Johnson Matthey
Catalysts

Ultrafines from Emission Control Devices: Results from the Real World

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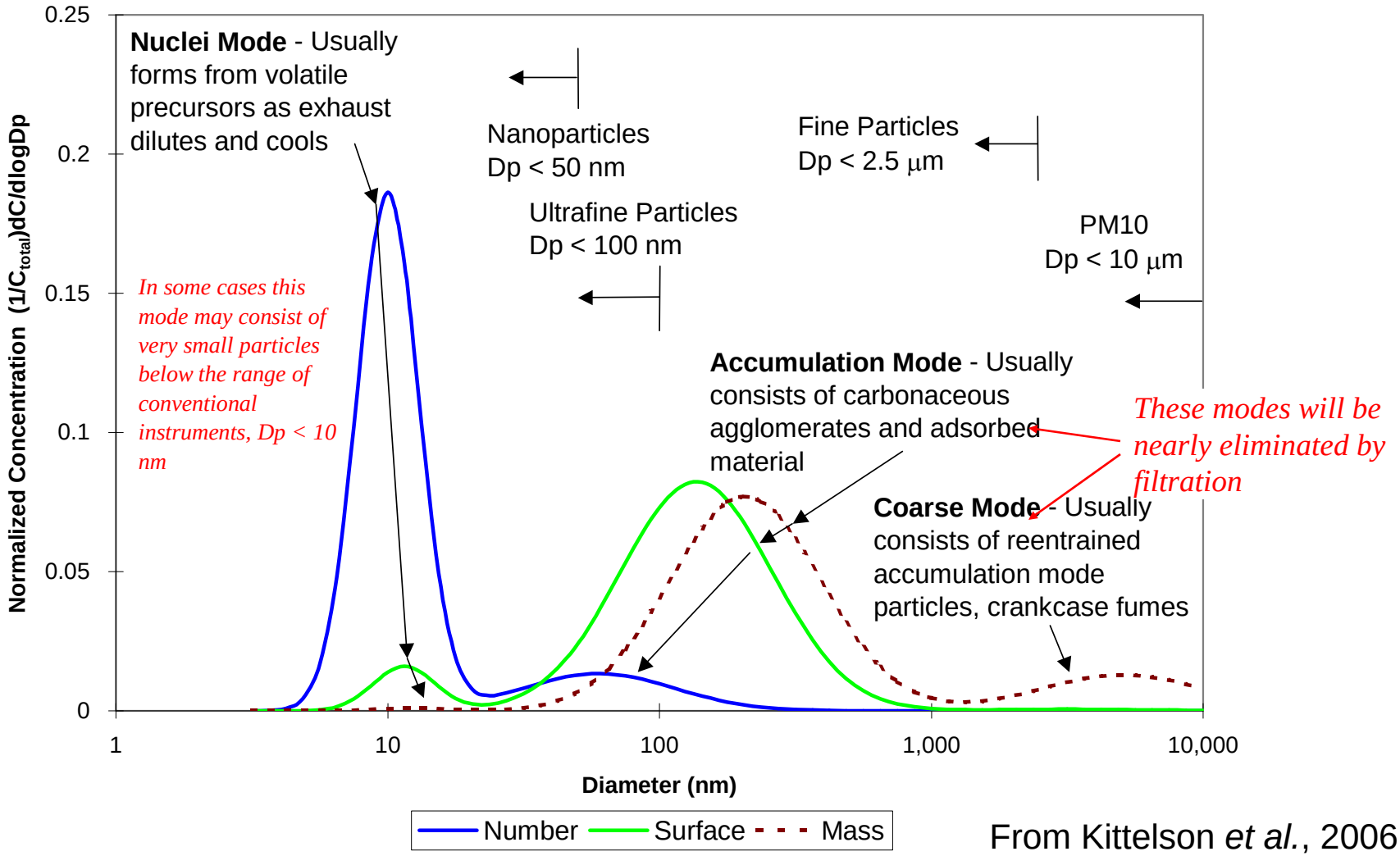
Some History

- Johnson Matthey CR-DPF System:
  - Extremely effective at removing 95%+ of engine-out particle ***mass*** emissions
  - Tests on particle ***number*** emissions have raised concerns about role of CR-DPF in formation of ultrafines
  - Previous work has suggested that these particles could be ***sulfate*** and/or ***volatiles*** (Kittelson *et al.*, CRC E-43 Final Report)

Experimental Approach

- What Could It Be?
  - Observed ultrafines are sulfur and/or volatiles-related
- How Can We Check?
  - Treat CR-DPF system as a “black box” and see what happens when we:
    1. Control sulfur content IN
    2. Control sulfur content OUT
    3. Control volatile content OUT

Particles Of Different Sizes Are Formed Differently

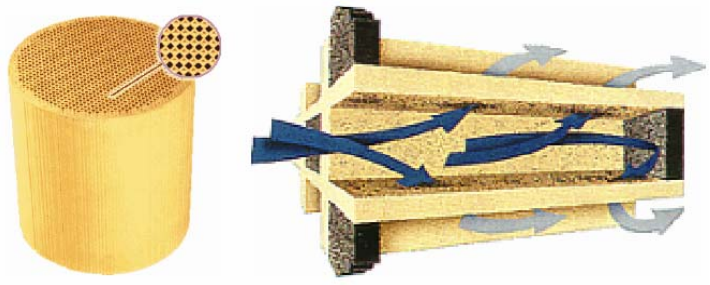


From Kittelson *et al.*, 2006

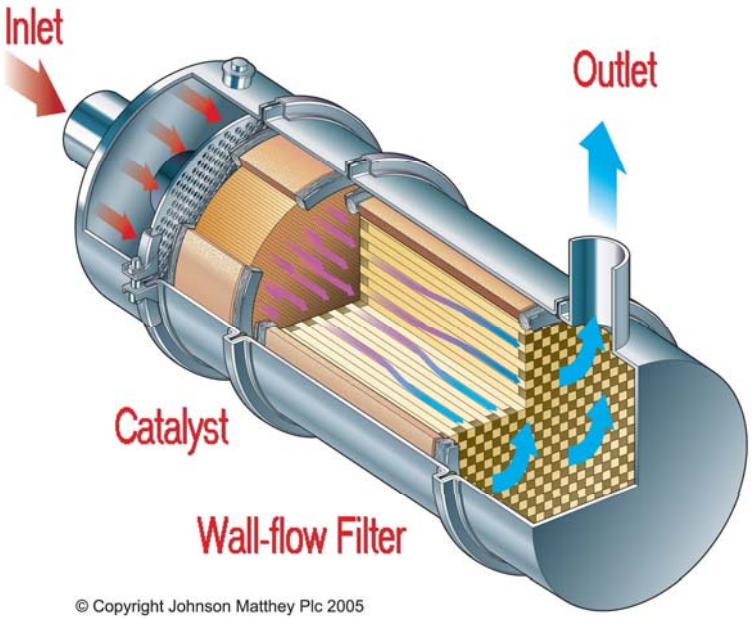
Emission Control Systems

Extremely effective at Diesel PM removal

(a)



(b)



a) Wall-Flow Filter (courtesy Corning, Inc.)

b) JM CR-DPF (DOC + Wall-Flow Filter)

How Did We Test? (1)

- All tests conducted on U of M MEL
- Year 2000, 12 L, 12 cyl 287 kW engine
- 65 mph cruise on Minnesota rural freeway

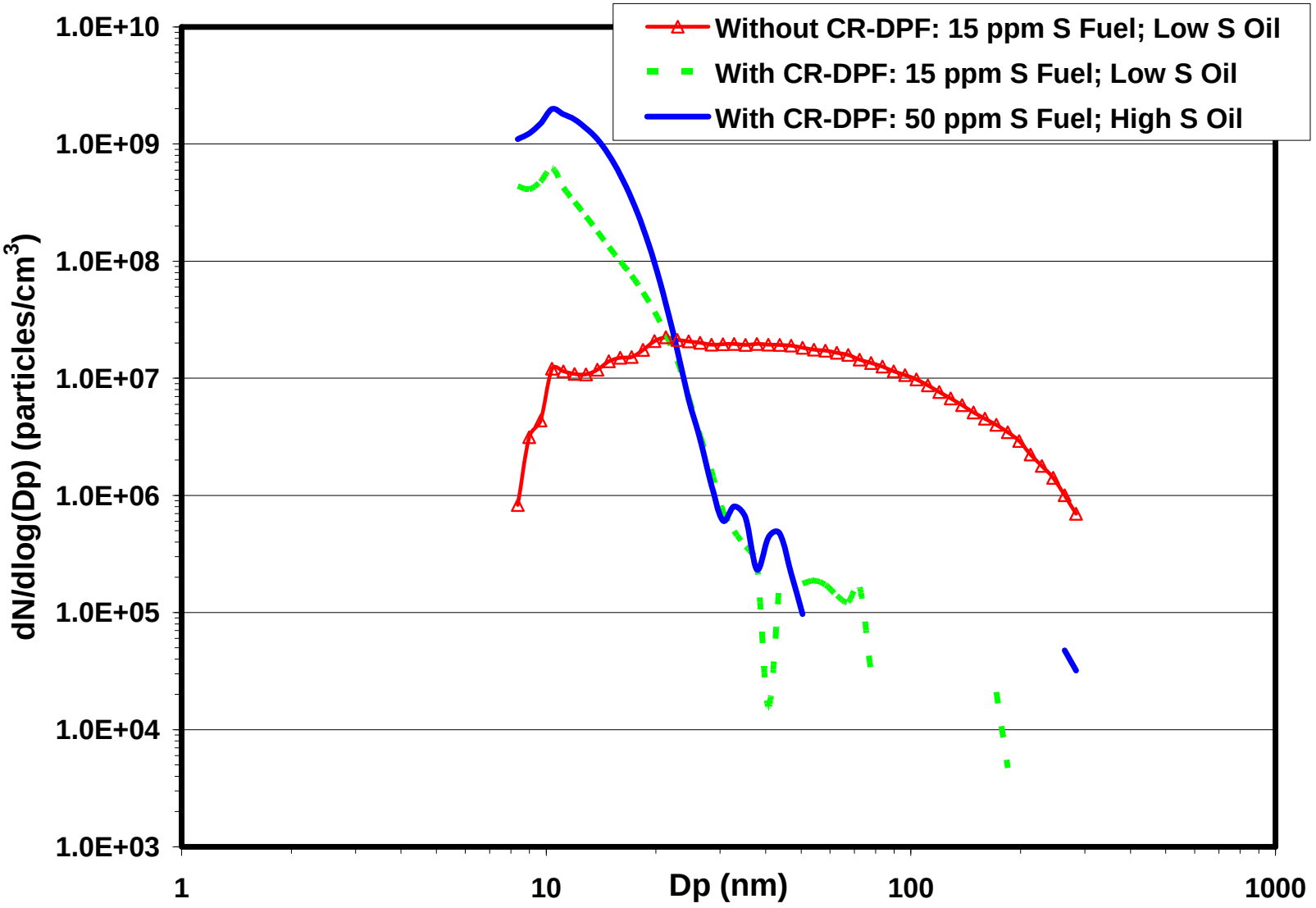
How Did We Test? (2)

- Control of S IN:
  - 50 ppm S fuel + ~5000 ppm S lube oil
  - 15 ppm S fuel + ~1500 ppm S lube oil
- Control of S OUT:
  - Use of low S fuel + low S lube oil
  - System tested with and without S trap
- Fuels from BP (15 ppm S: ULSD—2007 compliant), lube oils from Castrol

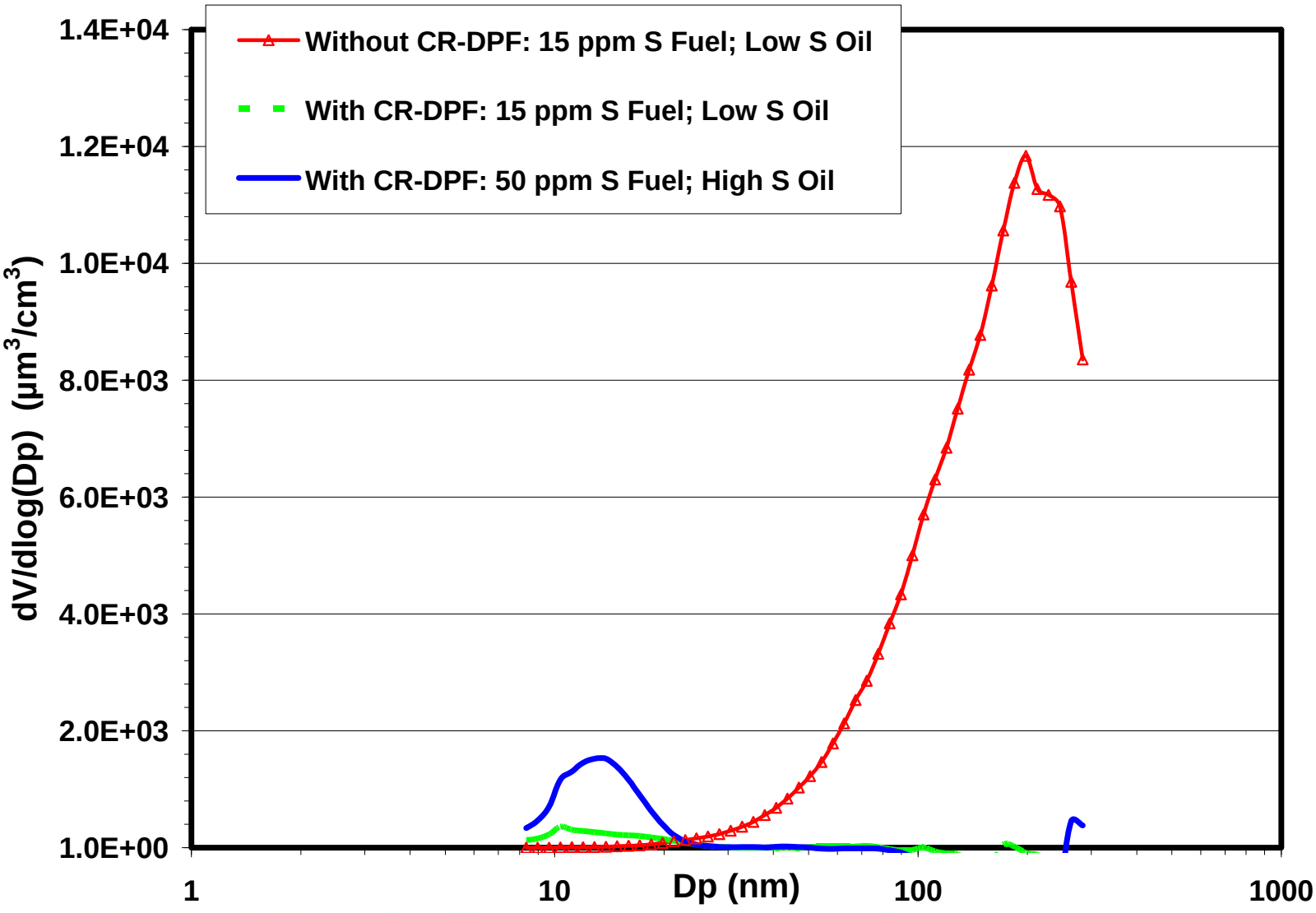
- Control of Volatiles OUT:
  - Use of a catalyzed CR-DPF

1. Control Sulfur Content IN

Lower Sulfur In → Lower ultrafine ***number*** out

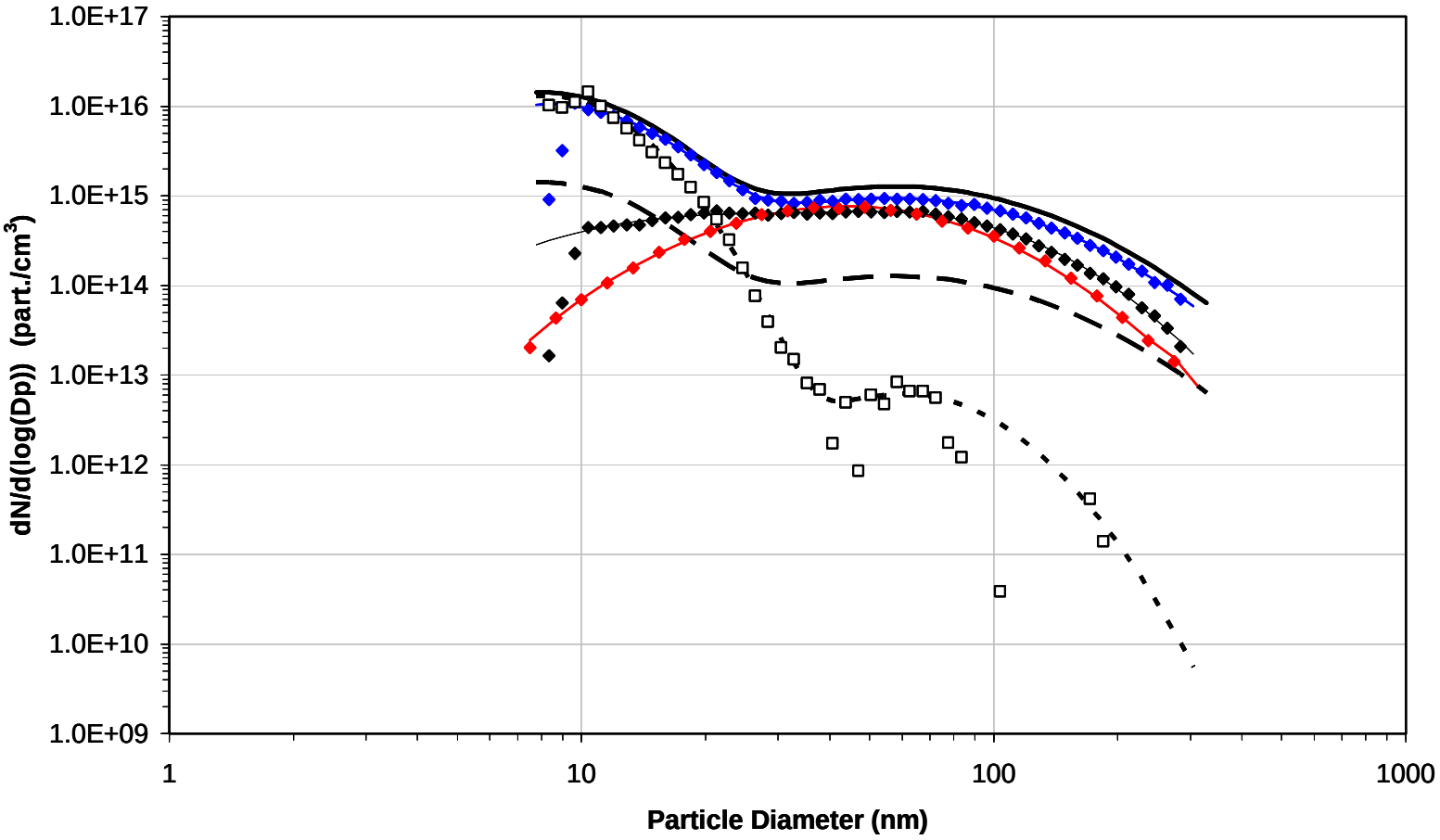


Lower Sulfur In → Lower ultrafine ***mass*** out



2. Control Sulfur Content OUT

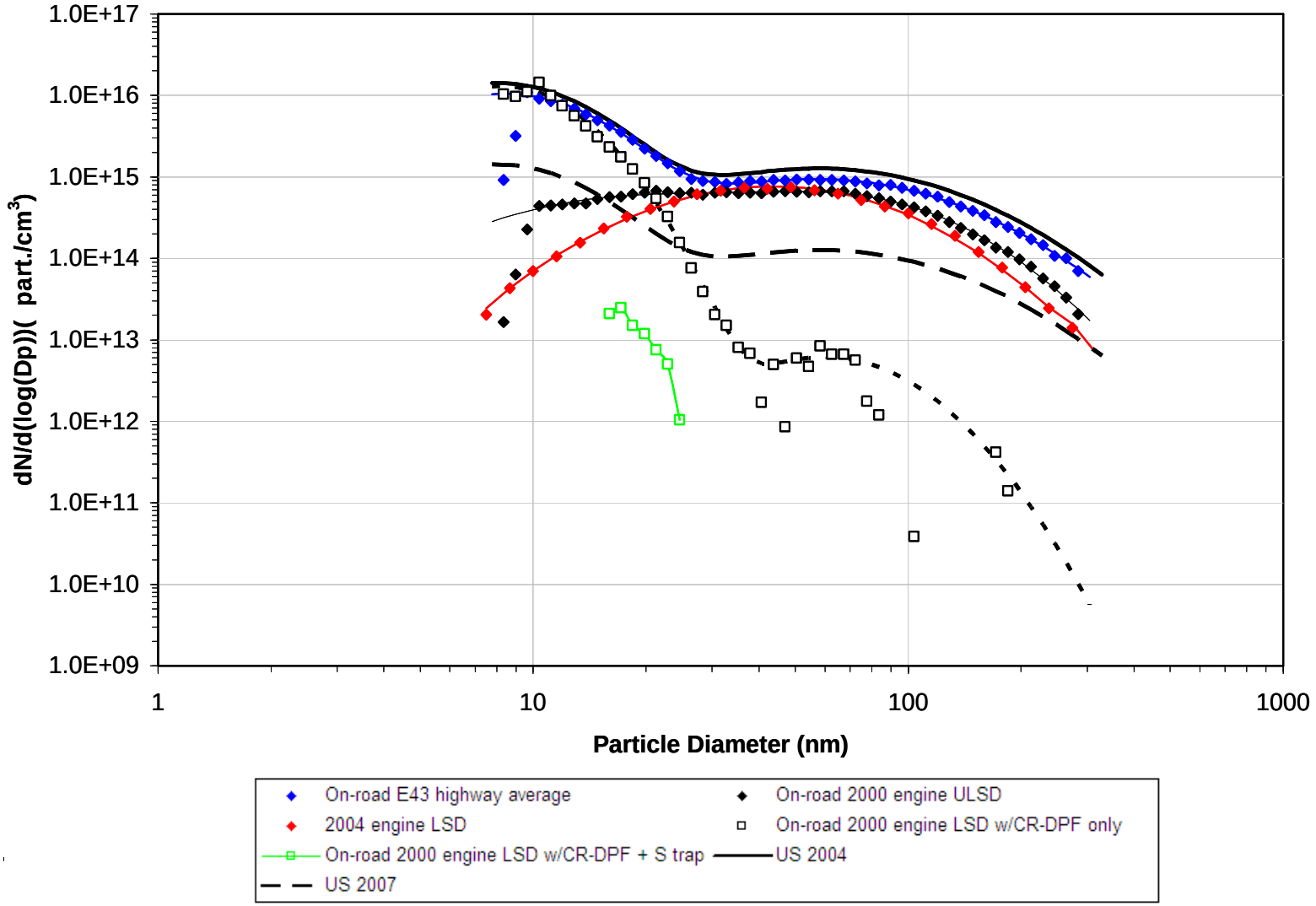
Ultrafine ***number***
No Sulfur control OUT



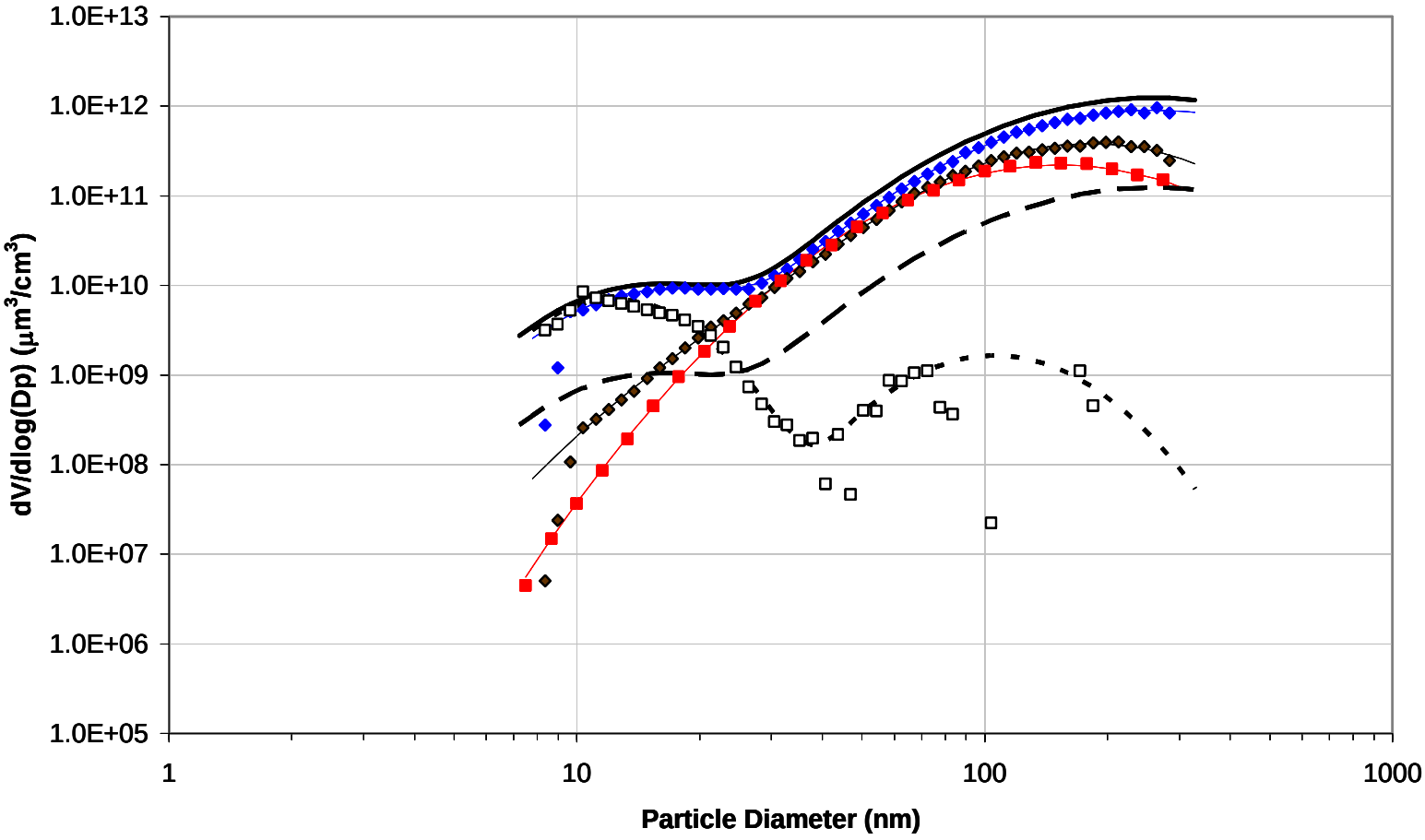
On-road E43 highway average — On-road 2000 Engine ULSD — 2004 engine LSD

On road 2000 retrofit CRT ULSD — US 2004 — US 2007

Ultrafine ***number***
Sulfur control OUT



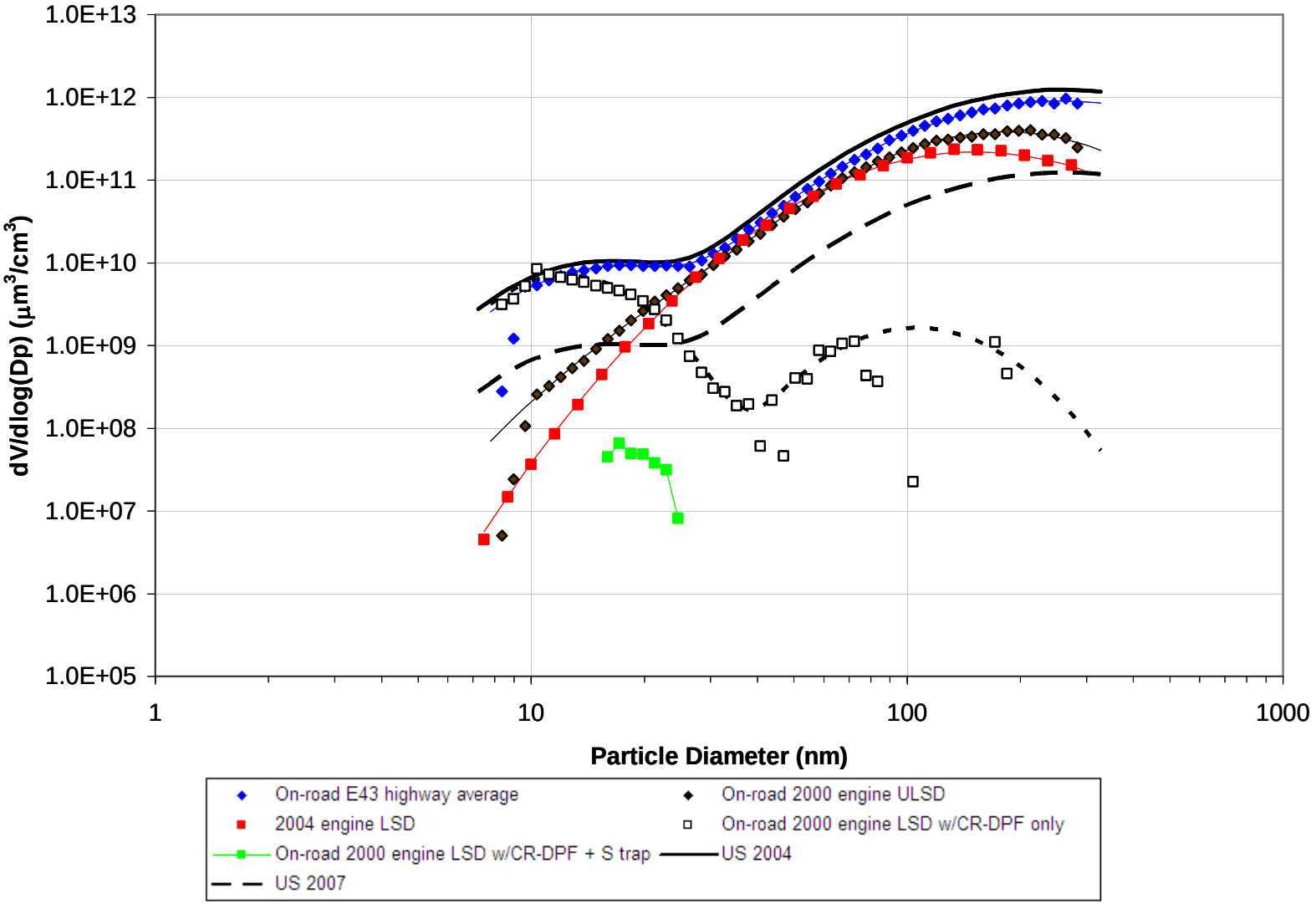
Ultrafine ***mass***
No Sulfur control OUT



On-road E43 highway average — On-road 2000 Engine ULSD — 2004 engine LSD

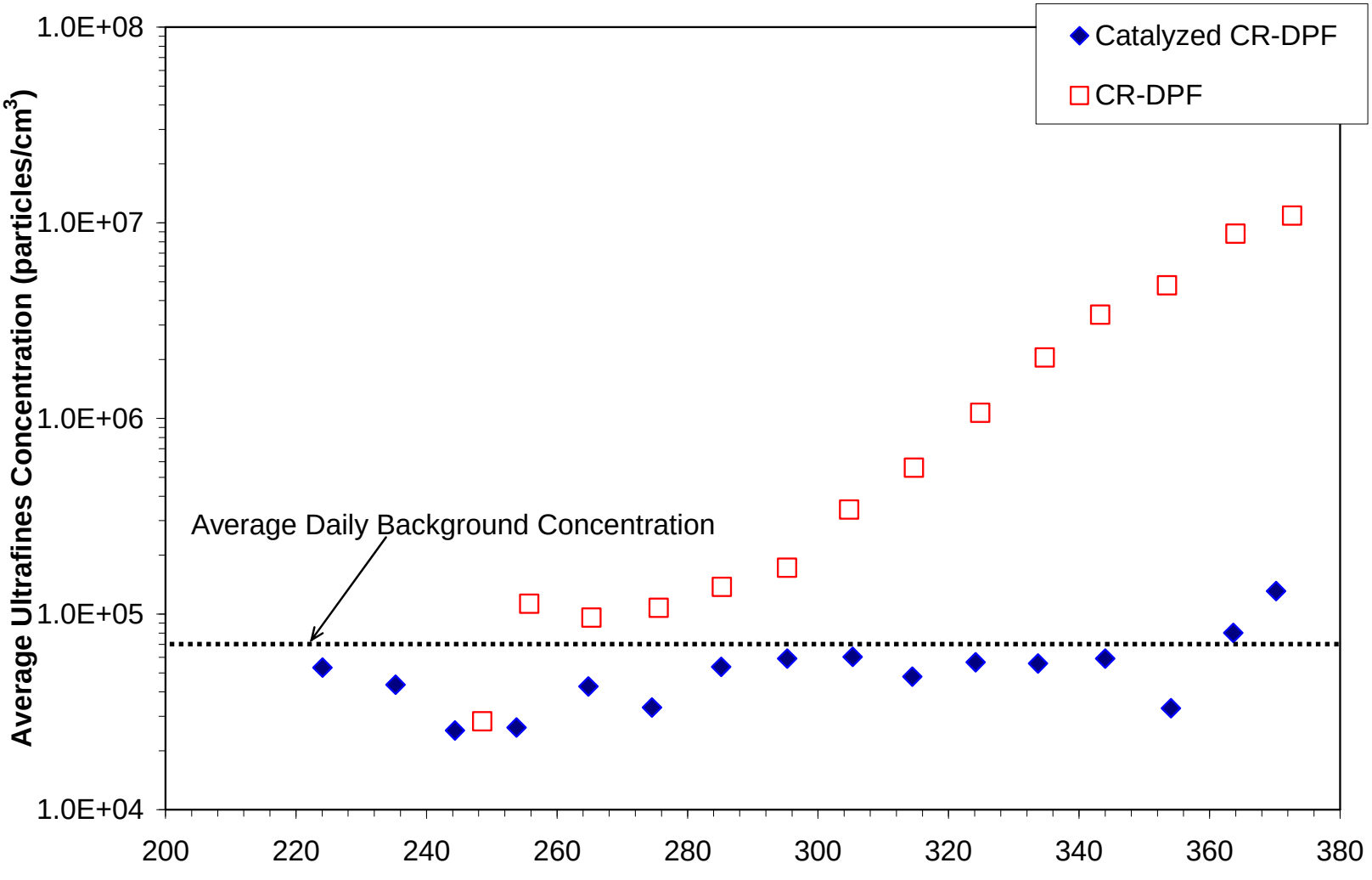
On road 2000 retrofit CRT ULSD — US 2004 — US 2007

Ultrafine ***mass***
Sulfur control OUT



3. Control Volatile Content OUT

Ultrafine ***number***
Volatile control OUT



What Did We Find?

- Sulfur control IN and OUT results:
  - Sulfur from fuel and oil can play an important role in ultrafine emissions
- Volatile control OUT results:
  - Catalyzed CR-DPF is very effective at removing volatiles that may have formed ultrafines after leaving the tailpipe

What Does All This Mean?

- Engines emit gases, particles and volatiles all at once
- Many of these components interact with each other as they pass through the tailpipe
- The presence of the emission control device changes the nature of these interactions—but does NOT add to the total mass emissions
  - Apparent “creation” of ultrafines by device
- Through proper control of engine, fuel, oil, and device, even these interactions can be minimized
- In any case, based on current knowledge, using currently available emission control devices is still beneficial for both the environment and for human health

Acknowledgments

- Prof. David Kittelson (U of M)
  - Group Members: W.F. Watts, J.P. Johnson
- Global Fuels Technology, BP plc
- Global Lubricants Technology, BP plc
- Corning, Inc.
- Volvo Technology Corporation

Glossary

- JM: Johnson Matthey Inc.
- CR-DPF: Continuously Regenerating Diesel Particulate Filter
- PSD: Particle Size Distribution
- PM: Particulate Matter (used here in the context of particle mass)
- DOC: Diesel Oxidation Catalyst
- U of M: University of Minnesota
- MEL: Mobile Emissions Laboratory