AAM Proposed Ph3		
	Flat	Avg	Cap	Flat	Avg	Cap	Avg InUse	Flat	Avg	Cap
RVP	7	-	7	6.9	-	6.4-7.2	6.7	7	-	7
Benzene	1	0.8	1.2	0.8	0.7	1.1	0.6	1	0.8	1.2
Sulfur	40	30	80	20	15	60/30	25	5	NA	NA
Aromatics	25	22	30	25	22	35	22.4	25	22	30
Olefins	6	4	10	6	4	10	5.8	5	3	10
Oxygen	1.8-2.2	-	0-3.5	1.8-2.2	-	0-3.7	1.9-2.1	1.8-2.2	-	0-3.5
T50	210	200	220	211	201	225	197	170-200	190	210
T90	300	290	330	305	295	335	310	300	290	330
DI	-	-	-	1225	-	-	(1160-70)	1200		1200
Inventory Impact				2005 CA 19.2 tpd				2005 CA 48.5 tpd		

- **ARB's relaxation of fuel standards to provide flexibility for refiners is at expense of air quality.**
- **Auto manufacturers emission control technology deployment to achieve LEV II is impeded by the ARB DI (T50/T90) and sulfur proposals.**
- **Vehicle emissions and drive performance will be degraded if this flexibility is adopted.**

Alliance Sulfur Test Program

Preliminary Results

ARB Phase 3 Gasoline Test Program

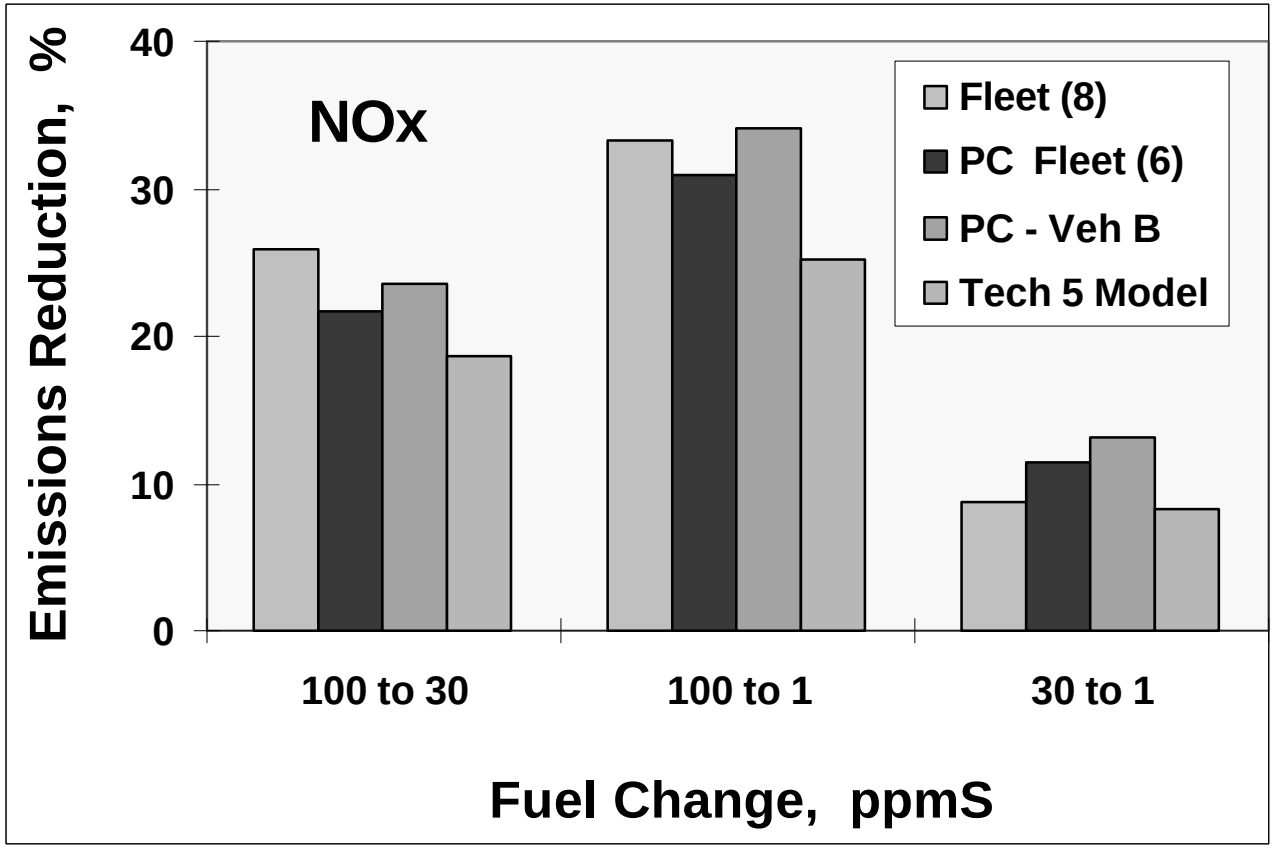
- ARB is modifying California's gasoline specifications to achieve air quality benefits, facilitate LEV II vehicle hardware and provide near-term flexibility to refiners.
- ARB is updating the Predictive Model with addition of Tech 5 vehicle category
    - Additional sulfur and oxygen data desired

- Auto test program to start mid-August
  - 8 auto manufacturers participating with common test protocol
  - 13 LEV & ULEV vehicles with aged catalysts (some SFTP intent calibrations)
  - Sulfur levels of 1, 30 and 100 ppm
  - Oxygenate study may be added later

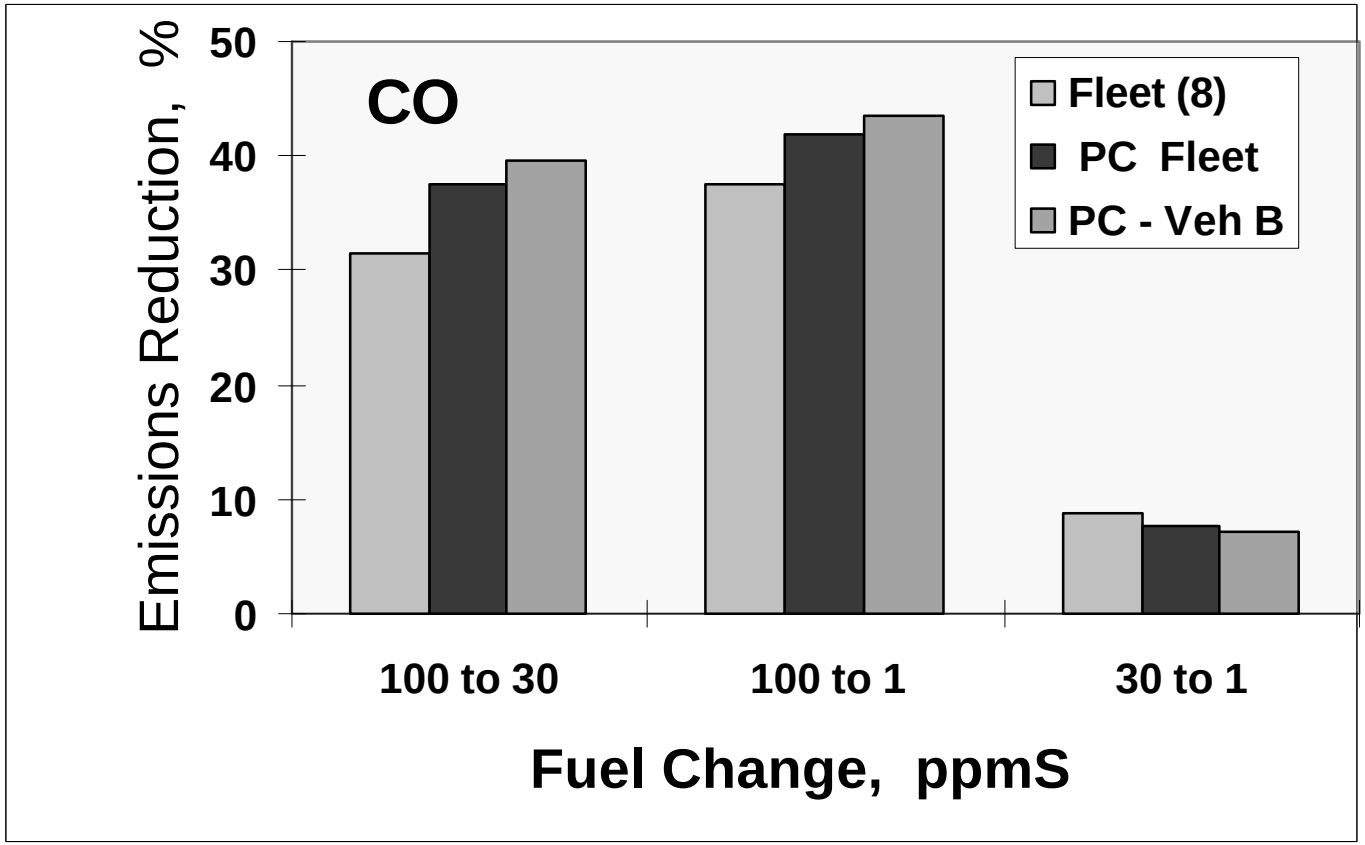
Status As Of November 12, 1999

- Phase 1 Sulfur Testing Complete On:
  - six passenger cars
  - two trucks

Preliminary Data Compared to Tech 5 Percent Reduction in Emissions



Preliminary Data
Percent Reduction in Emissions



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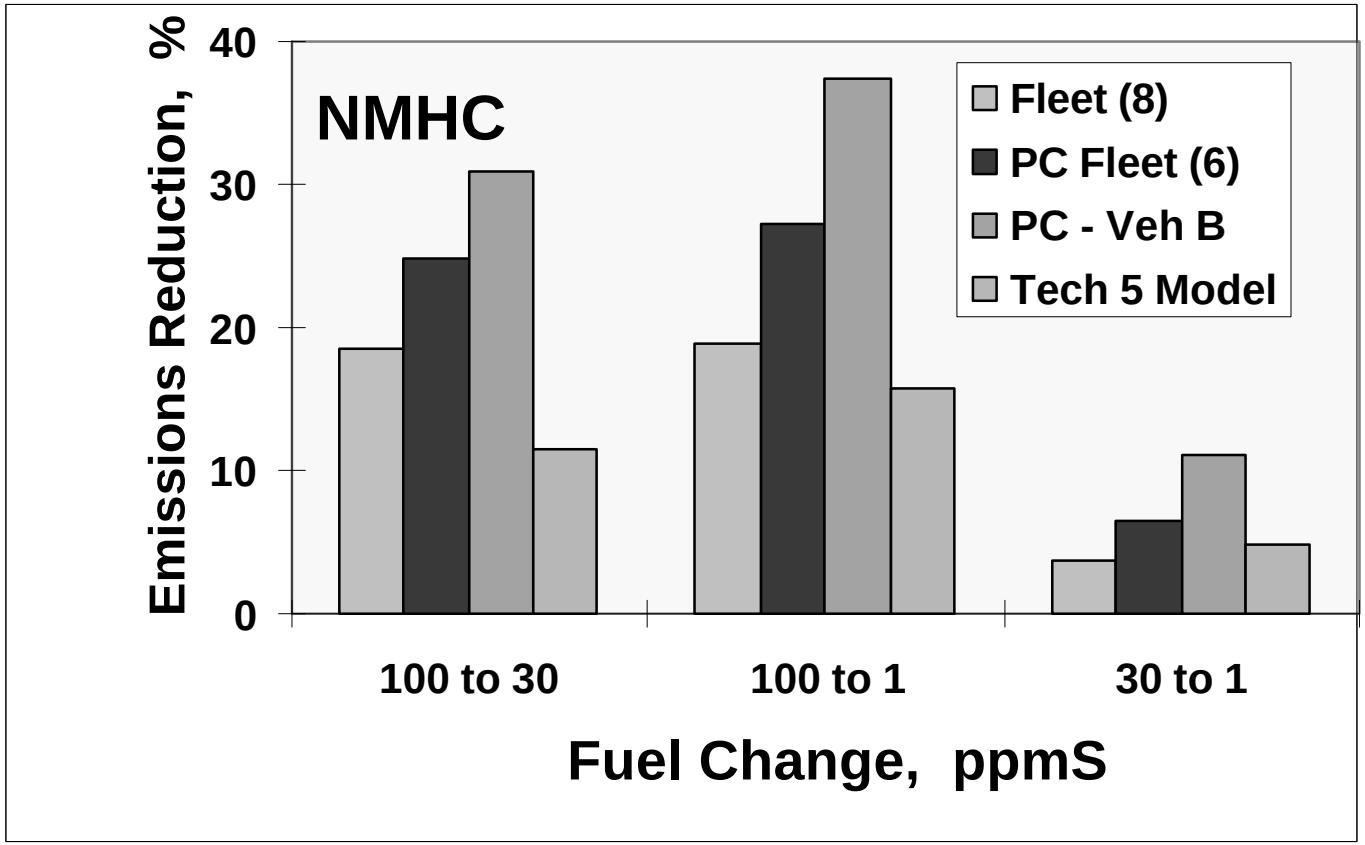
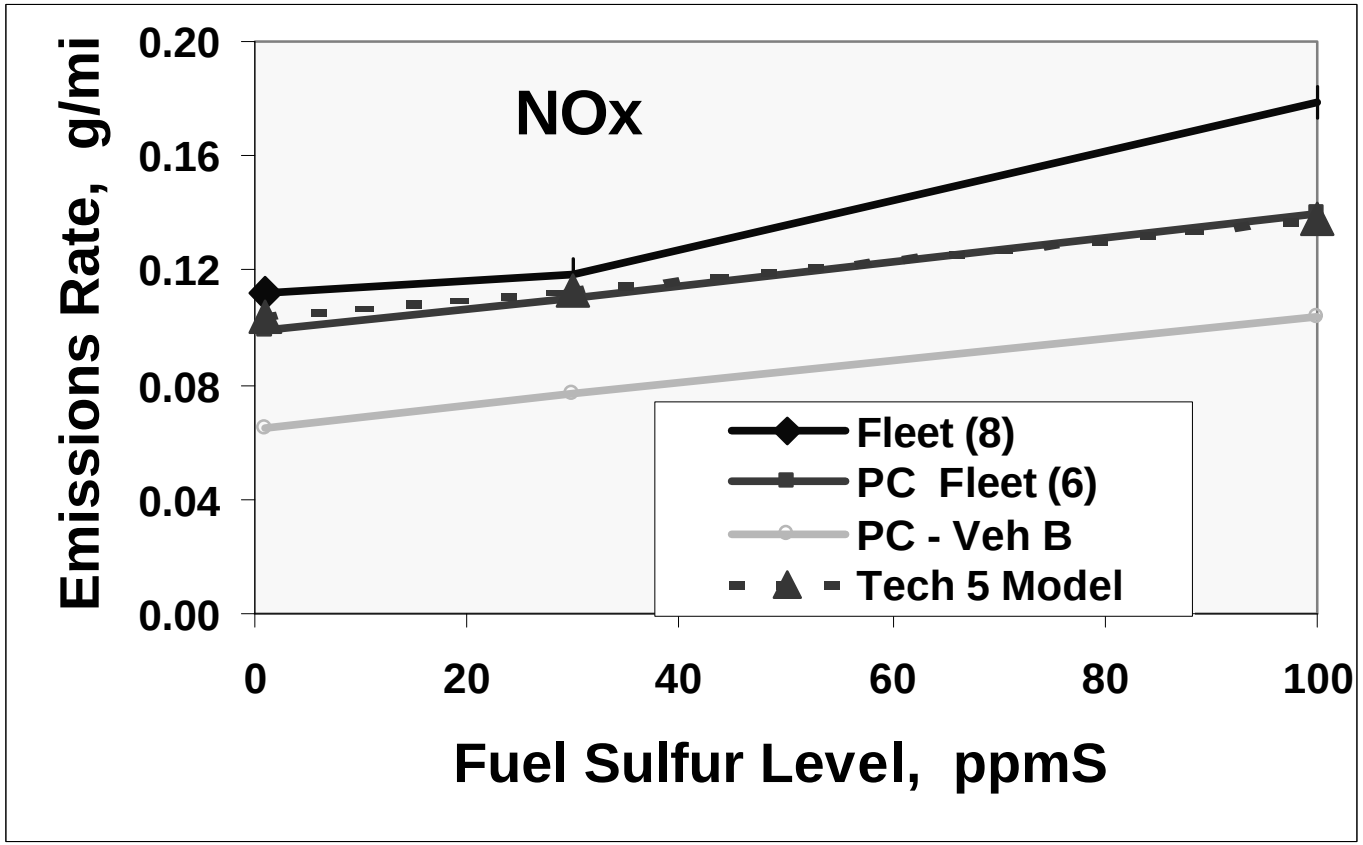
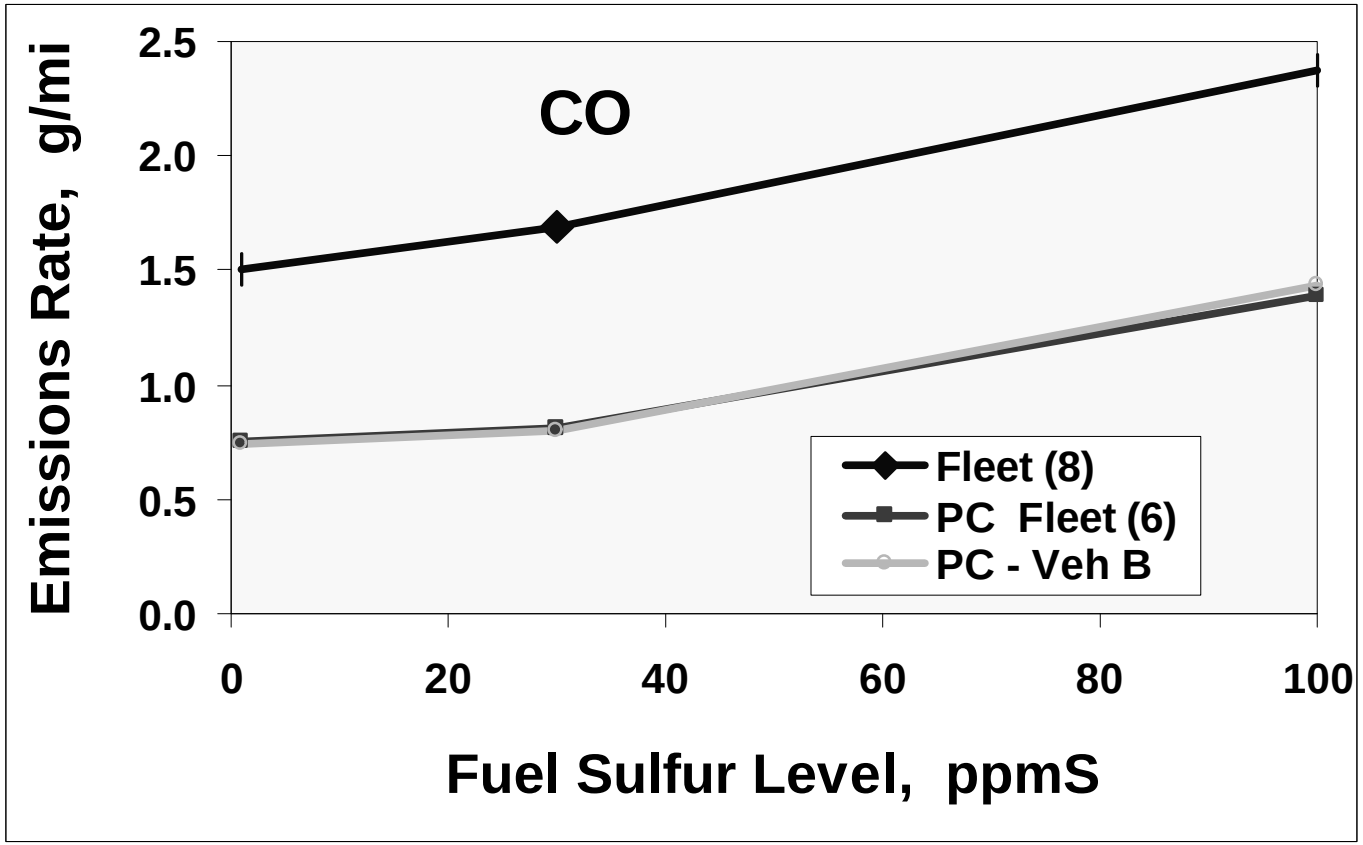


Preliminary Data Compared to Tech 5 Mass Emissions



Preliminary Data
Mass Emissions



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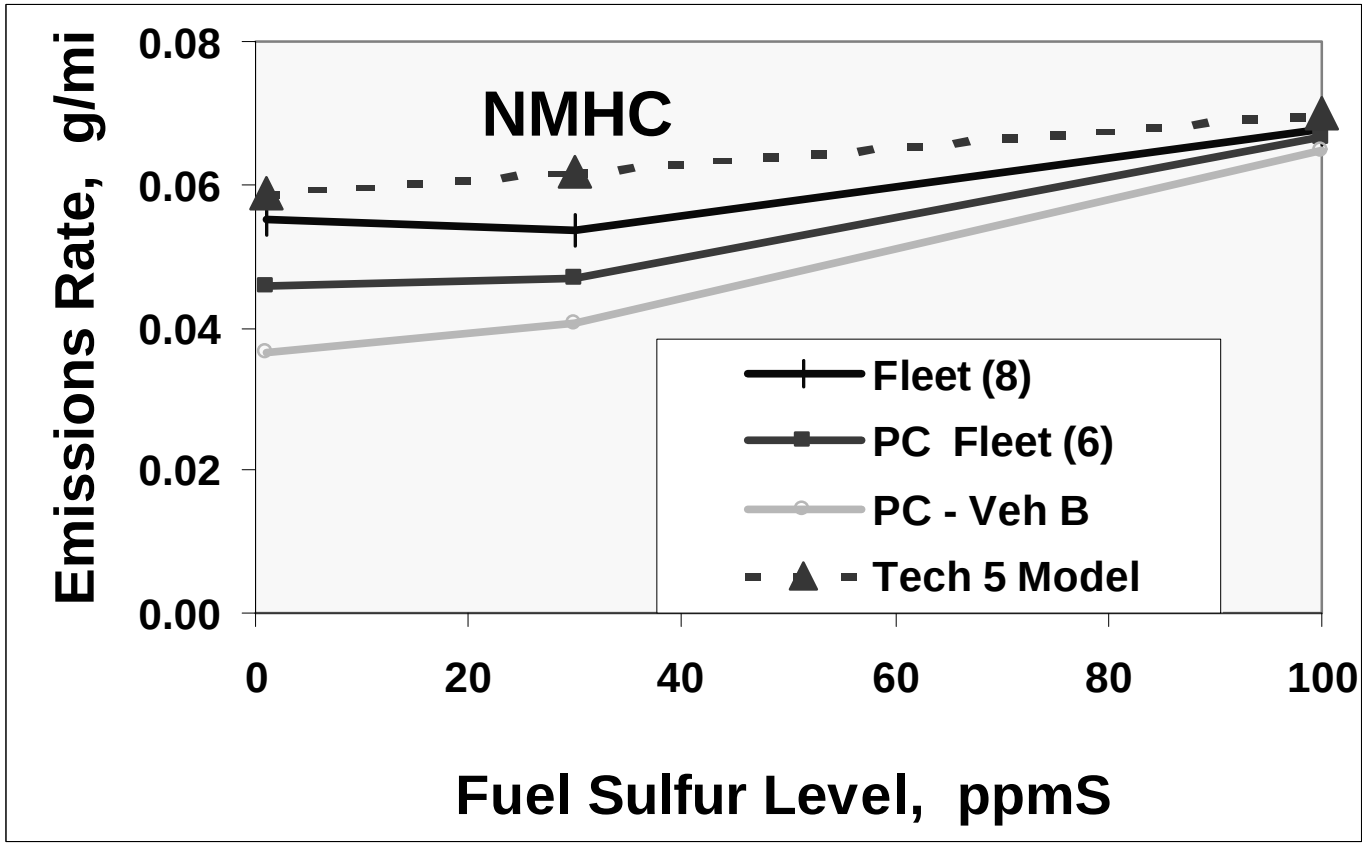


Caveats

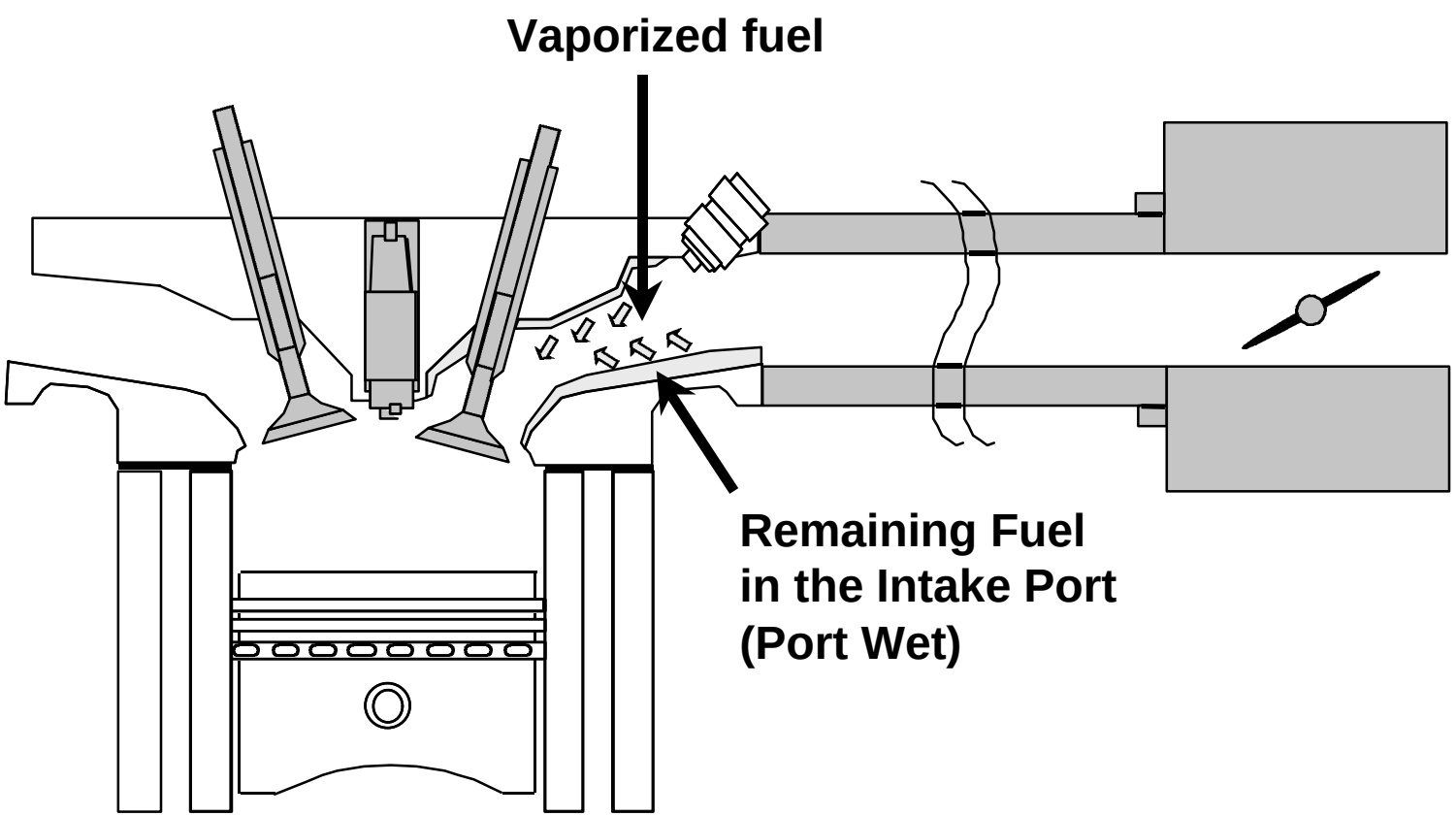
- Results are preliminary for initial 8 vehicle sub-fleet
- No outlier analysis applied to data
- Data on five additional models is pending

Volatility

- How does it affect emissions?
- Effects on THC (of in-use vehicles)
  (of future vehicles)

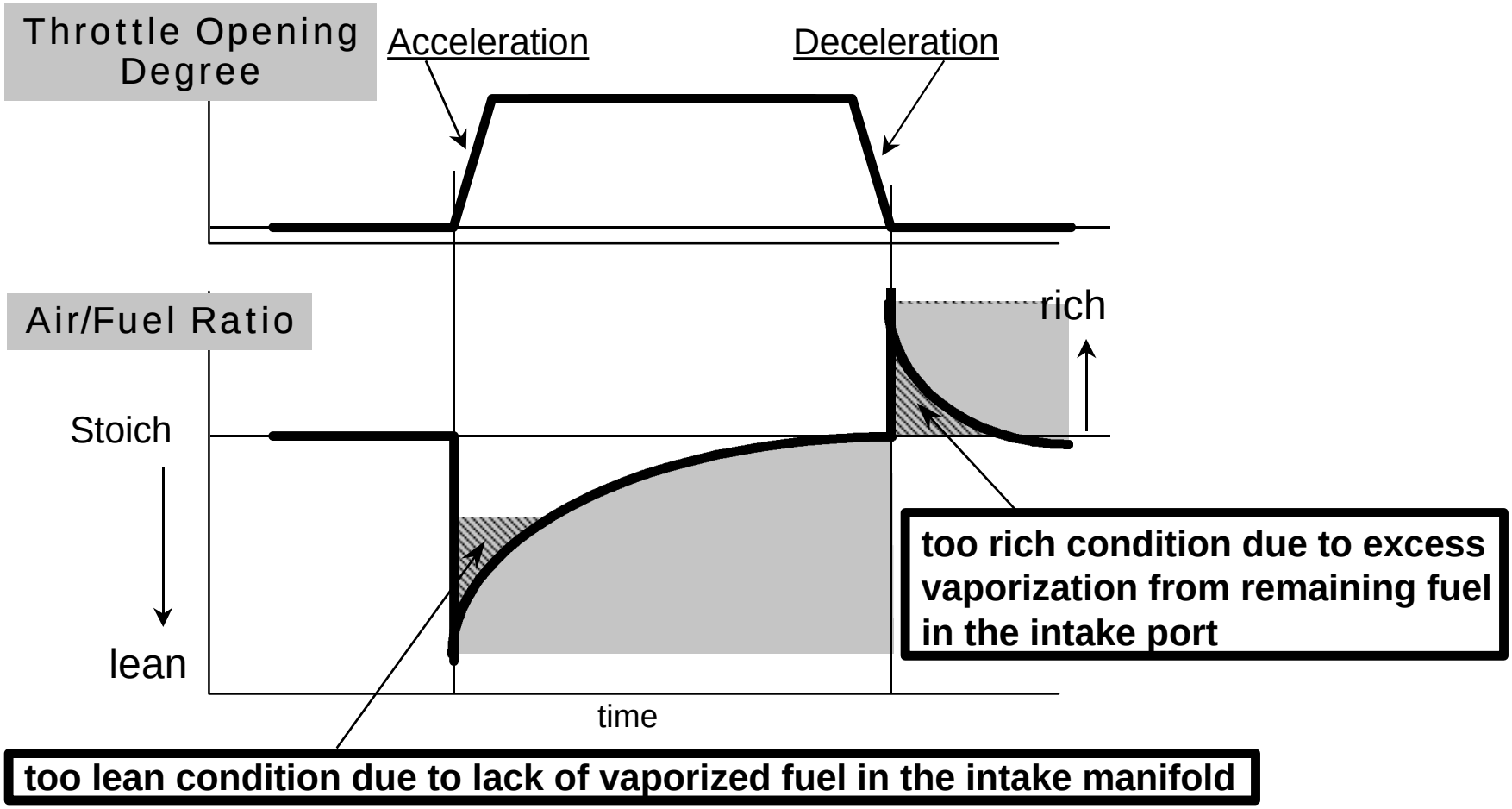
How does volatility affect emissions?

- **Transient operation (i. e. acceleration) changes the vaporization of liquid fuel in the intake port and thereby changes the air/fuel mixture entering the cylinder .**

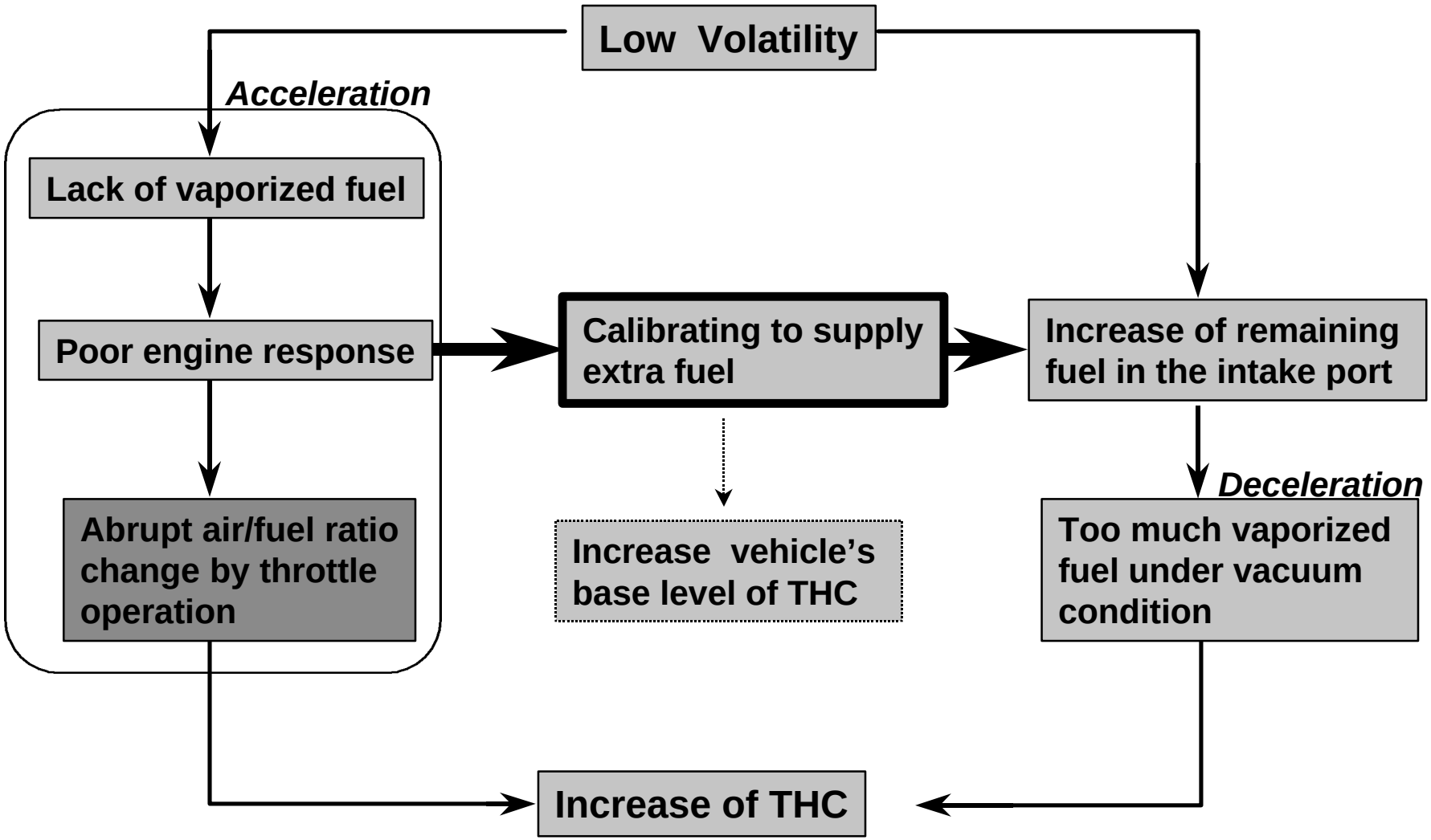


Volatility - Influence of Low Volatility Fuel

- **Air/fuel ratio can not be controlled properly with low volatility fuel.**

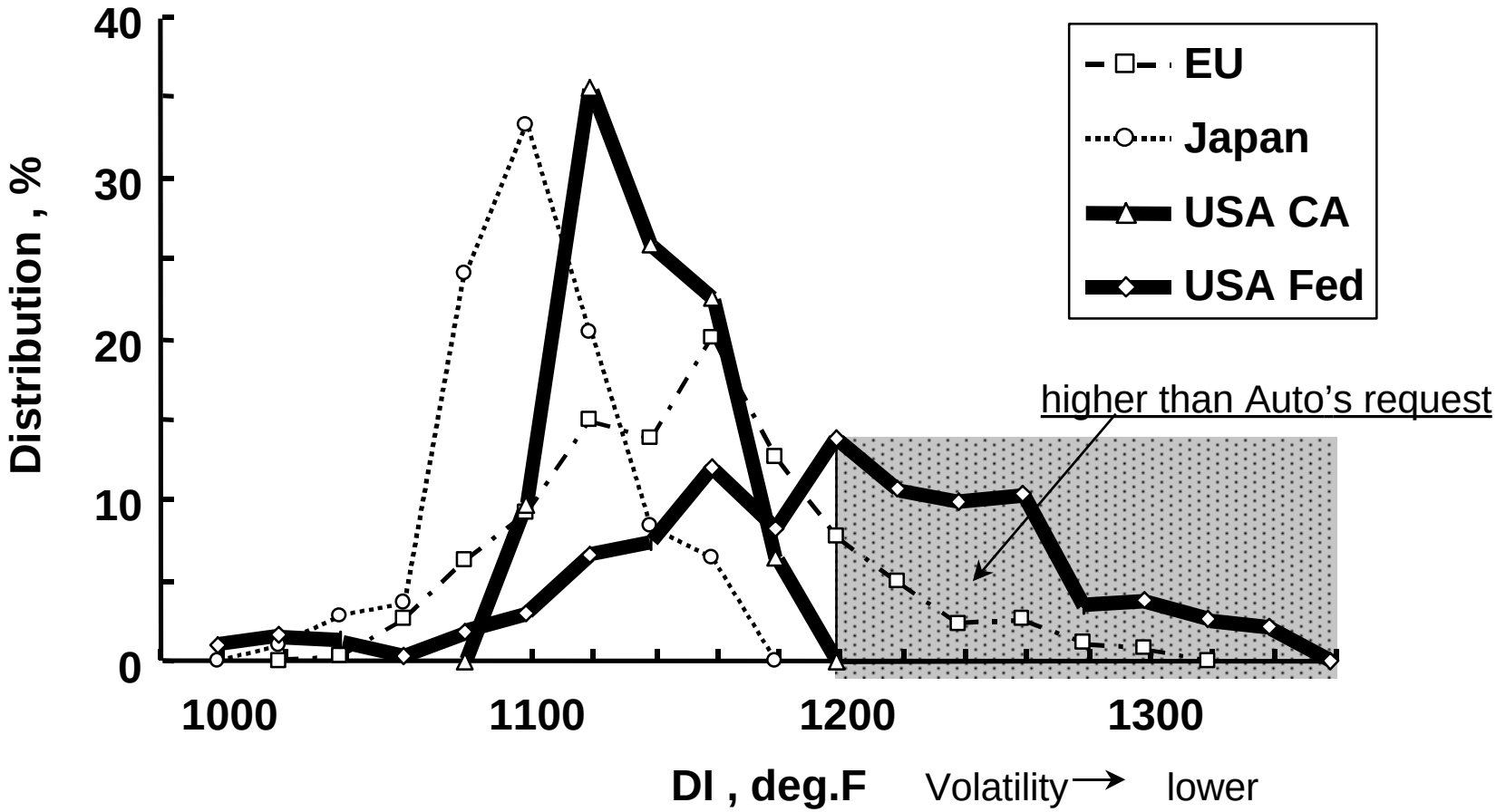


Volatility - Relation to exhaust HC emission



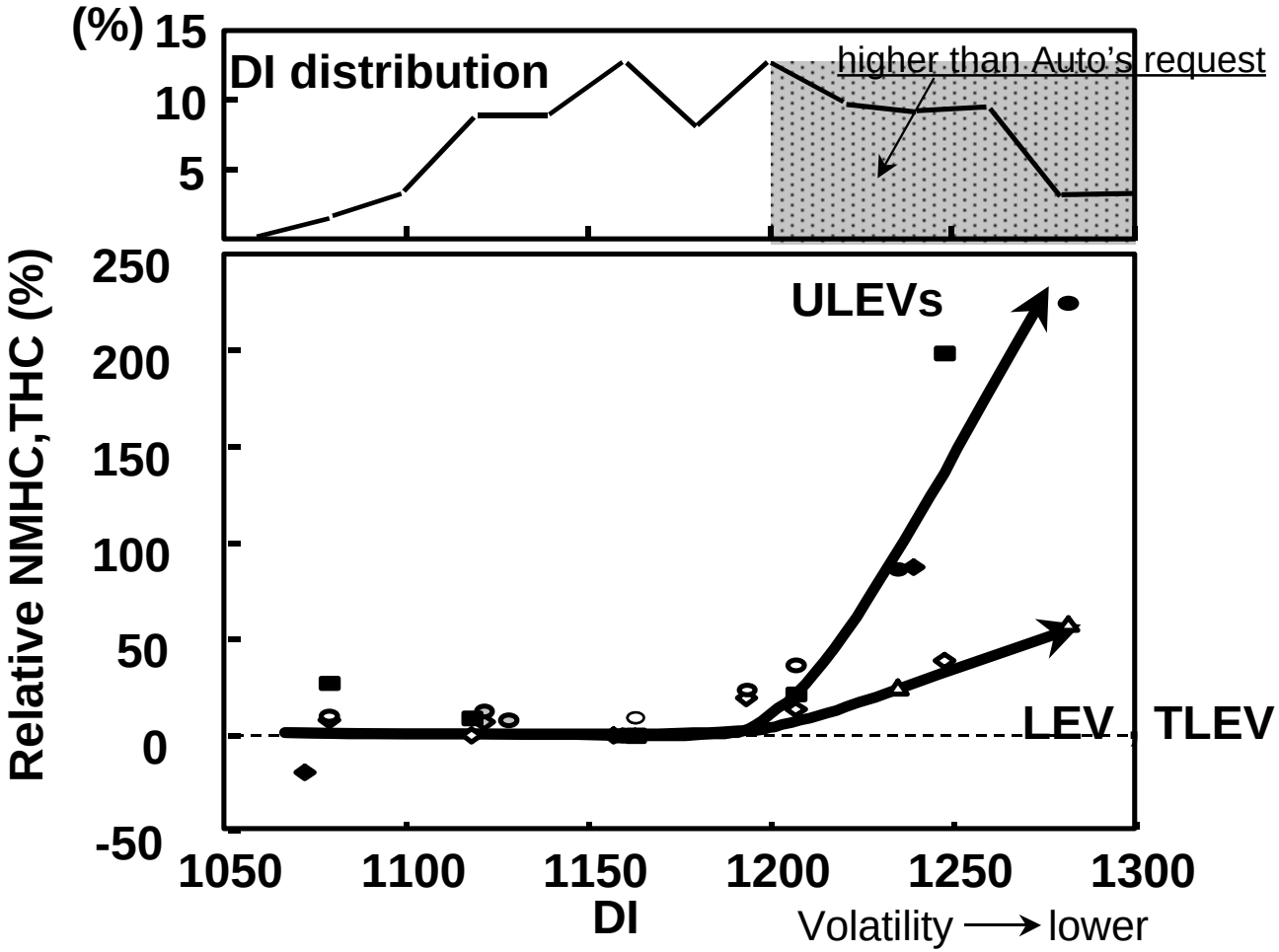
Volatility - Distribution of DI in Market Fuel

- **Volatility distribution in the US market is relatively wider.**
  -> Existence of lower volatility fuels causes THC increase of in-use vehicles.



Volatility - Effects on In-Use Vehicle THC

- **Fuel with lower volatility makes THC emissions worse in the fleet.**

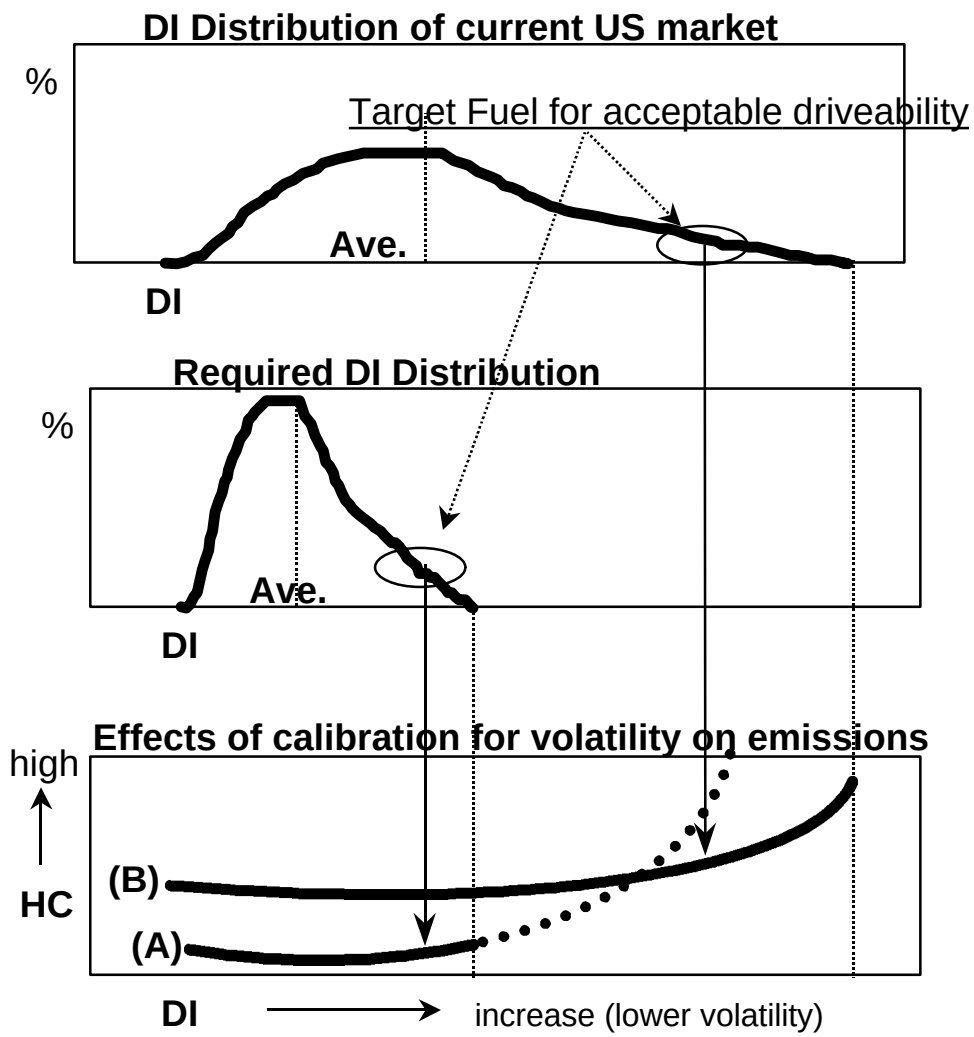


Volatility - Effects on Future Calibration

- **Relation between HC emissions and DI distribution in the market is illustrated.**

- **If the DI distribution would be narrower and lower, the vehicle's base HC level can be kept lower as shown by curve (A) in the bottom plot. Because calibration of enrichment for lower volatility fuels is not necessary.,**

- **Current DI distribution is too wide for future vehicles to comply with stringent new standards that require more precise air/fuel ratio control.**



Volatility - Conclusion

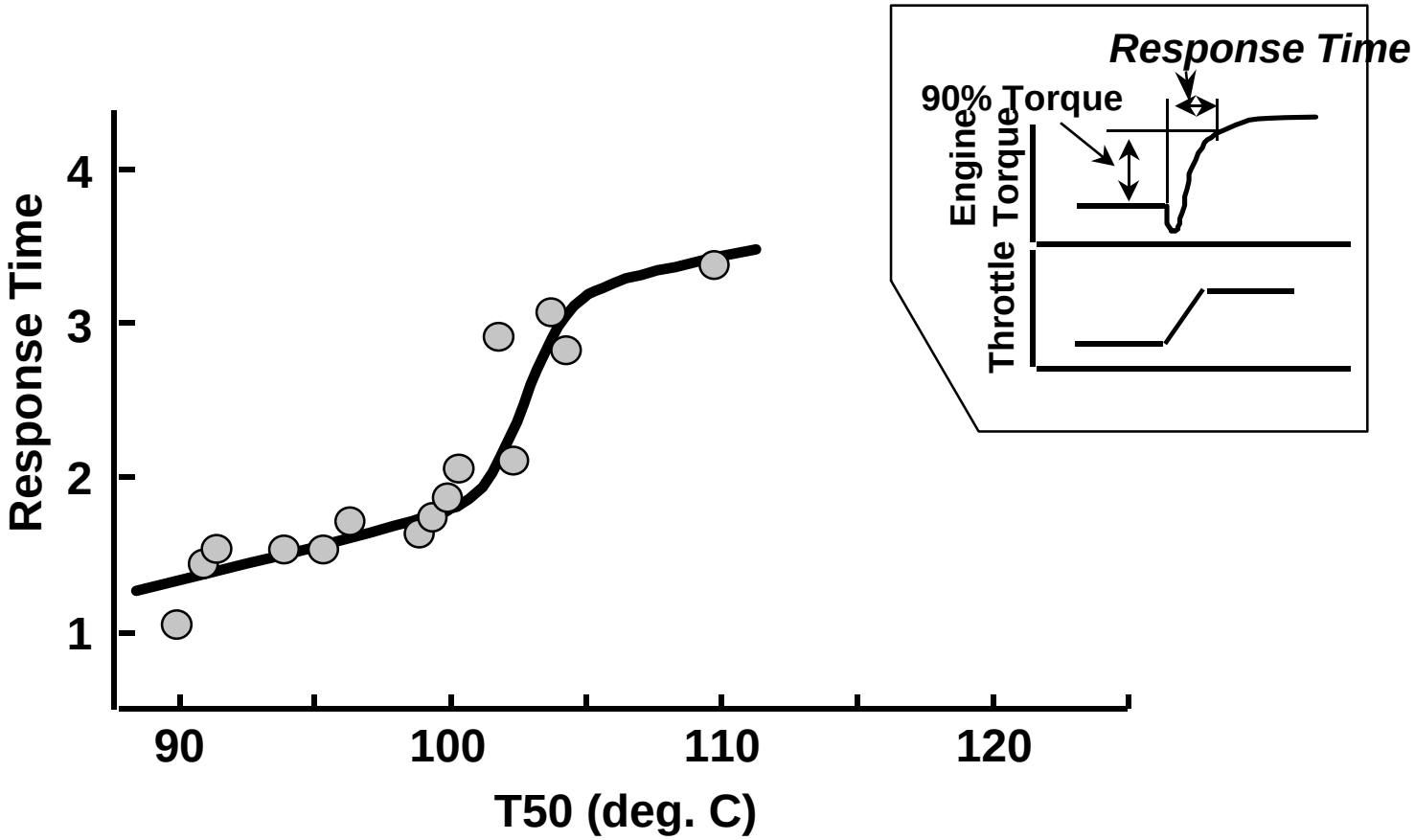
- Fuel volatility in the market should be controlled to reduce THC.
  - Capping the market volatility is important.

- Necessary level of capping is 1200 in DI for current vehicles as called for in the World Wide Fuel Charter.

- A lower cap and narrower distribution of DI will be necessary for future vehicles complying with more stringent standards.

Volatility - Effects on Driveability

- **Response time increases with lower volatility fuels.**



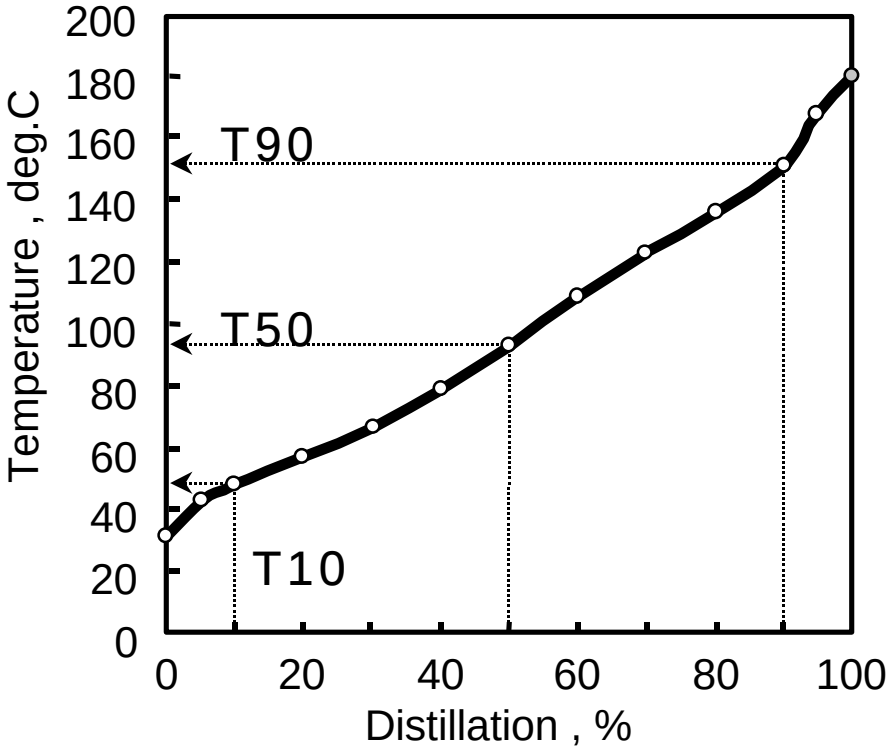
TOYOTA/SAE902094

Volatility - Indicator of fuel volatility

- DI (Driveability Index)
  =1.5xT10+3xT50+T90+11xOxy.wt%

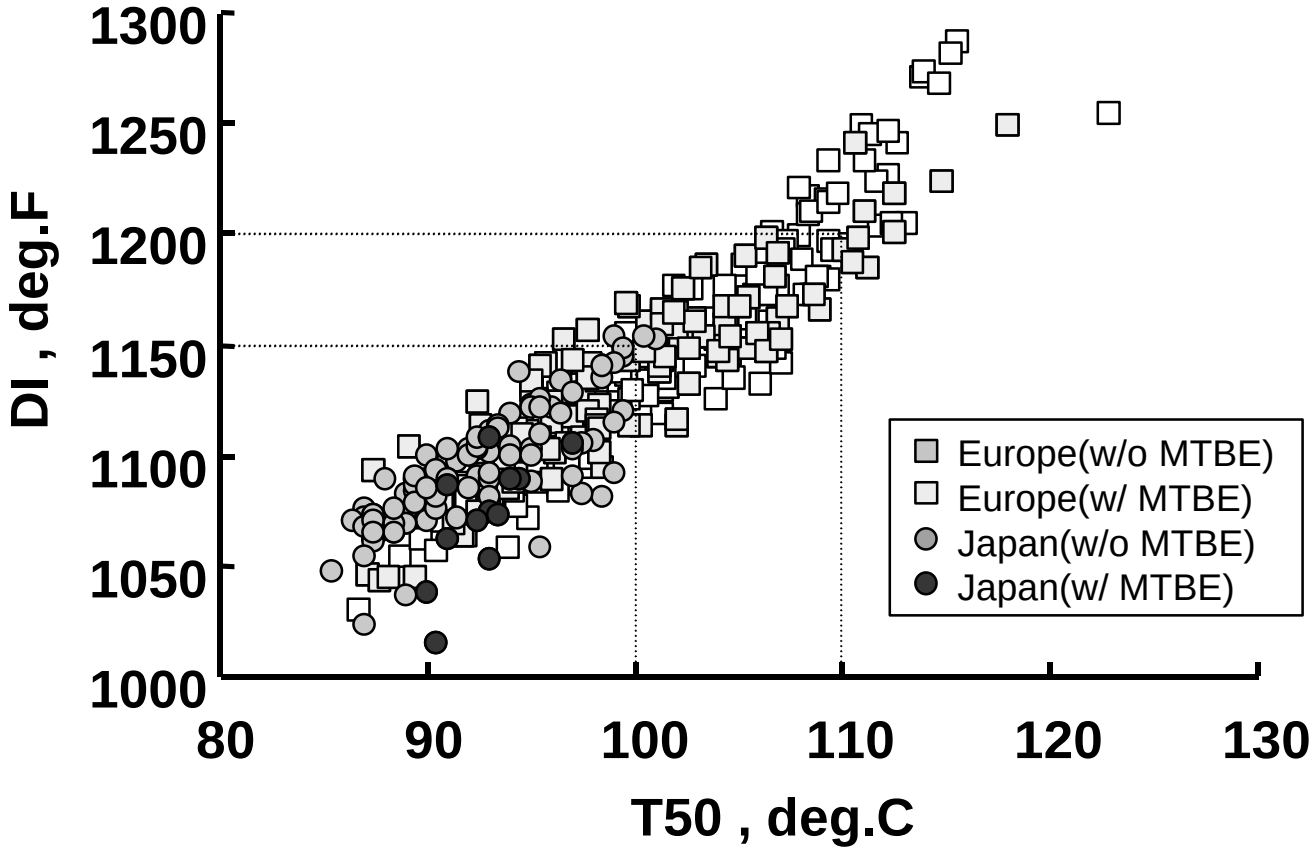
  or

- (T50, T90)



Measure of Fuel Volatility

Although T50 is used as an indicator of fuel volatility in this comment, DI as is recommended in the DI petition and the World Wide Fuel Charter is also suitable because of good correlation with T50.



Notes: DI = 1.5 x T10 + 3 X T50 + T90 + 20 x O2(Ethanol only)

Low Sulfur Fuel Enables Advanced Emission Control Technology

California RFG 3 Workshop

November 15, 1999

Sulfur Has Negative Impacts on All Catalyst Technology

- Advanced 3-way stoichiometric catalysts
- Lean burn catalyst technology

Gasoline Engines with 3-way Stoichiometric Catalysts

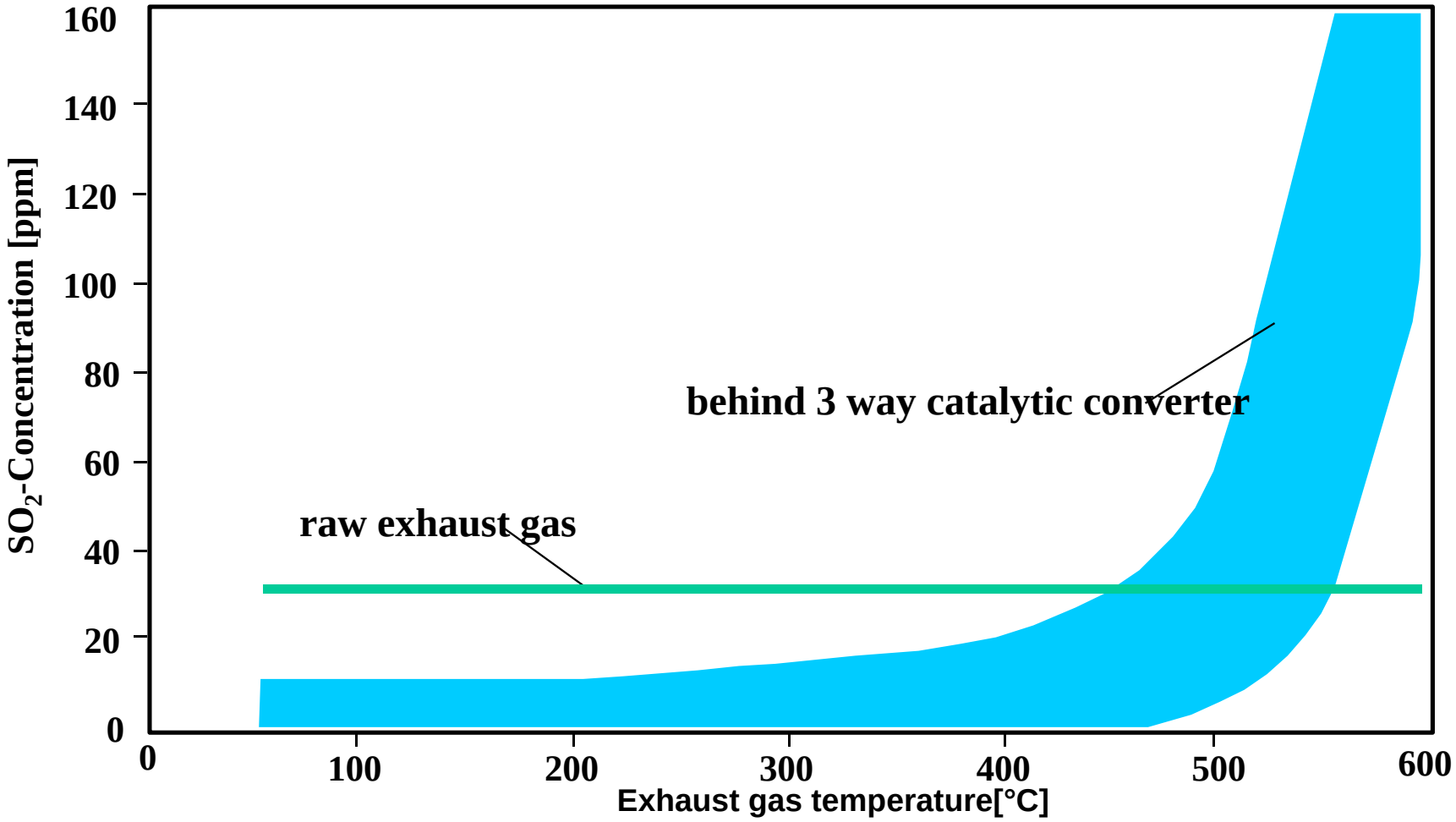
- Must go through regeneration to remove sulfur – requires hot, rich events
- Always a recognized issue
- More difficult to do with SFTP and low FTP standards
- Advanced catalysts not fully reversible

Sulfur in Gasoline…

- Inhibits catalytic activity by occupying active sites
- Causes sulfate formation
- Contributes to SO2 formation
- Reduces N2 formation
- Contributes to particulate and air toxics emissions

Disposition and regeneration of sulfur

Test procedure:US-FTP 75, gasoline [600 ppm S]



Gasoline Engine with NOX Storage Catalyst

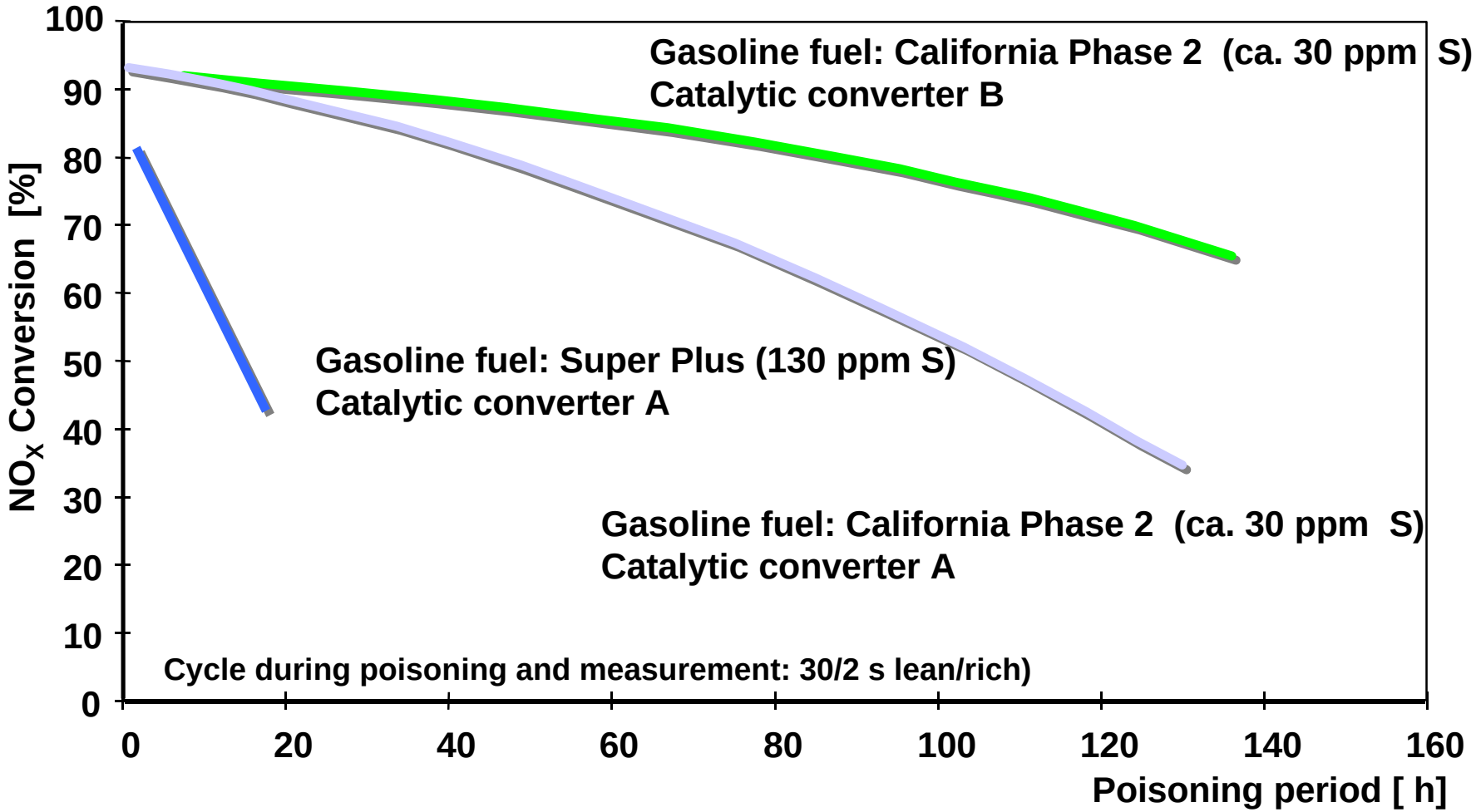
- Sulfur occupies absorption sites
- Modest sulfur levels result in rapid poisoning of catalyst
- More difficult to regenerate
- Regeneration more sensitive to driving conditions

Effects of increased sulfur content on NOX Conversion

- NOX storage catalysts more sensitive
- Catalyst is poisoned even at very low sulfur concentrations
- More regeneration events are necessary
- Fuel economy/emission benefits compromised

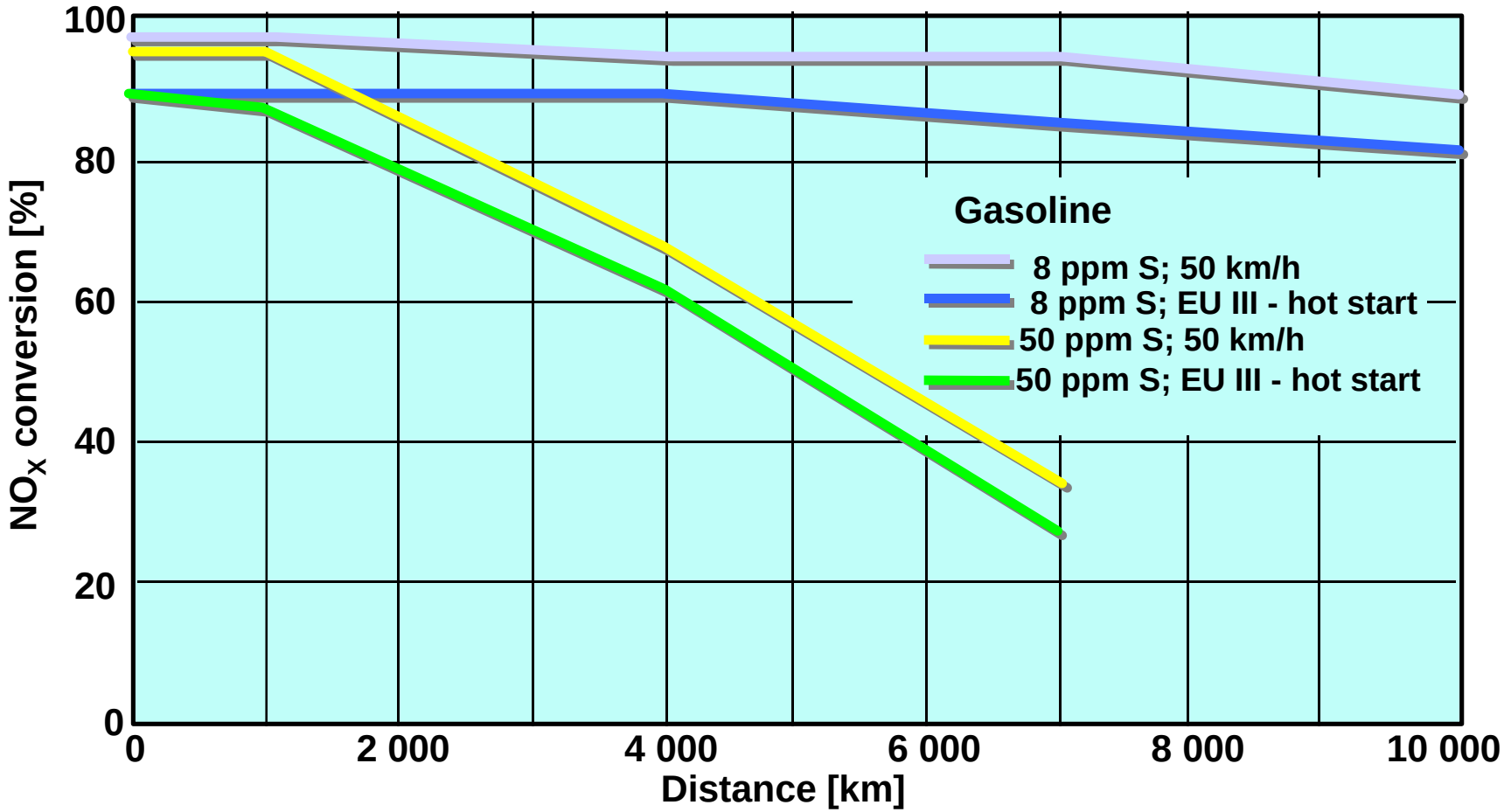
Influence of sulfur content on NO_x Conversion

Test procedure: Engine test-bench, part load operation



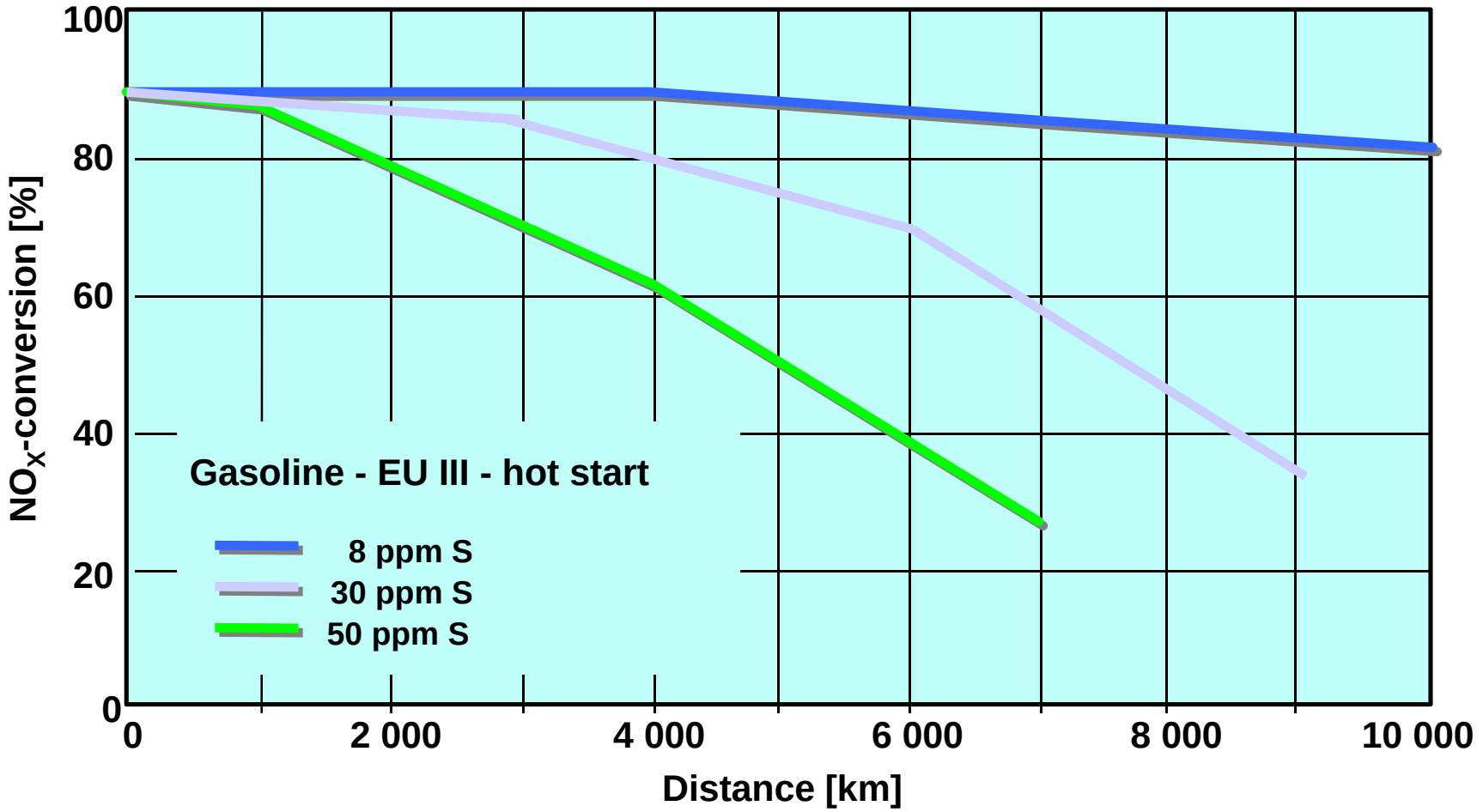
Influence of the sulfur content on durability

Vehicle with DI gasoline engine



Influence of the sulfur content

Vehicle with DI gasoline engine



Every Sulfur Molecule is Poisonous

- Both for conventional and lean burn concepts
- Regeneration strategies result in lower fuel economy and increased emission
- Both regulated and unregulated pollutants increased

Global Interest in Lean Burn Gasoline/Low Sulfur

- Systems approach
- Proposed ARB RFG3 fuel precludes lean burn gasoline concepts
- Less than 10 ppm occurring elsewhere

Emission Reductions of the Alliance/AIAM RFG3 Proposal

ARB RFG3 Workshop

November 15, 1999

Overview

- Part I - Review of Staff’s inventory analysis
- Part II - Effects of Consumer Commingling (AIR)
- Part III - Inventory analysis of Alliance/AIAM proposal (GM)

Staff's Inventory Analysis

- AIR repeated all of the calculations in Tables V-1 through V-5 of the Staff Report for two purposes:
  - check the numbers
  - familiarize ourselves with the methods so that we could do the Alliance analysis the same way

Properties Used in Inventory Analysis

Property	1998 In-Use Fuel	Representative Future Fuel
Aromatic	22.4	22
Benzene	0.6	0.4
Olefin	5.8	4.0
Sulfur	25	15
T50	197	203
T90	310	298
O2 max	2.1	2.2
O2 min	1.9	1.8
RVP	**6.7**	**6.7**

Predictive Model Configuration for Inventory Analysis

- Beta Model % Reductions * MVEI7G gasoline inventories in 2005 = 2005 Inventory reductions

Review of Staff's Inventory Analysis

- Findings
  - The 2010 inventory reductions in Table V-5 use 2010 inventories for MVEI7G, but keep the 2005 Tech fractions in the Beta Predictive Model. Because Tech 5 vehicles are more sensitive to sulfur than early vehicles, this has an impact on the 2010 benefits. Tech fractions in Beta model should be consistent with calendar year of inventory analysis;

Review of Staff's Inventory Analysis

- Findings
  - No analysis of the impacts of "consumer commingling" in the summer ozone season
  - Report mentions ongoing UC Davis study
  - "If it is determined that a significant increase in emissions is occurring…staff will develop appropriate recommendations to preserve the emission benefits of Ca RFG3"
  - Our view is that unless all gasoline marketed in California contains ethanol, or none of it (both of which are very unlikely), commingling is a significant issue now, and staff must develop recommendations now in order to meet Governor's requirement to retain CBG emission reductions

Effect of Commingling

- Commingling: if 6.8 RVP fuel with ethanol is mixed in vehicle fuel tank with 6.8 RVP fuel from pump, tank RVP increases by 0.2-0.4 psi

- This increases evap emissions, negating benefits

Commingling

- EPA Commingling Model/Study - 1995
  - (SAE 940765)

- Study shows major inputs are:
  - brand loyalty
  - based RVP of fuels
  - market share of ethanol

Commingling

- EPA model shows that for 30% ethanol market share, 8 RVP fuel, medium to no brand loyalty, effect is 0.2-0.4 RVP
- Assuming 0.3 RVP impact, inventory increase in 2005 is 23.1 tpd (about 7.7 tpd per 0.1 psi)
- This more than negates the 18.7 tpd benefit
- Staff must quantitatively address commingling impacts in its proposal prior to adoption at Board Hearing

AAM/AIAM Proposal

- For inventory purposes, we created an “expected future fuel” based on AAM proposed flat limits (same process as ARB)
- This was compared to 1998 in-use fuel
- Uses same “margins” with respect to flat limits as ARB fuel

Comparison of Proposed Flat Limits

Parameter	Alliance/AIAM	ARB
RVP	7.0	6.9
Benzene	0.8	0.8
Sulfur	5 max	20
Aromatics	25	25
Olefins	5	6
O2	1.8 to 2.2	1.8 to 2.2
T50	200, min 170	211
T90	300	305
DI	1200 max	1225 max

Predictive Model Inputs for Alliance/AIAM Fuel

Property	Alliance/AIAM Proposed Flat Limits	Alliance/AIAM Expected Future Fuel
RVP	7.0	6.8
Benzene	0.8	0.4
Sulfur	5	2
Aromatics	25	22
Olefins	5	3
O2	1.8 to 2.2	1.8 to 2.2
T50	200	192
T90	300	293

Comparison of Expected Future Fuels

Parameter	Alliance/AIAM	ARB
RVP	6.8	6.7
Benzene	0.4	0.4
Sulfur	2	15
Aromatics	22	22
Olefins	3	4
O2	1.8 to 2.2	1.8 to 2.2
T50	192	203
T90	293	298

Model Assumptions

- Beta release of Predictive Model
- With and without commingling
- Other assumptions consistent with ARB’s analysis

2005 Statewide Emission Reductions

Program	NOx	HC	NOx + HC
Without commingling			
Alliance/AIAM	38.6	9.9	48.5
ARB	18.7	0.5	19.2
With commingling			
Alliance/AIAM	38.6	-13.2	25.4
ARB	18.7	-22.6	-3.9

Summary

- December Board Hearing next opportunity to address emission reductions
- SIP black box remains
- EMFAC2000 inventories higher
- Greater challenges
- Alliance/AIAM proposal could reduce inventories by 25 tpd (with commingling)
- ARB proposal may offer no net benefit
- Commingling must be considered

Cost of 5 ppm Sulfur Gasoline is Reasonable for Air Quality Benefits

- A MathPro study of the refining system in PADDs 1-3 estimated a cost of 2.2-3.2 cpg to reduce sulfur from 30 ppm to 5 ppm.
  - California costs are likely to be lower, because the average fuel is already about 23 ppm sulfur
- Achieving the SC5 case (5 ppm sulfur) appears to be technically feasible -- MathPro
- The European experience shows that even very small tax subsidies were sufficient to lead to the early introduction of low-sulfur fuels

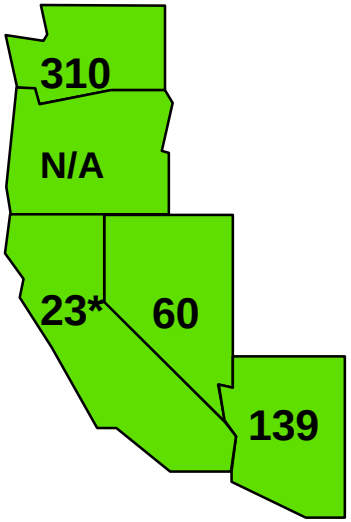
Items Identified as Necessary for 5ppm Sulfur in MathPro Study

- Deeper desulfurization of FCC naphtha using advanced desulfurization technology
- Desulfurization of other streams in the gasoline pool (including straight run naptha and MtBE), by means of established desulfurization technology; and
- Application of best practices in refining operations to control the sulfur content of other gasoline blendstocks, including alkylate, reformate, and hydrocrackate.

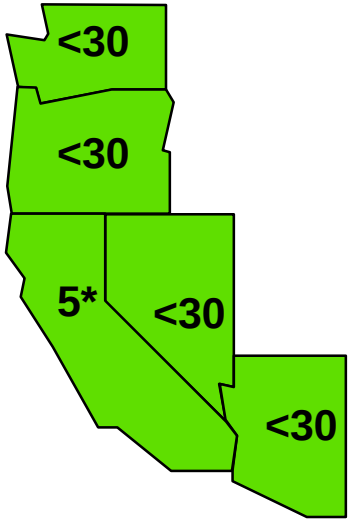
Supply Disruption Concerns should NOT Drive Specification

- California found with a 30 avg / 80 cap sulfur specification, 30% of fuel was < 10 ppm sulfur.
- Adoption of a nation-wide 30 ppm sulfur average is likely to lead to widespread availability of 5ppm sulfur fuel in adjacent states and Canada. The total shortage of gasoline in California during the recent disruptions was on the order of 5%.

1999 Sulfur Average



2004 Sulfur Average



* with 5 ppm compliance margin subtracted

* cap

Supply Concerns Can Be Minimized

- Inventory, supply and price were a concern with Phase 2 CBG, and the risk was deemed acceptable for air quality benefit:
  - Question - "Will there be adequate supplies of cleaner-burning gasoline?" Answer - "Yes. Cleaner-burning gasoline will be available in California to meet the demand. However, **as we have experienced in the past**, (emphasis added) it is possible that unusual conditions could lead to a temporary disruption in the fuel supply." - ARB, Nov. 8, 1995
  - "CGB was only one of a number of factors that sharply pushed up gas prices this past spring. These other factors included increases in crude-oil prices and refinery breakdowns … California gasoline prices on average are comparable to those in other western states." - ARB, Oct. 1996
- Adoption of best practices by refining industry can minimize refinery outages
  - API Technology Vision plan recognizes need for improvements in process control, equipment integrity, alloy selection and analytical technologies

Summary

- Clean fuel works; tighter RFG3 specs will help California meet emissions shortfall
  - especially 5 ppm S, 1200 DI
- Must sunset any short term flexibility
- Big benefits for pennies
  - Alliance: 48.5 tpd (25.4 tpd*)
  - CARB: 19.2 tpd (-3.9 tpd*)
- Next opportunity to fix is Dec. 9

*considering commingling effect