Step Forward In Diesel Engine Emissions Reduction:

System Incorporating A Novel Low Emission Diesel Fuel & Conventional Lubricant

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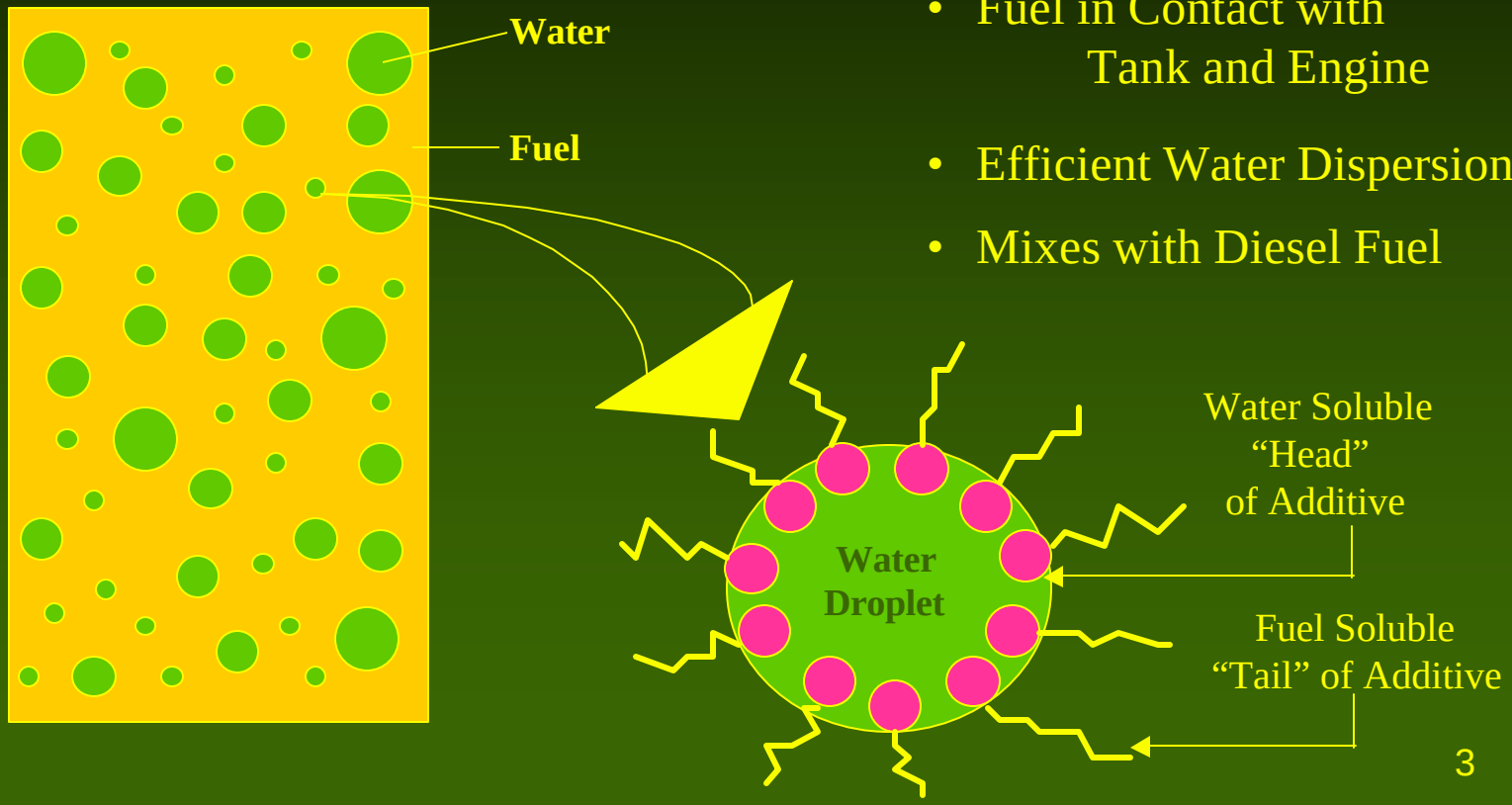
Outline

- Test Program
  - Vehicle
  - Test Cycle
  - Test method
  - Fuel Matrix
  - Aftertreatment Matrix
  - Instantaneous effects
- Results
  - Legislated Emissions and Fuel Economy
  - Speciation / Non Legislated
  - Particulates detail (size v number)
- Summary

Water-in-Diesel Fuel

(PuriNOx™ Fuel)

State-of-the-Art Technology



- Low Viscosity
- Fuel in Contact with Tank and Engine
- Efficient Water Dispersion
- Mixes with Diesel Fuel

PuriNOxä Performance Systems

PuriNOx™ Additive Package

Water

Diesel Fuel

Seasonal or Other Components

PuriNOx™ Blending Unit

PuriNOx™ Fuel

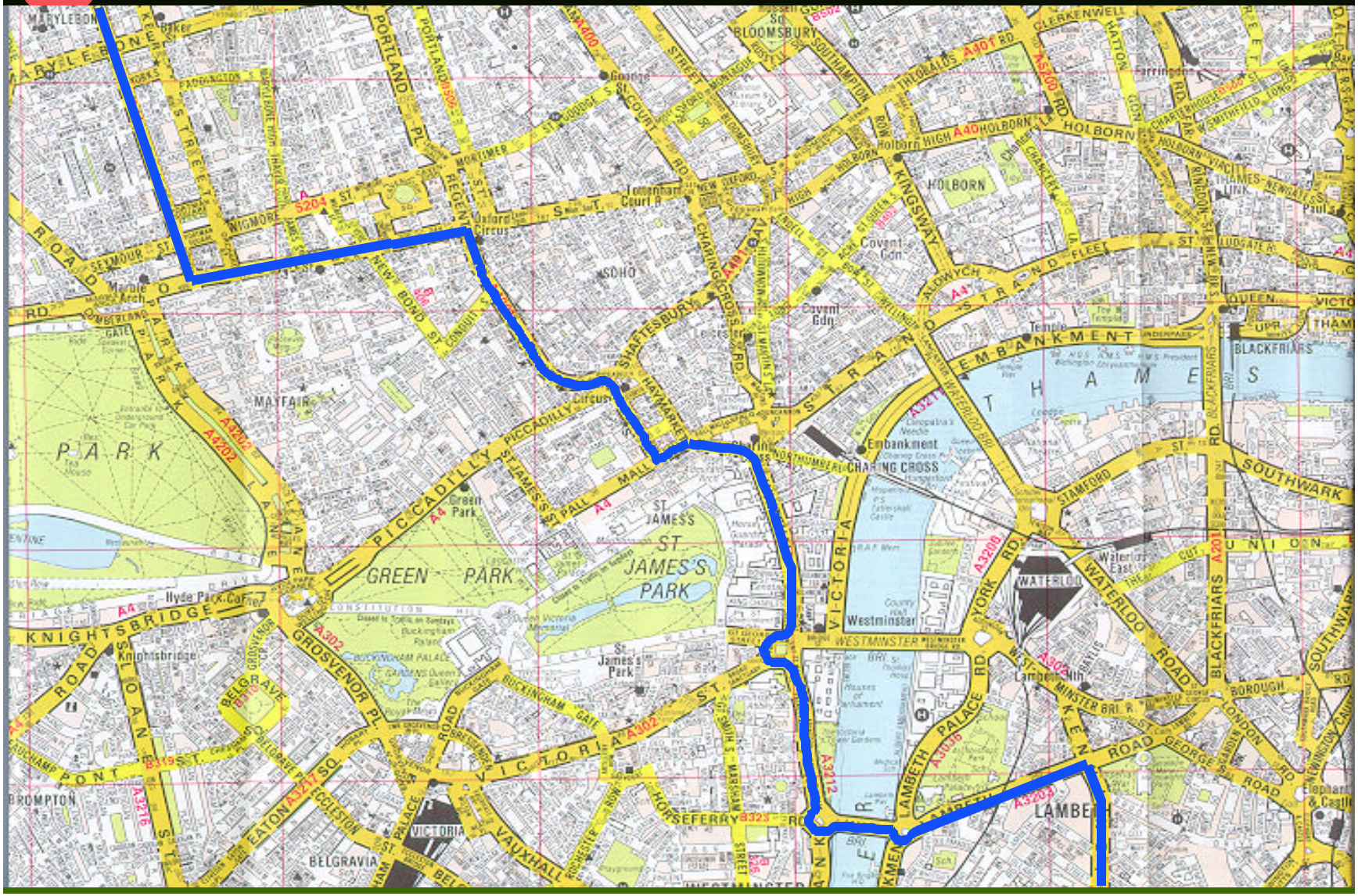
PuriNOx™ Performance Systems Fuel

- Reduces NOx by 9 - 25% and Particulates by 25 - 50%
- Can be Used Immediately By Dispensing Fuel Directly into Vehicle Tanks
- Uses Existing Storage, Distribution, and Vehicle Fueling Facilities
- Handles Like Diesel Fuel and Remains Stable in Storage and Vehicle Tanks
- Has Enhanced Safety Potential Compared to Gaseous Fuels
- Lubricity and Anti-Corrosion Equivalent to Diesel Fuel

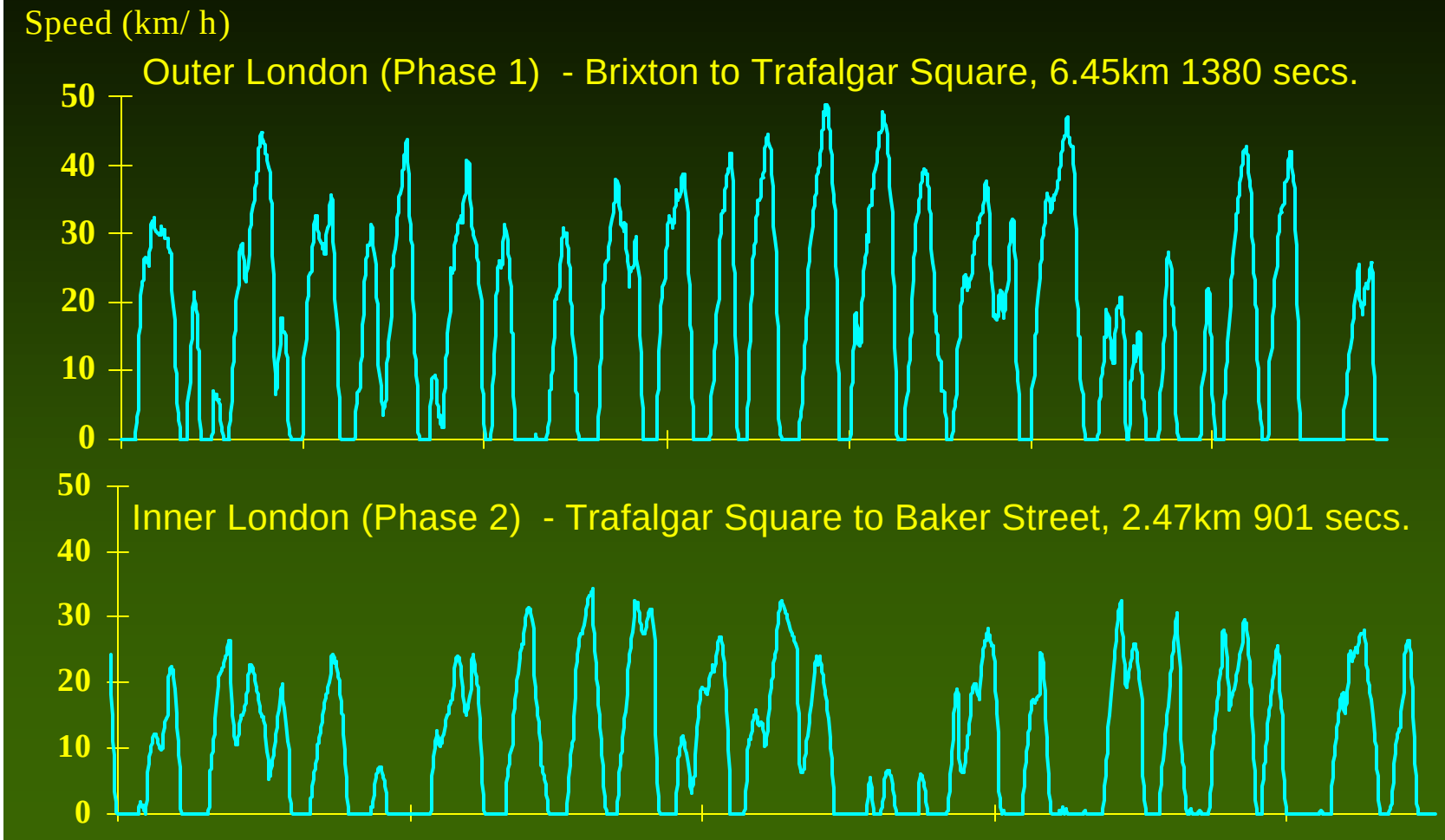
Test Vehicle

- Euro 2 Volvo Olympian B10A bus, mechanically fuel injected with automatic gearbox
- Rated power Max. 183 kW @ 2000rpm, 1050 Nm torque @ 1450rpm
- Dynamometer road load simulated - 13,723 kg to represent vehicle weight + nominal 75 % passenger loading
- No changes were made to the engine set-up
- No exhaust after-treatment on vehicle

London Transport - Route 159

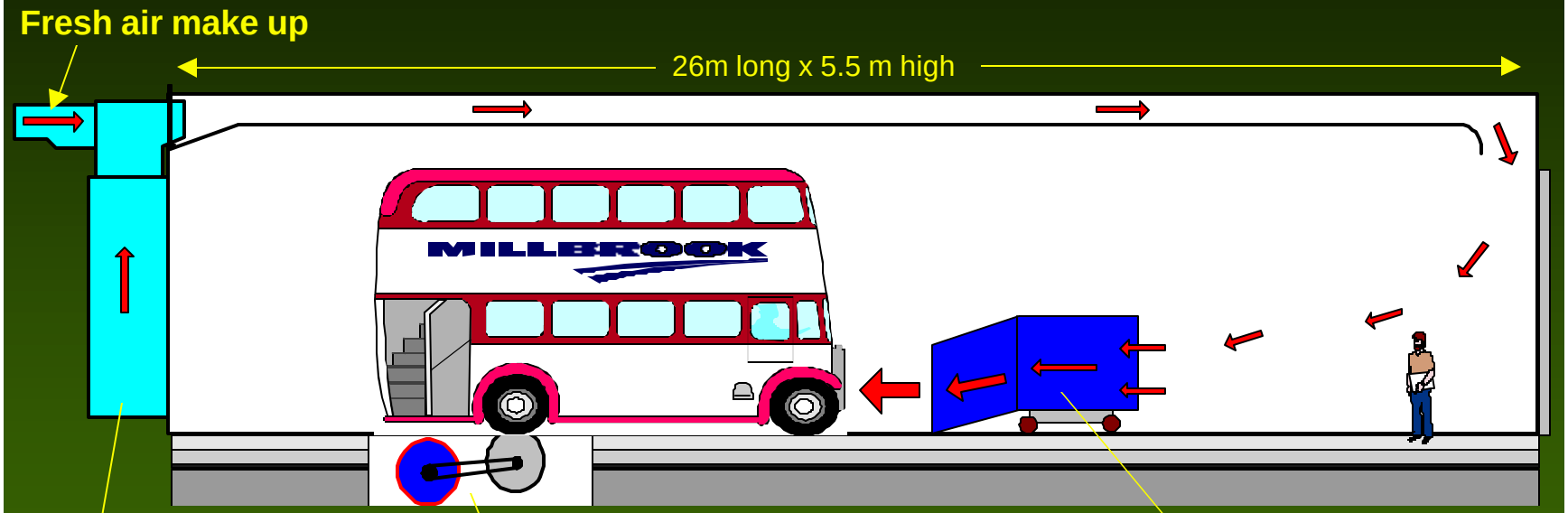


London Transport Bus Cycle (LTB)



The V.T.E.C

Variable **T**emperature **E**missions **C**hamber
Unidirectional Air Flow system (-30 to +50ºC)



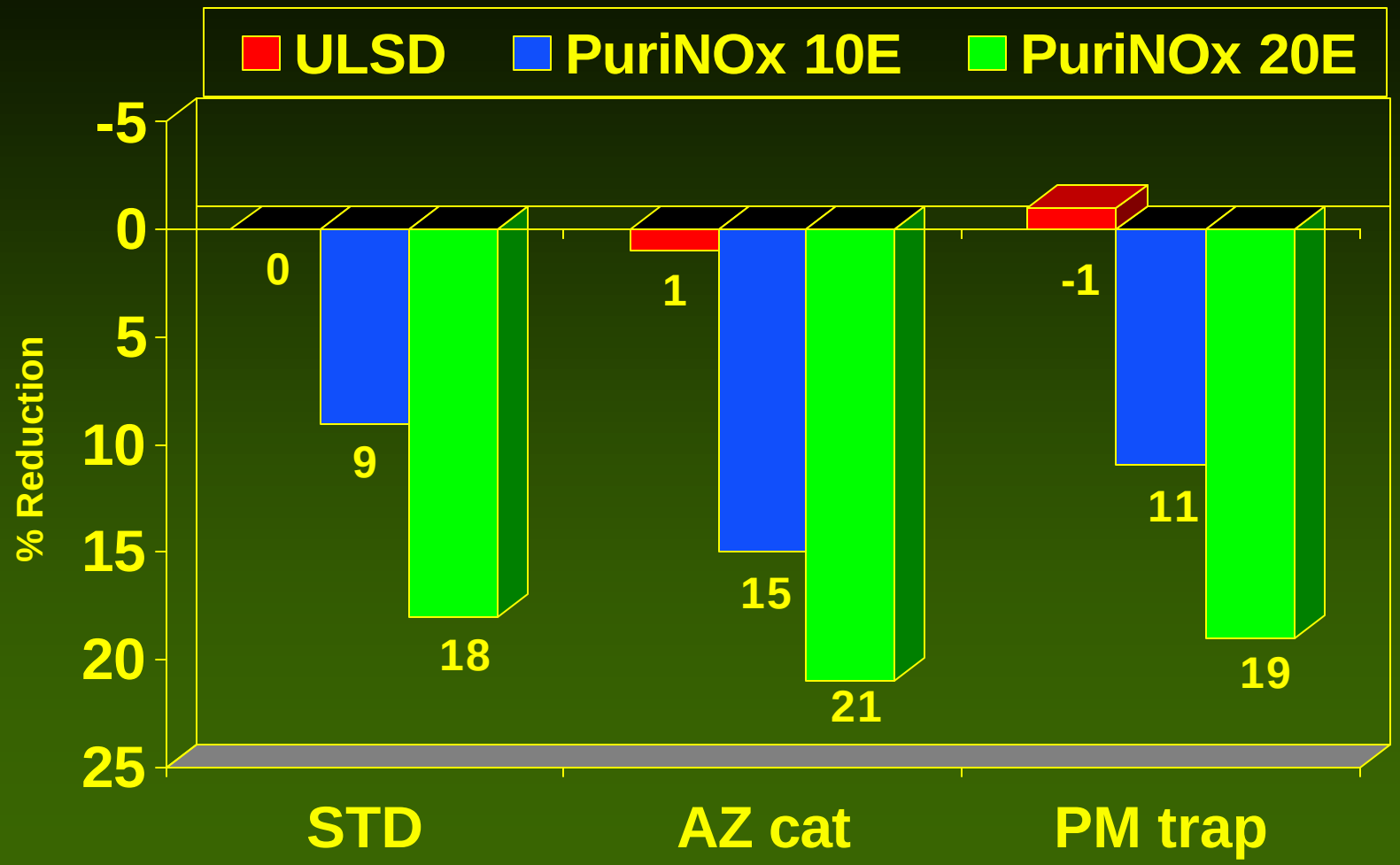
PuriNOx Bus Program

- Fuels:
  - 1.Ultra Low Sulphur Diesel (ULSD <50 ppm S),
  - 2. PuriNOx 10E (10% mass water),
  - 3. PuriNOx 20E (20% mass water).
- Exhaust after-treatment:
  - 1. None - Original Equipment (OE),
  - 2. Oxidation (AZ) Catalyst,
  - 3. Particulate trap.
- A two-stage programme looking at:
  - (i) MLTB Transient Cycle, (3 repeat tests in each condition)
  - (ii) Instantaneous changes from ULSD to PuriNOx fuels.

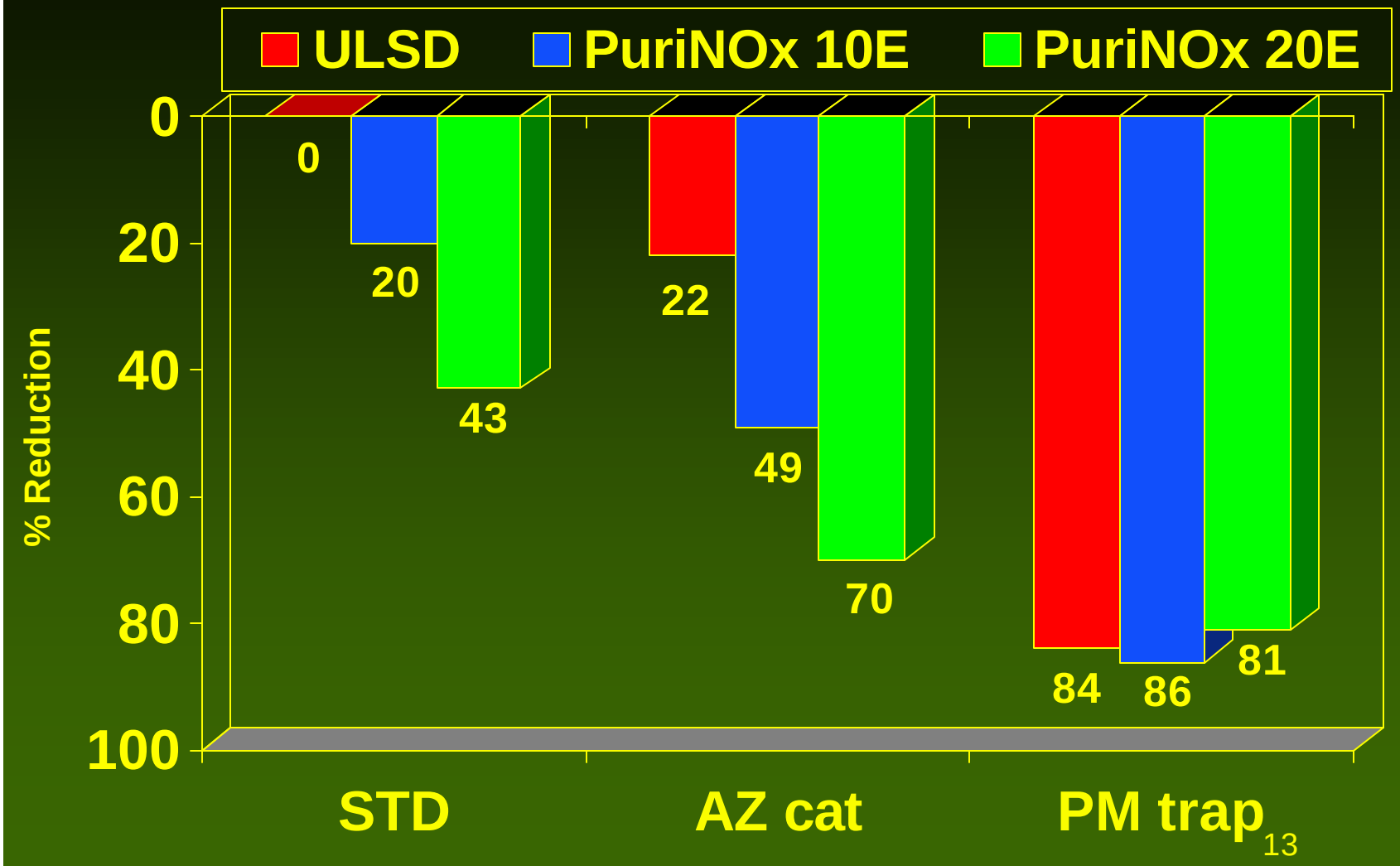
Emissions Analysis

- Legislated emissions (THC, CO, NOx, CO2 PM) by bag
- Legislated emissions modal data
- Volumetric fuel consumption
- Exhaust gas temperature
- HC Speciation and carbonyl analysis
- Particulate Size via ELPI

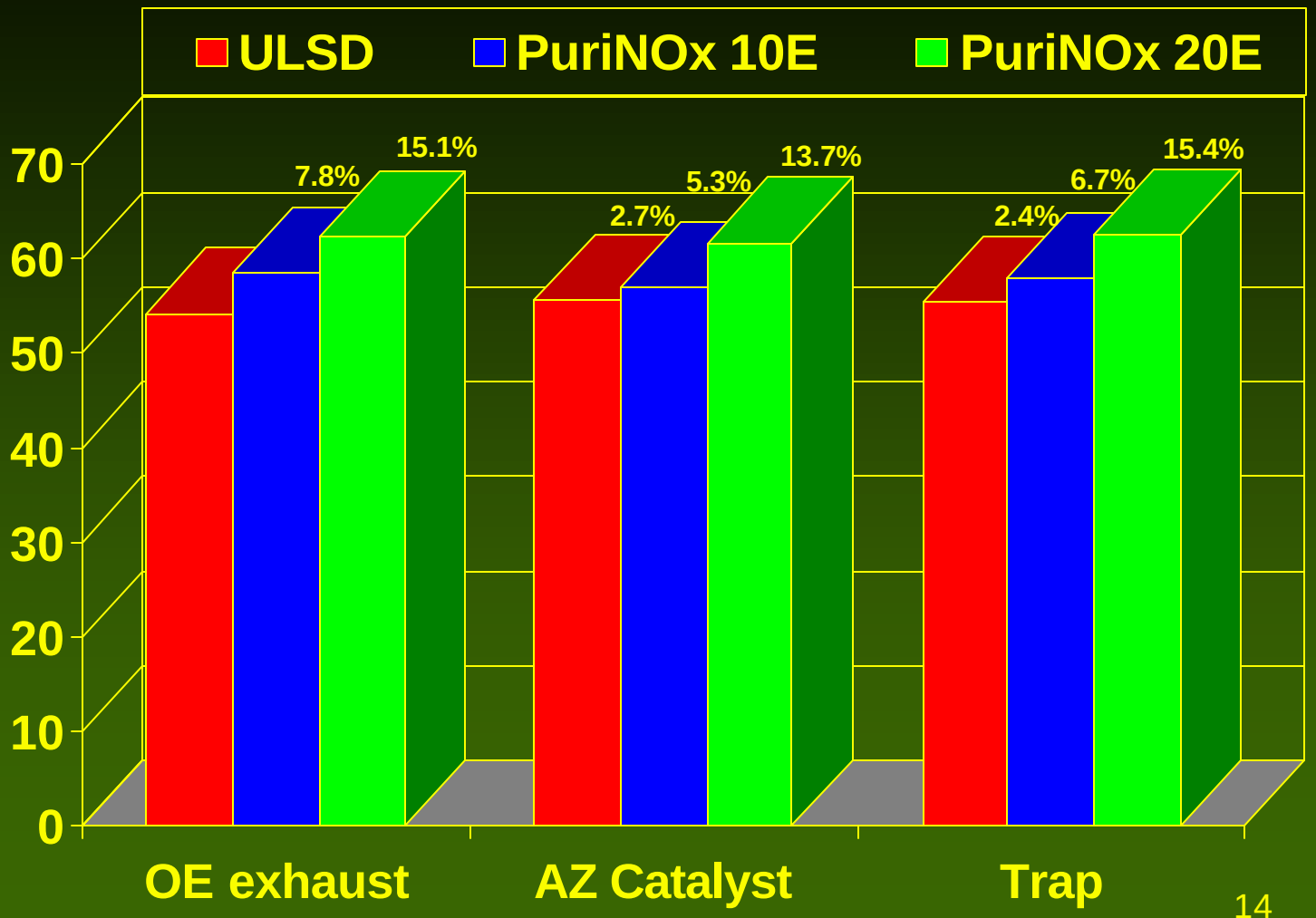
NOx Reduction (%) MLTB



PM Reduction (%)



Fuel consumption (l/100km)



Non Legislated Emissions

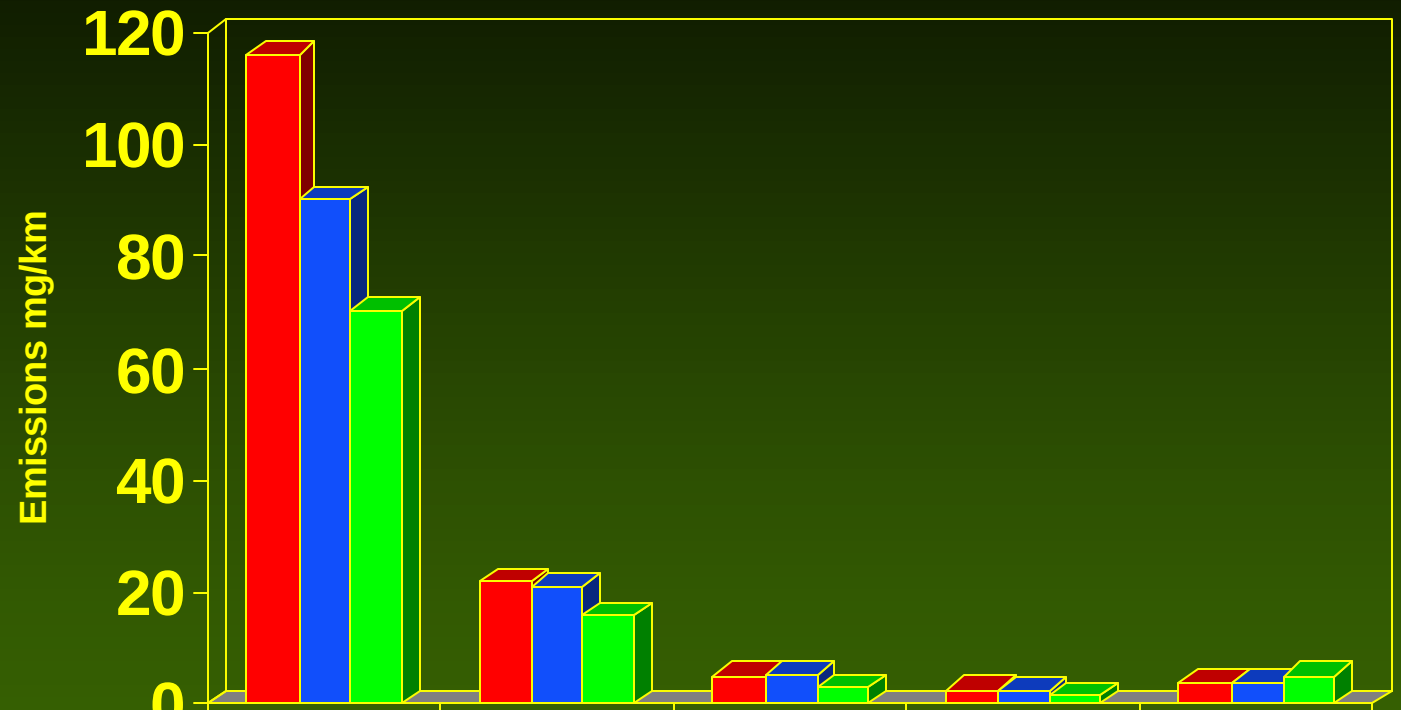
Identified as Air Quality Parameters

- **Benzene**
- **1,3-Butadiene**
- **Ozone**
- **CO_2 (Global Warming)**
- **Formaldehyde (USA)**
- **Specific interest in Particulate Size**
- **VOF analysis of PM**

Speciation of gaseous emissions

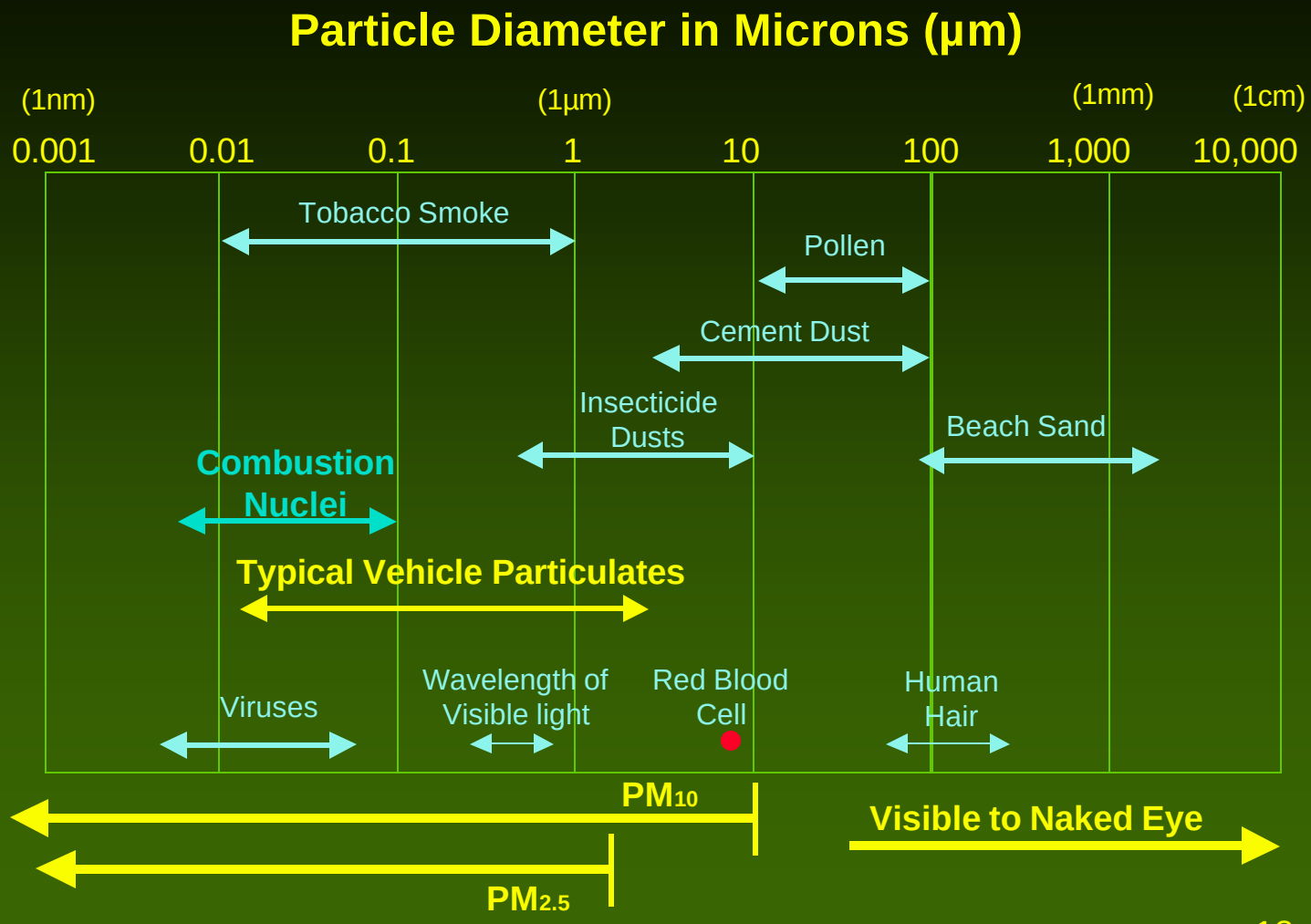
- Protocol is as per that established at GM Milford laboratories with CARB approval
- Carbonyls - cartridge sampling of dilute exhaust to make 2,4 di-nitro phenylhydrazone, then HPLC
- Hydrocarbons - bag sampling then GC analysis separately for C1-C4 and C4-C12
- CARB procedure looks for 169 non-methane organic gas (NMOG) species
- Ozone forming potential is based on mass of chemical in gaseous stream multiplied by its CARB reactivity factor

EPA Hazardous Air Pollutants (OE)

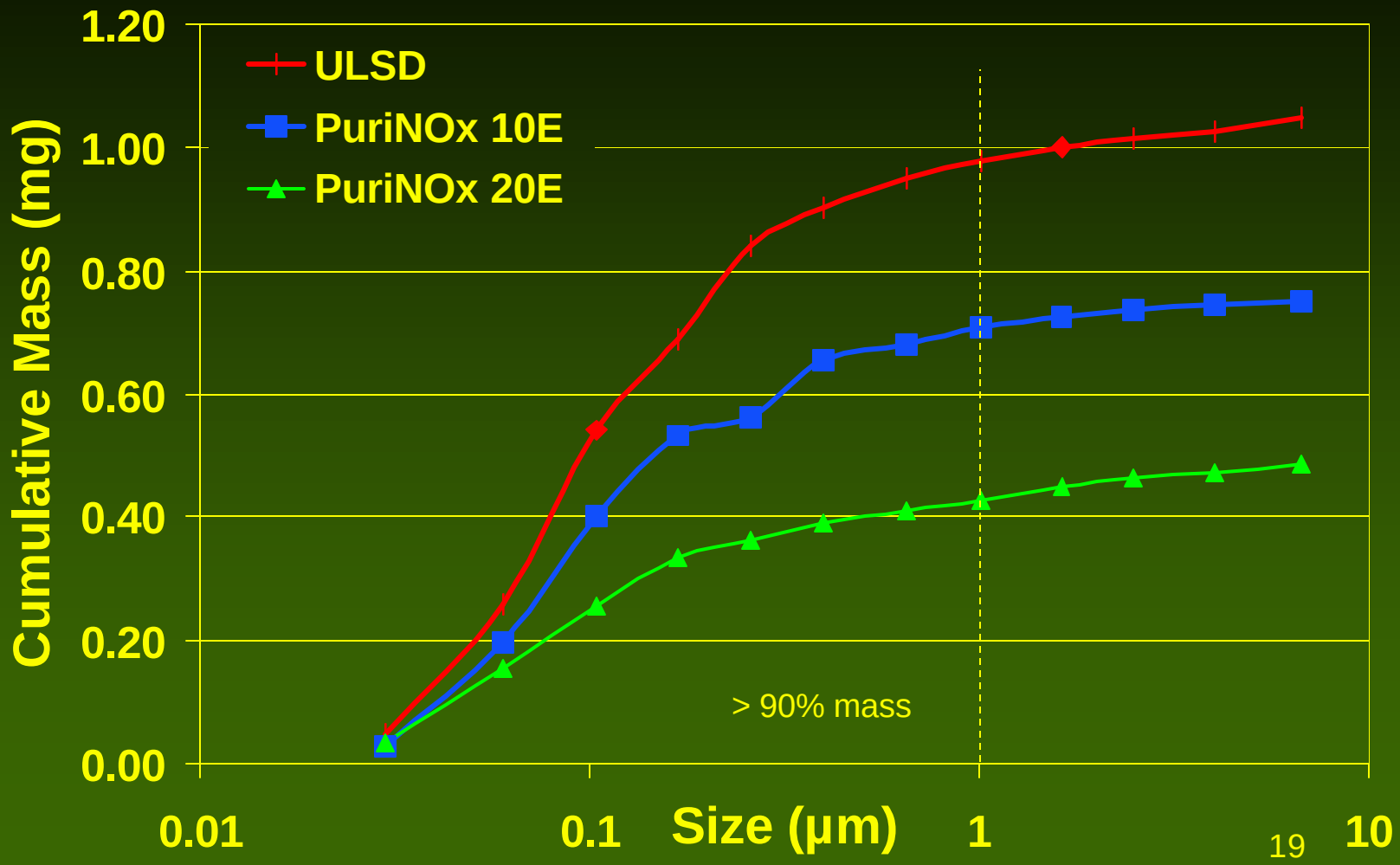


	Formaldehyde	Acetaldehyde	Acrolein	1,3 butadiene	Benzene
ULSD	116	22	5.2	2.8	4
PuriNOx 10E	90	21	5.3	2.6	4
PuriNOx 20E	70	16	3.1	1.6	5.2

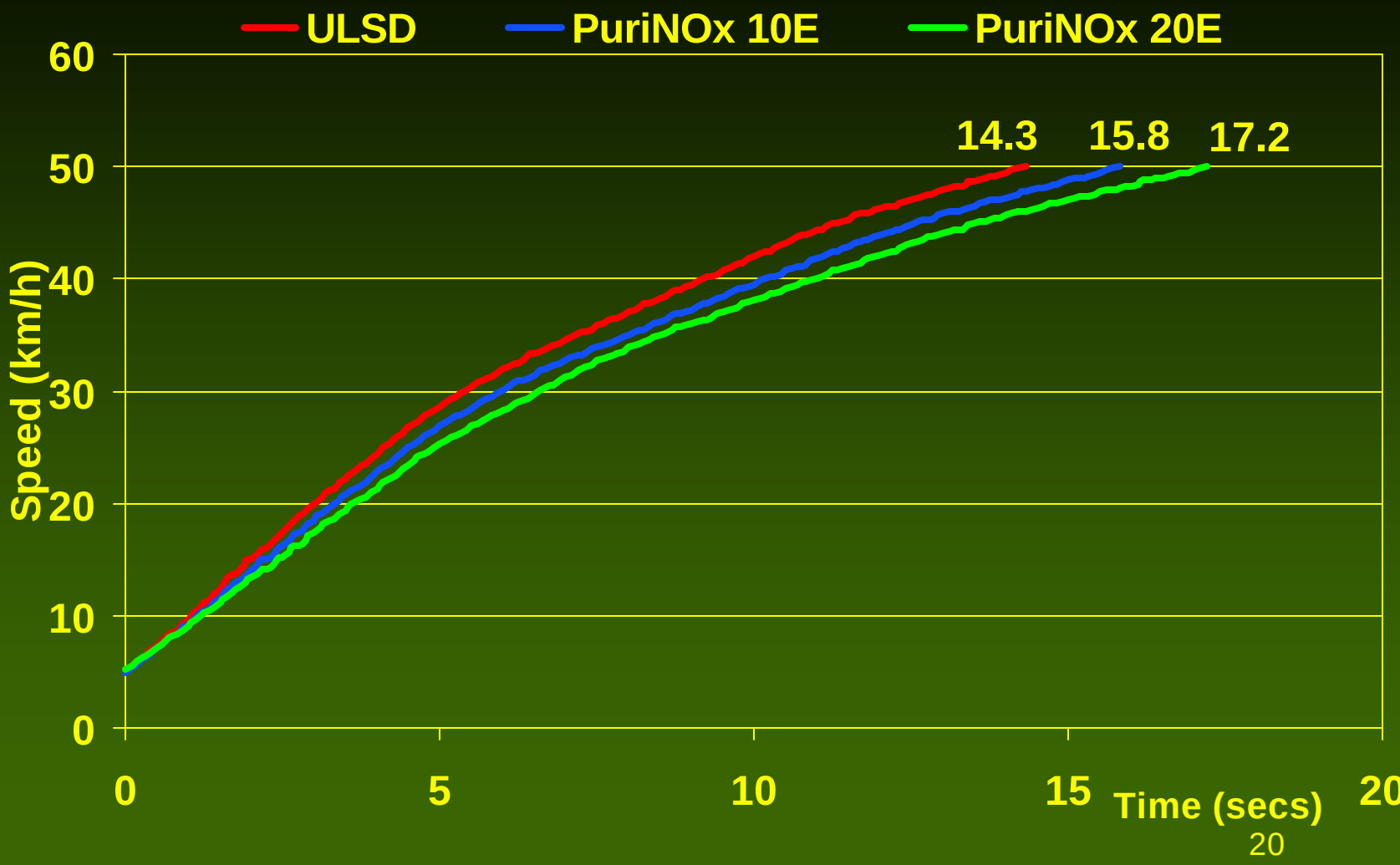
Typical size of Particulates



PM Mass v Size (AZ Catalyst)



5 - 50 km/h Acceleration

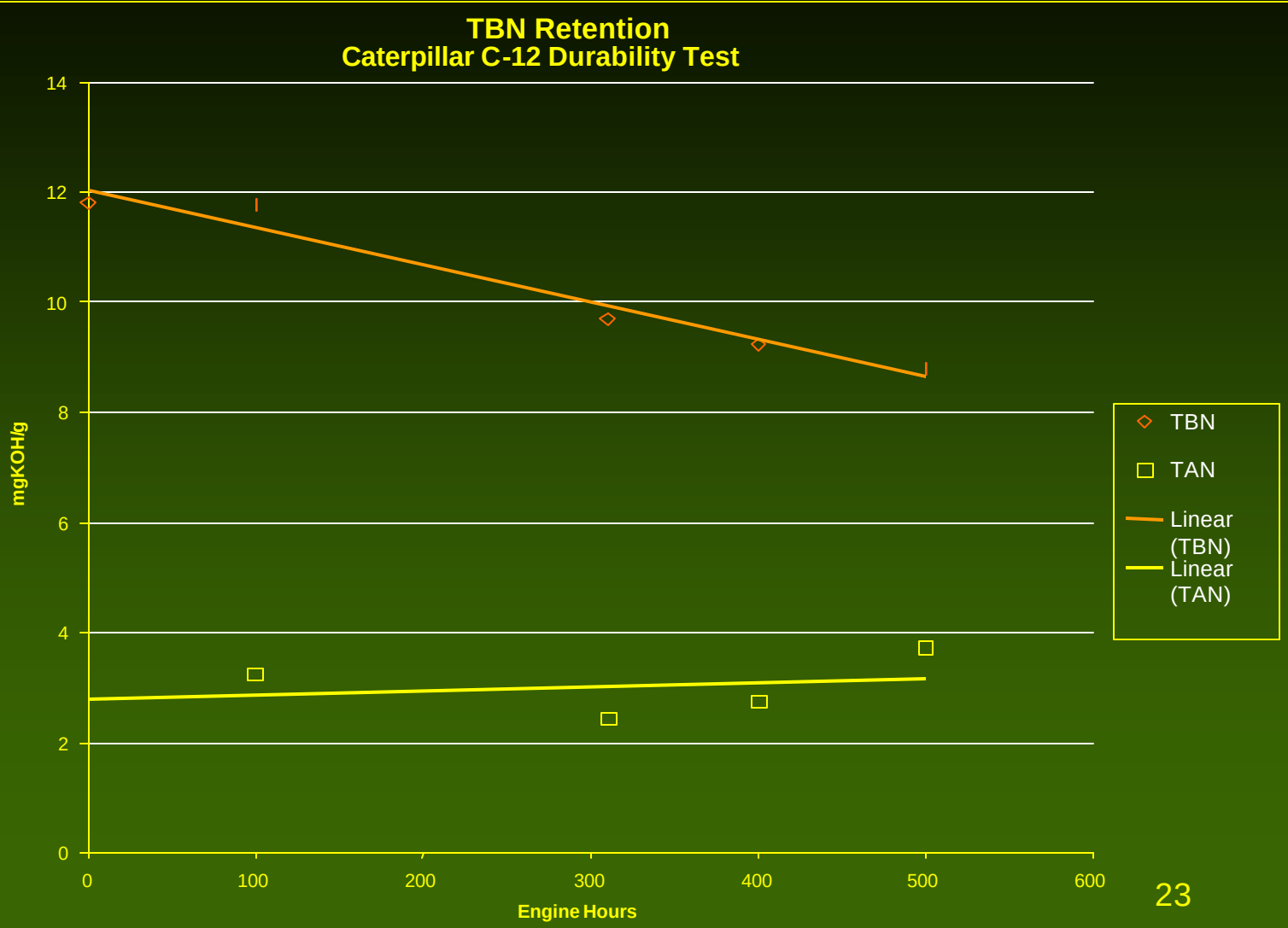


Lab Durability Test

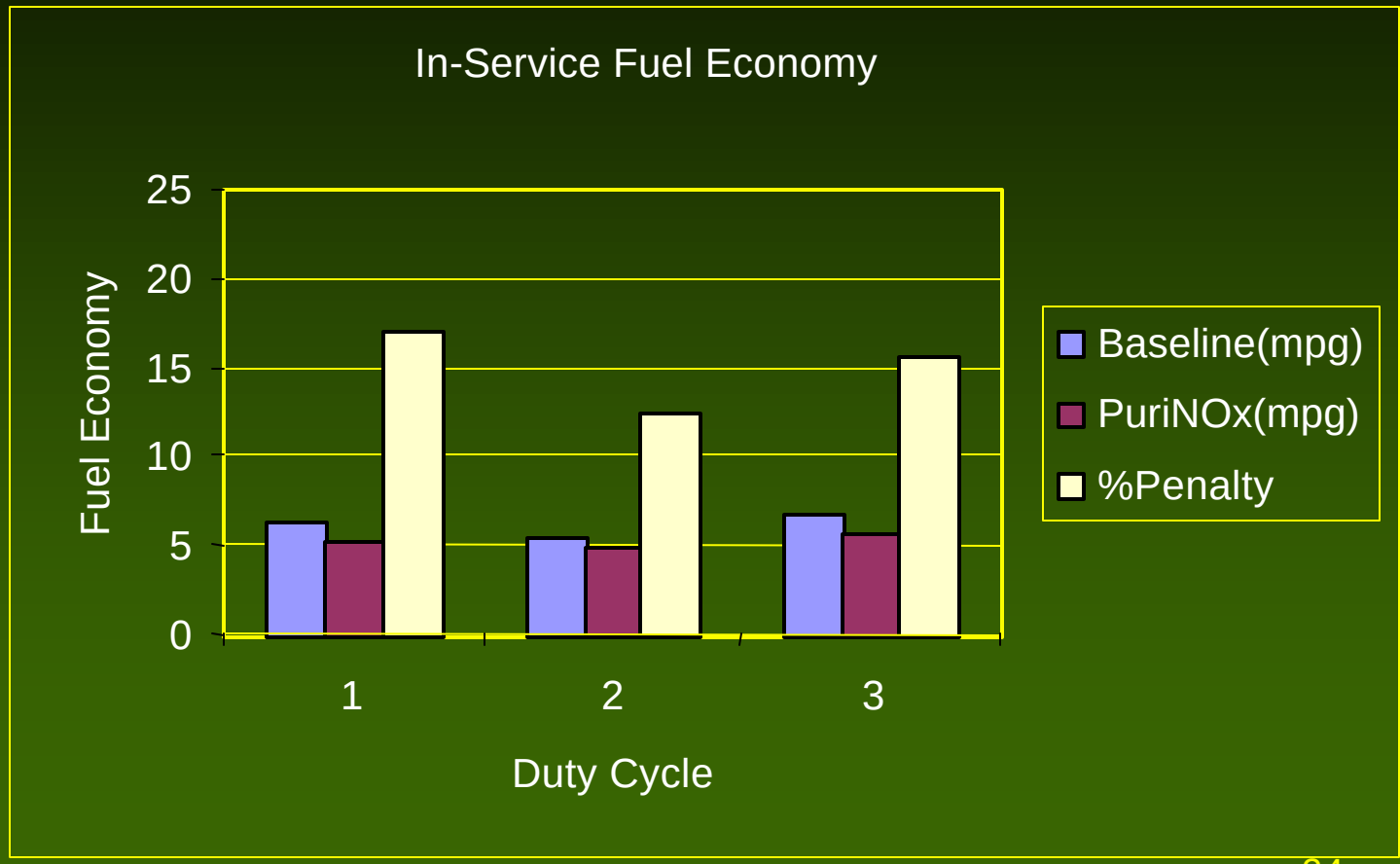
- CAT C-12 Engine
- CAT Highway Truck Cycle
- 1000 hrs on PuriNOx
  followed by 1000 hrs
  on Diesel
- Durability + Spot Emissions,
  Noise, Opacity

Lab Durability
Oil Drain Wear Metals

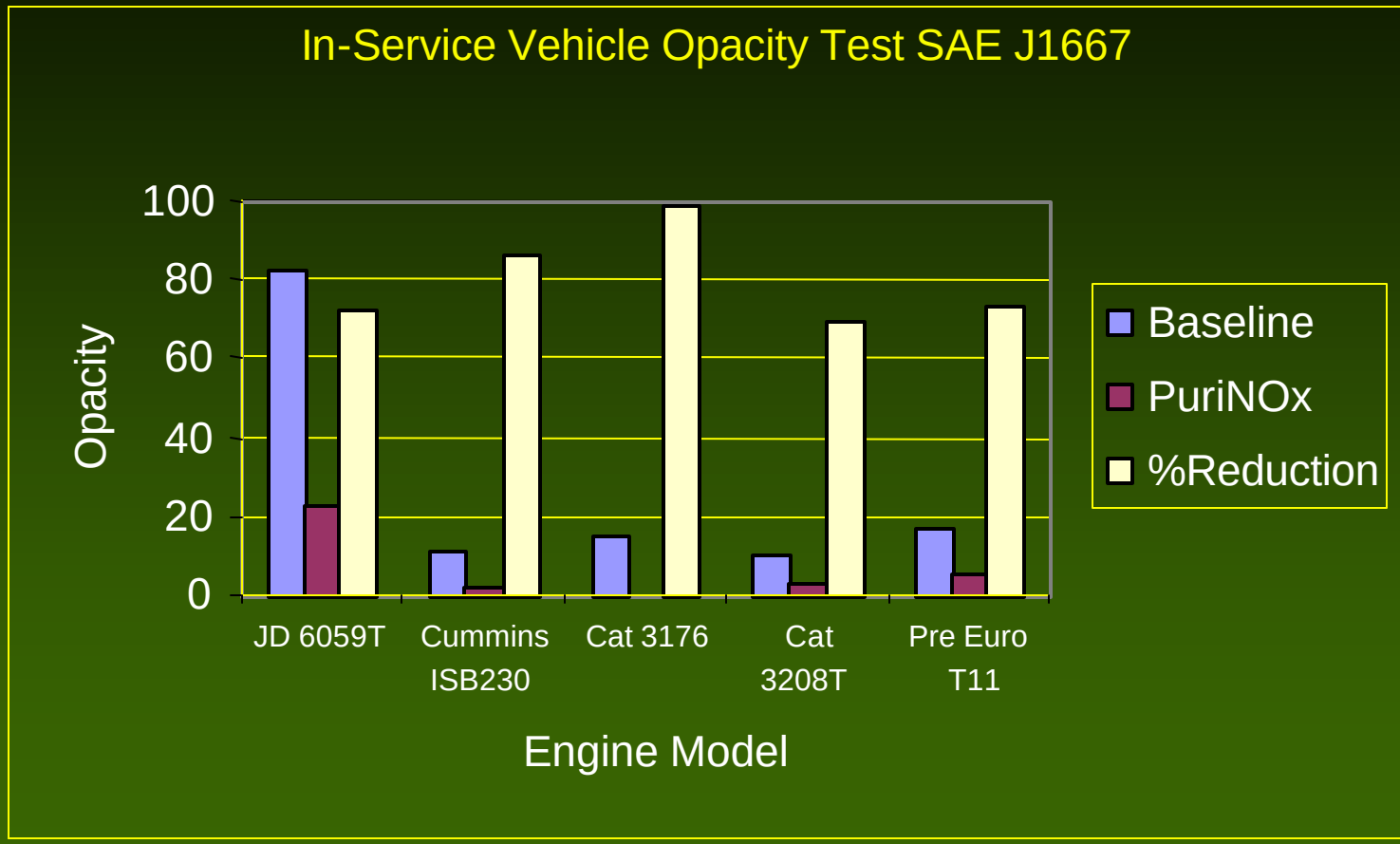
Durability Test - Drain Analyses



PuriNOx Fuel Economy

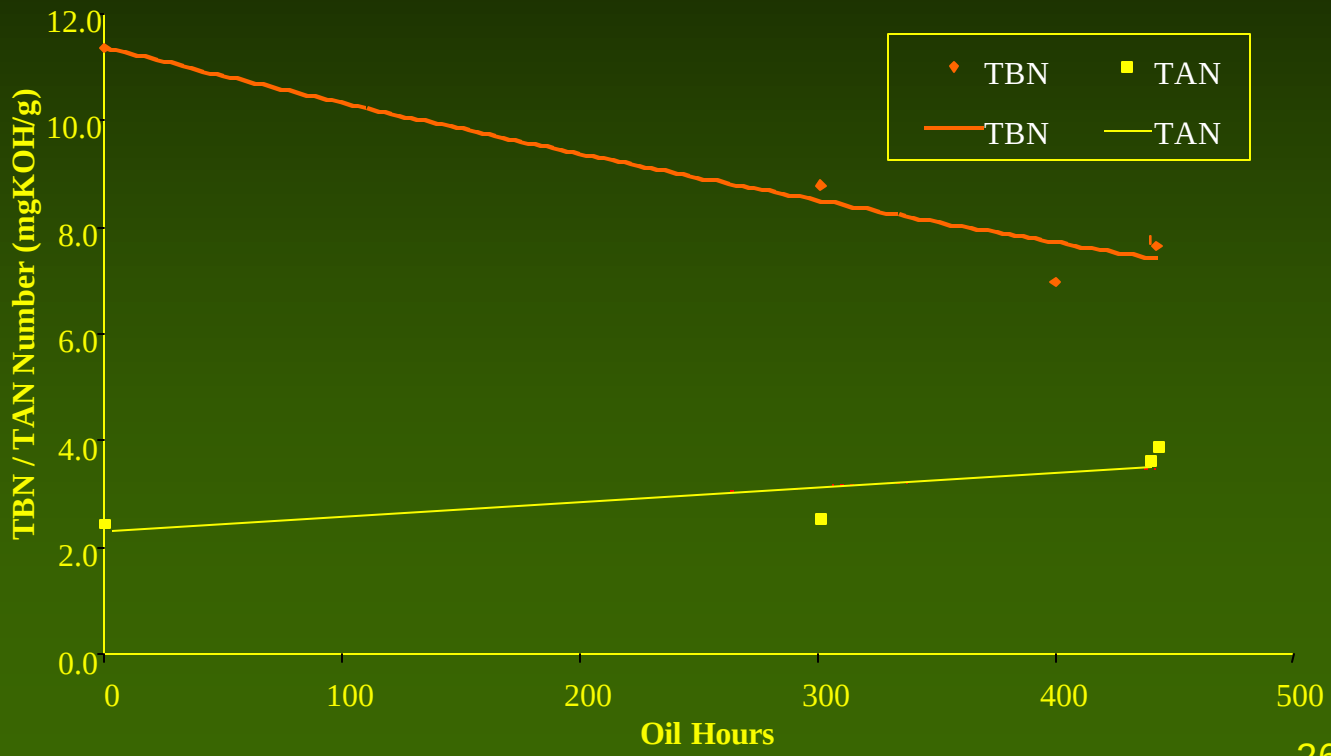


In-Service Opacity Results



Morton Salt Drain Analyses

TBN Retention
1995 Caterpillar 988F Wheel Loader
with Caterpillar 3408 DITA Engine
using PuriNOx fuel



Morton Salt Drain Analyses

Viscosity @ 100 degrees C
1995 Caterpillar 998F Wheel Loader
with Caterpillar 3408 DITA Engine

Summary

- Relative to ULSD, PuriNOx 10 achieves a 9 % reduction in NOx and 20% reduction in particulates. PuriNOx 20 achieves reductions of 18% for NOx and 43% for particulates
- No detriment to exhaust after-treatment devices has been noted
- Non legislated emissions analysis shows further benefits
- Good engine durability performance is observed with conventional lubricant