Volatile Nanoparticle Number Emissions from a Diesel Engine Equipped with a Catalyzed Particle Filter

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Outline

- Background
- Experimental Setup
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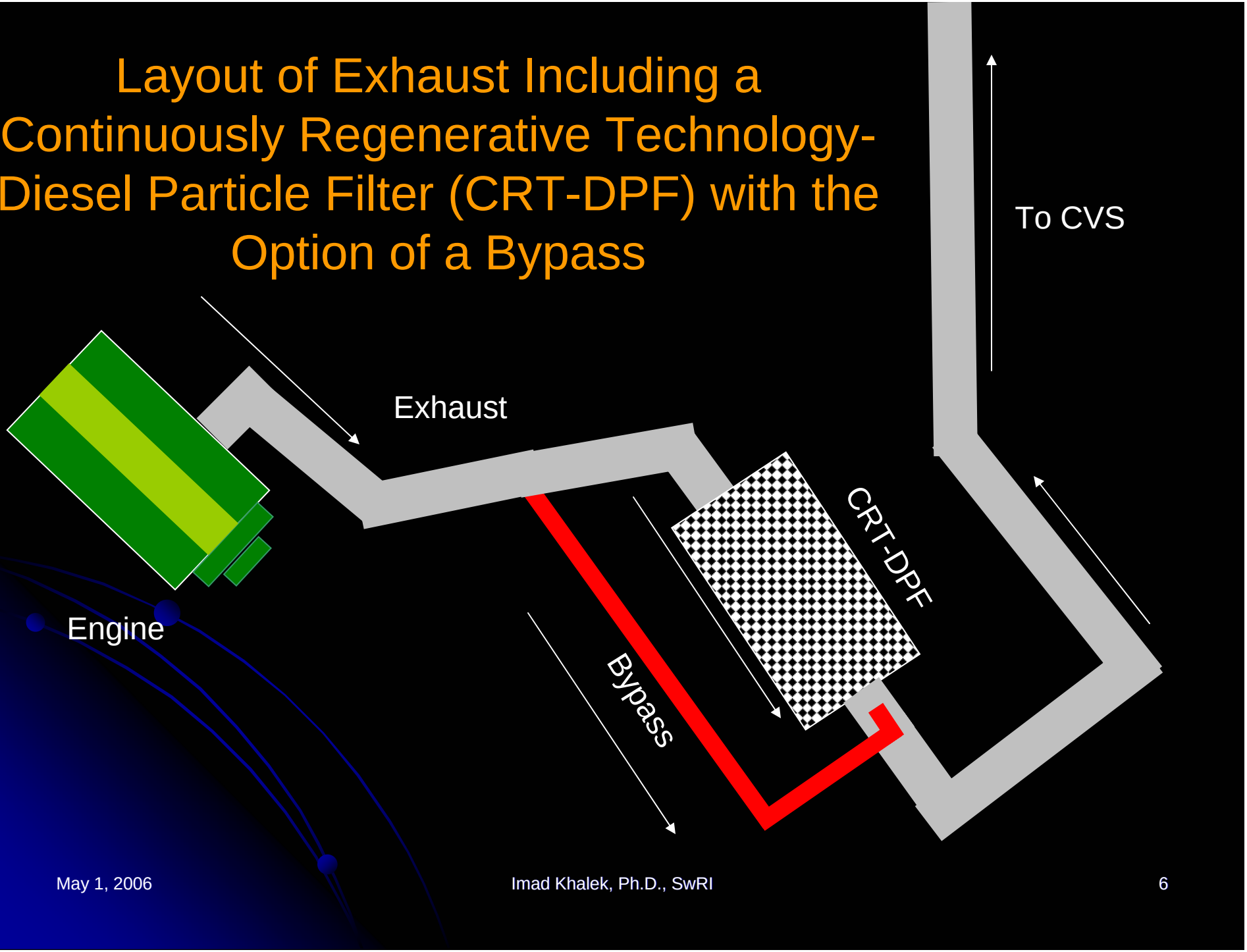
Background

- For on-highway heavy-duty diesel engines model year 2007 and beyond:
  - Use of exhaust particle filters are expected to flourish
  - More than 90 percent reduction in particle mass emissions is expected to be achieved
  - Solid particles are to be virtually absent from the tailpipe if only high efficiency wall-flow diesel particle filters are used
- What is really left to be measured?

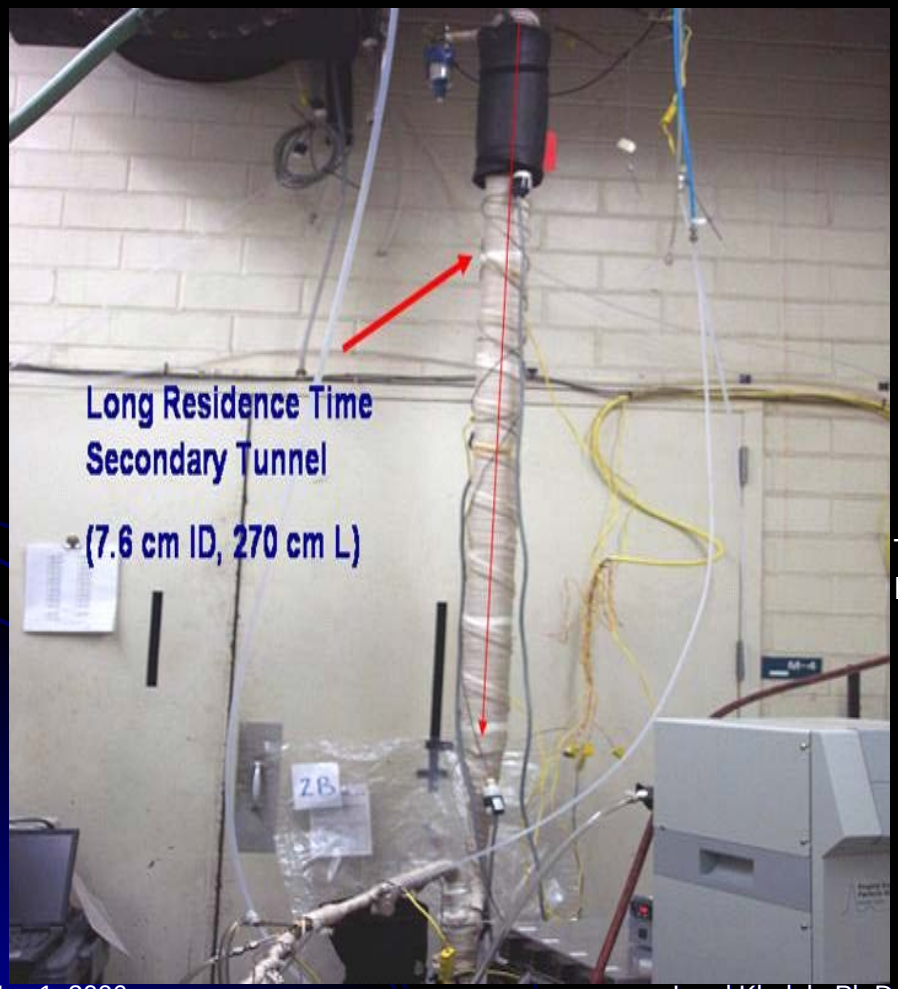
Diesel Engine, Trap, Oil, and Fuel for Project E-66

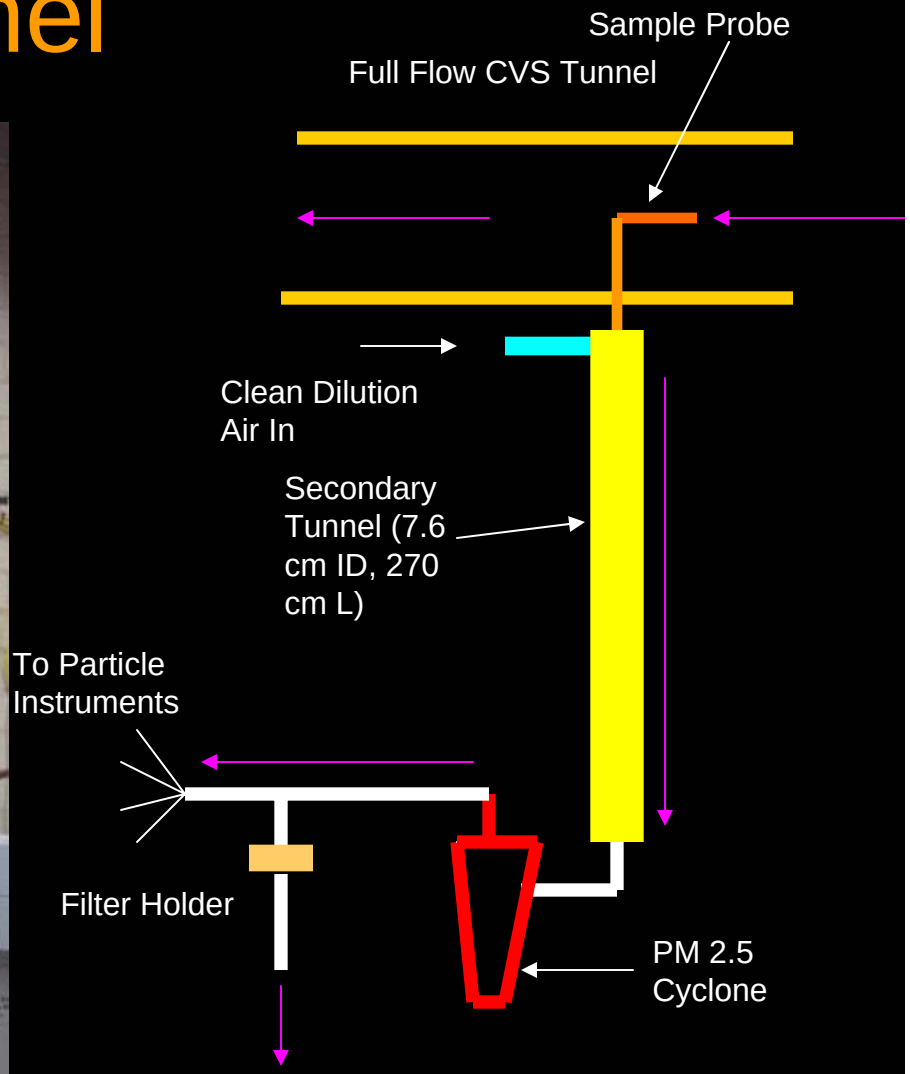
- Engine:
  - 1998 DDC Series 60, 12.7 liter, heavy-duty on-highway diesel engine
- Diesel PM Filter
  - Johnson Matthey CRT-DPF
- Oil
  - Experimental oil (supplied by Lubrizol)- 2007 lubricant chemical limits
- Fuel
  - Ultra low sulfur diesel (ULSD) fuel, 4 ppm, supplied by Chevron-Phillips

Layout of Exhaust Including a Continuously Regenerative Technology-Diesel Particle Filter (CRT-DPF) with the Option of a Bypass

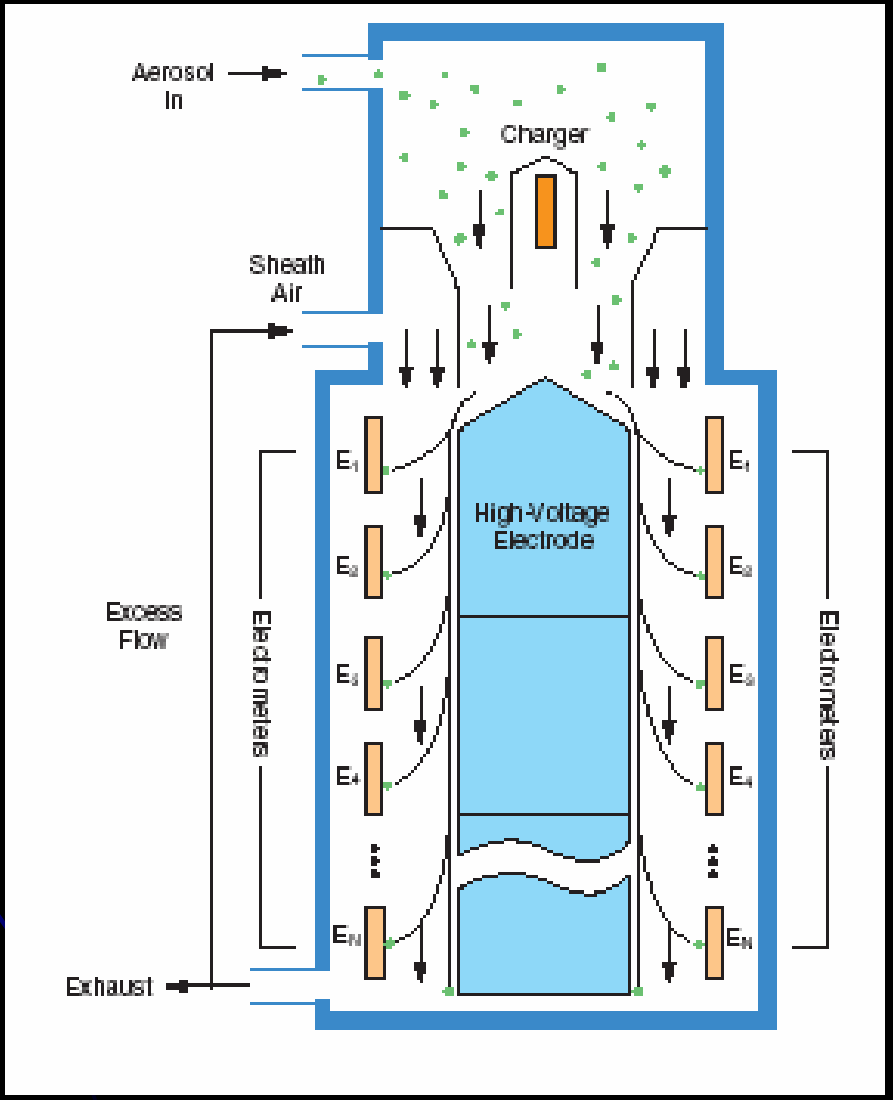


Long Residence Time Secondary Tunnel





Engine Exhaust Particle Sizer (EEPS, 5.6 to 560 nm, TSI)



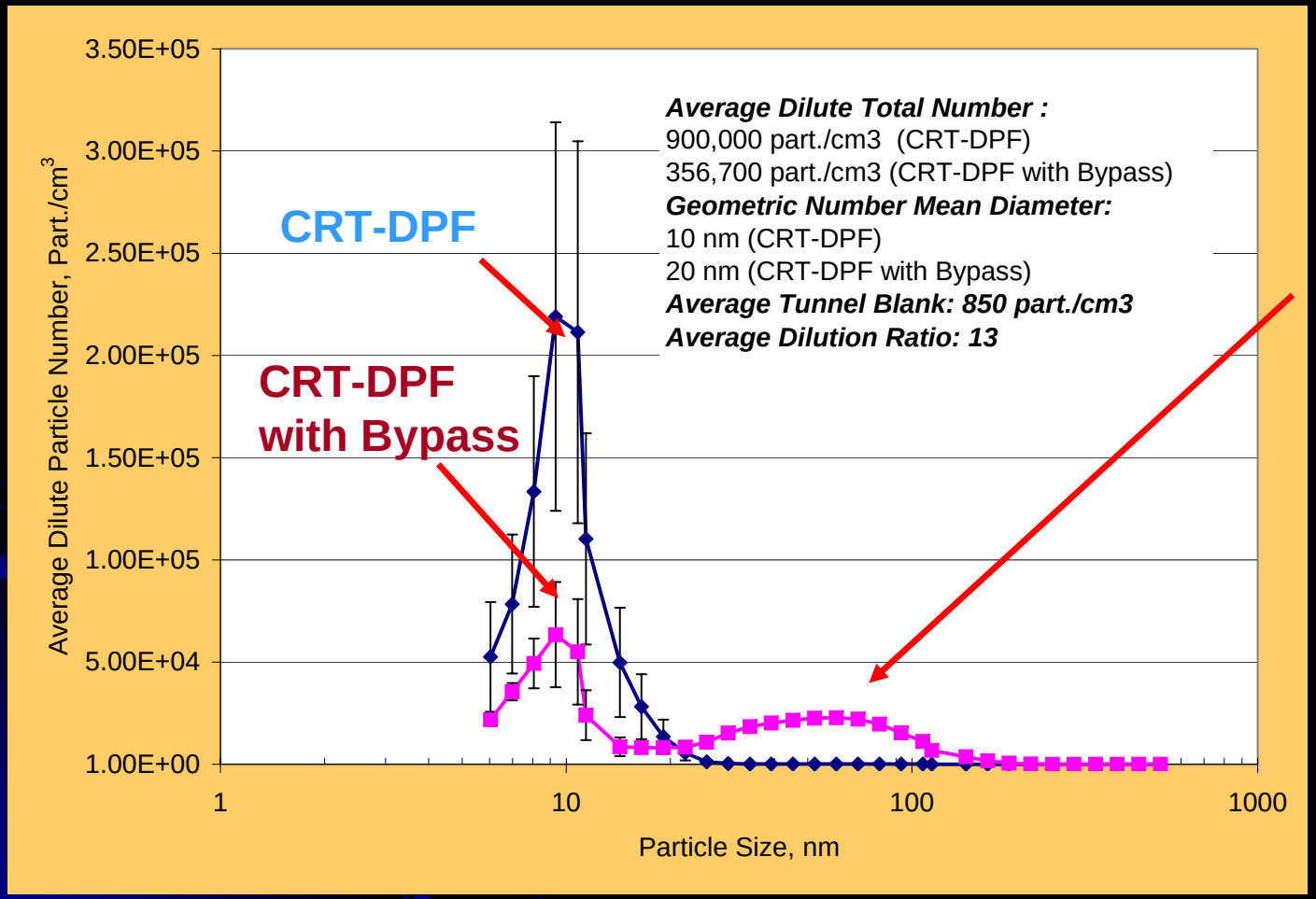
Test Matrix

- Seven repeats of:
  - Federal test Procedures (FTP) hot-start transient cycle
  - Rated power (rated speed, 100 percent load) steady-state engine operation

Particle Number Measurement Approach

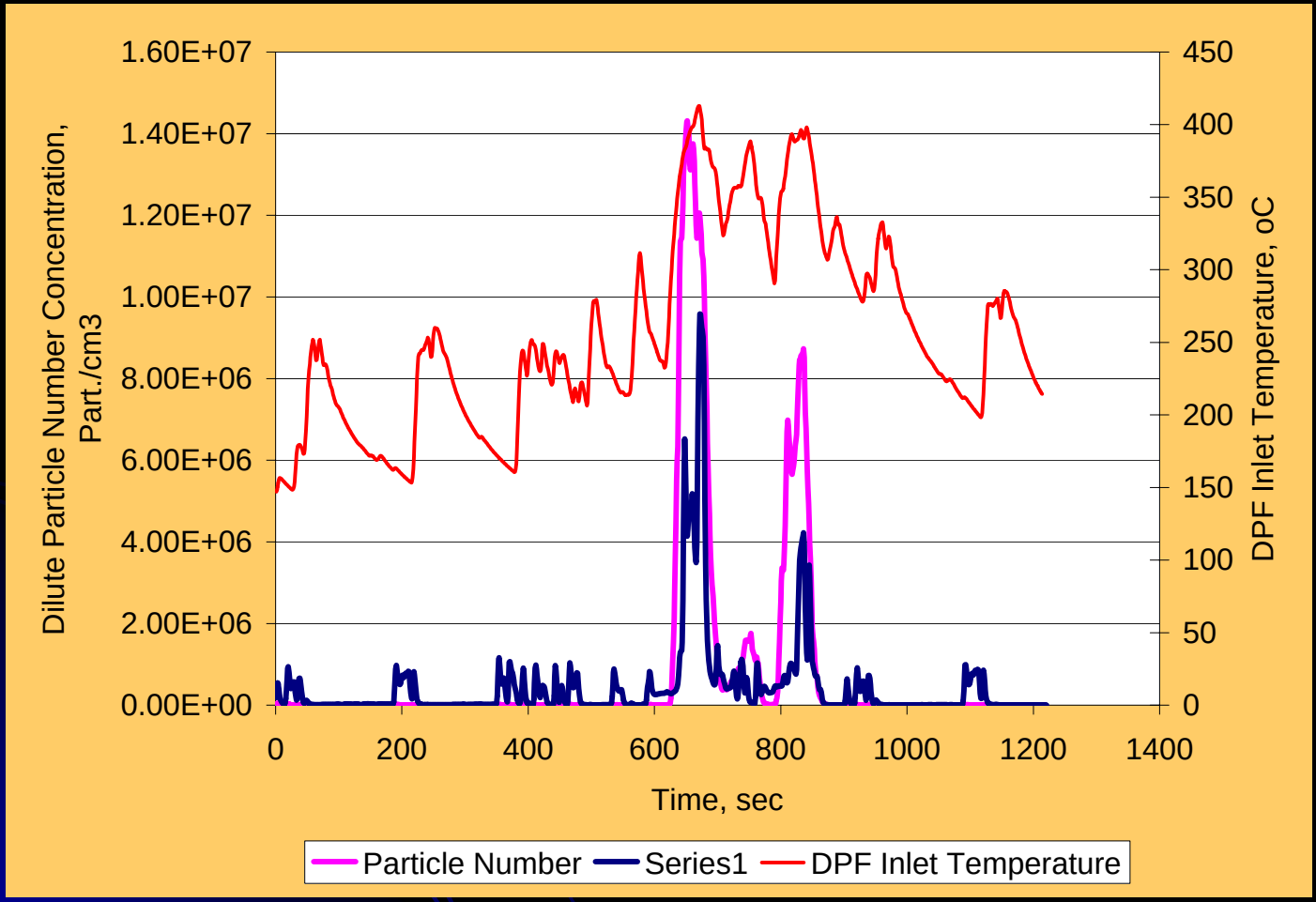
- The particle number measurement method used in this work:
  - Adheres to the filter measurement method defined in code of federal regulations (CFR) Part 1065 for 2007 engines and beyond
  - Uses a long secondary dilution tunnel residence time of 10 seconds that seemed sufficient to maximize particle growth based on previous work conducted under Project E-66
  - Uses a final measurement temperature of 25 ^{o}C instead of 47 ^{o}C used for filters
  - Can be argued to be a worst case scenario in terms of PM emissions because of the long secondary dilution residence time used
    - It is important to note that a much shorter residence can also be used under CFR Part 1065

Average Dilute Particle Size Distribution for the FTP



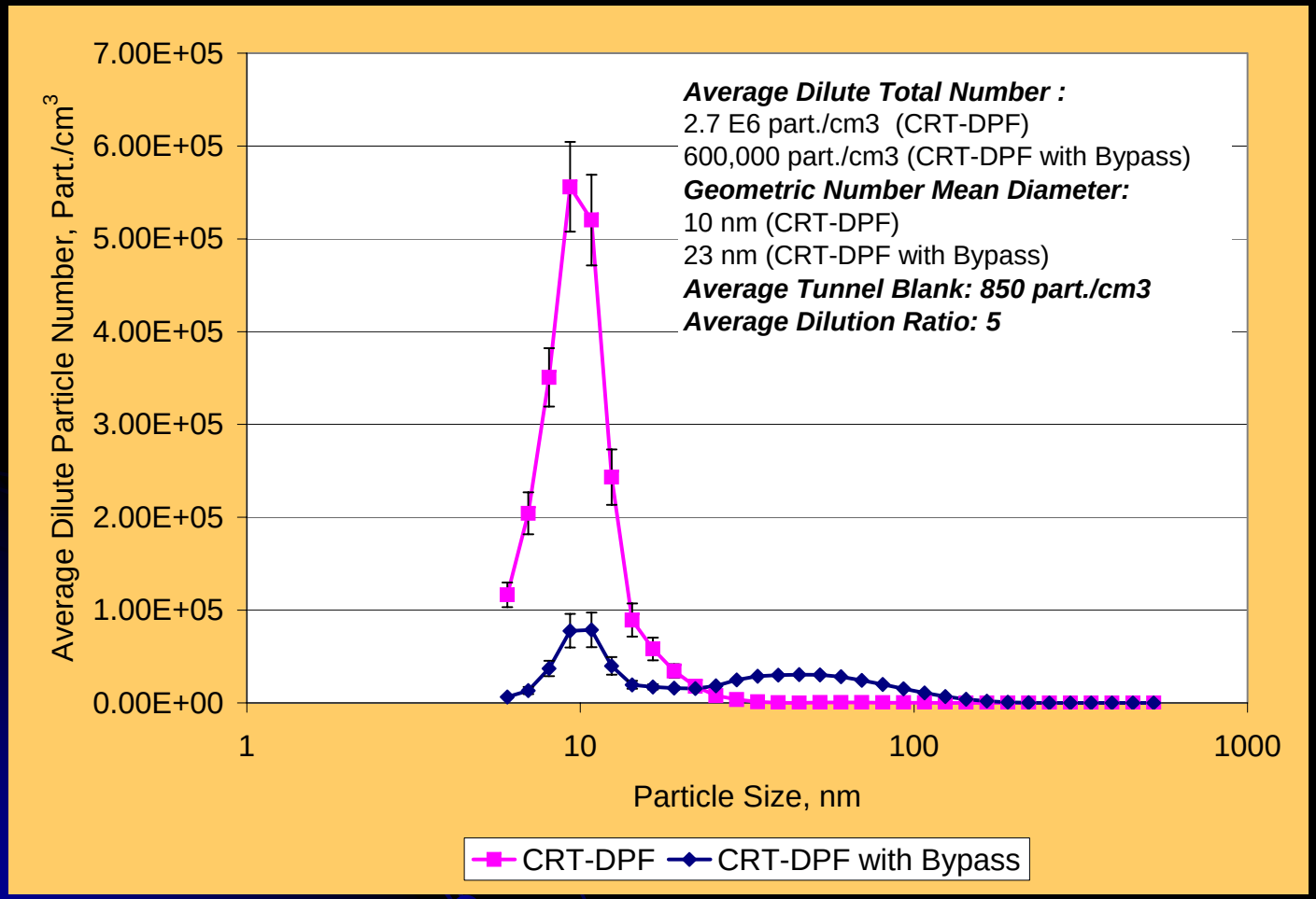
It is likely that the presence of accumulation mode particles (~ solid particles) suppresses particle nucleation and growth. Other unknown mechanisms may also play a role.

Dilute Particle Number Concentration Profile for the FTP



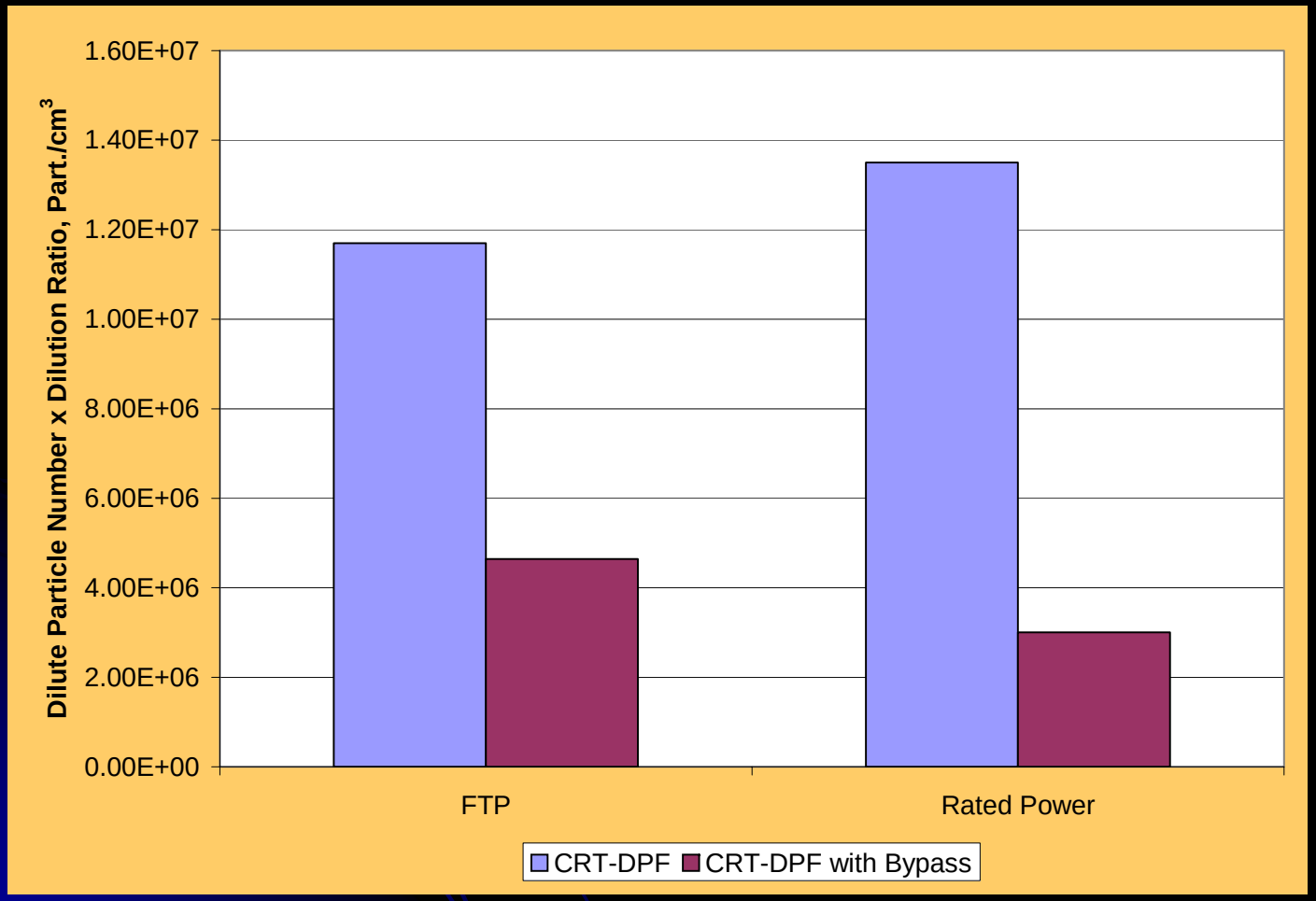
Storage and release of volatile material from the surface of the CRT-DPF may lead to particle nucleation during the most aggressive portion of the cycle where exhaust temperature is the highest.

Average Dilute Particle Size Distribution at Engine Rated Power



The CRT-DPF inlet temperature at rated engine power was about 415 ^{o}C. The catalyst of the DPF is likely to promote the formation of SO3 from SO2 at this temperature. Sulfuric acid nucleation is likely to occur during dilution and cooling of the exhaust leading to more nanaoparticles.

Comparison of Particle Number Concentration at Different Engine Operating Conditions



Note that the number concentration reported here is not exhaust particle concentration because volatile particles are not present in the hot exhaust. Volatile particle number should never be reported as exhaust concentration.

Summary

- A particle number measurement method that adhered to the EPA 2007 PM mass sampling method was used in this work to maximize the nucleation and growth of particles
- Nanoparticle emissions in the sub 30 nm size range was observed downstream of the CRT-DPF
- CRT-DPF alone resulted in a factor of three to five higher particle number emissions than the CRT-DPF with bypass
- While it can be argued that the dilution process adopted in this work is not representative of the atmospheric dilution process, it can also be argued that it is difficult to make a laboratory dilution system that can mimic all possible scenarios of atmospheric dilution
  - Within the constraint of laboratory measurement, the presented work here attempted to show a worst case scenario for nanoparticle emissions rather than showing a best case scenario of no nanoparticle emissions using very short residence time, as reported previously under Project E-66 and elsewhere. What is the right way of doing the measurement is an important subject for discussion and more research.