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## **Effect of lubricant sulfur levels on nanoparticle emissions**

# **Effect of Lubricant Sulfur Levels on Nanoparticle Emissions**

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# OBJECTIVES

**INVESTIGATE THE EFFECT OF *LUBRICANT SULFUR CONTENT ON SIZE DISTRIBUTIONS AND CONCENTRATIONS OF PARTICULATE MATTER EMISSIONS* FROM ENGINES OPERATING ON FOSSIL-FUEL DERIVED *ULTRA-LOW SULFUR FISCHER-TROPSCH FUEL*, AND *FEDERAL ON-HIGHWAY DIESEL FUEL*.**



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# APPROACH

- OPERATE A RICARDO PROTEUS, DIRECT INJECTION, SINGLE-CYLINDER RESEARCH ENGINE ON:
  - FEDERAL ON-HIGHWAY DIESEL NO. 2 (343 ppm SULFUR)
  - FOSSIL-FUEL DERIVED FISCHER-TROPSCH FUEL (<3 ppm SULFUR)
- OPERATE THE ENGINE ON BOTH FUELS WITH:
  - COMMERCIALY AVAILABLE LUBE OIL (4500 ppm SULFUR)
  - ULTRA-LOW SULFUR CONTENT LUBE OIL (280 ppm SULFUR)



# APPROACH

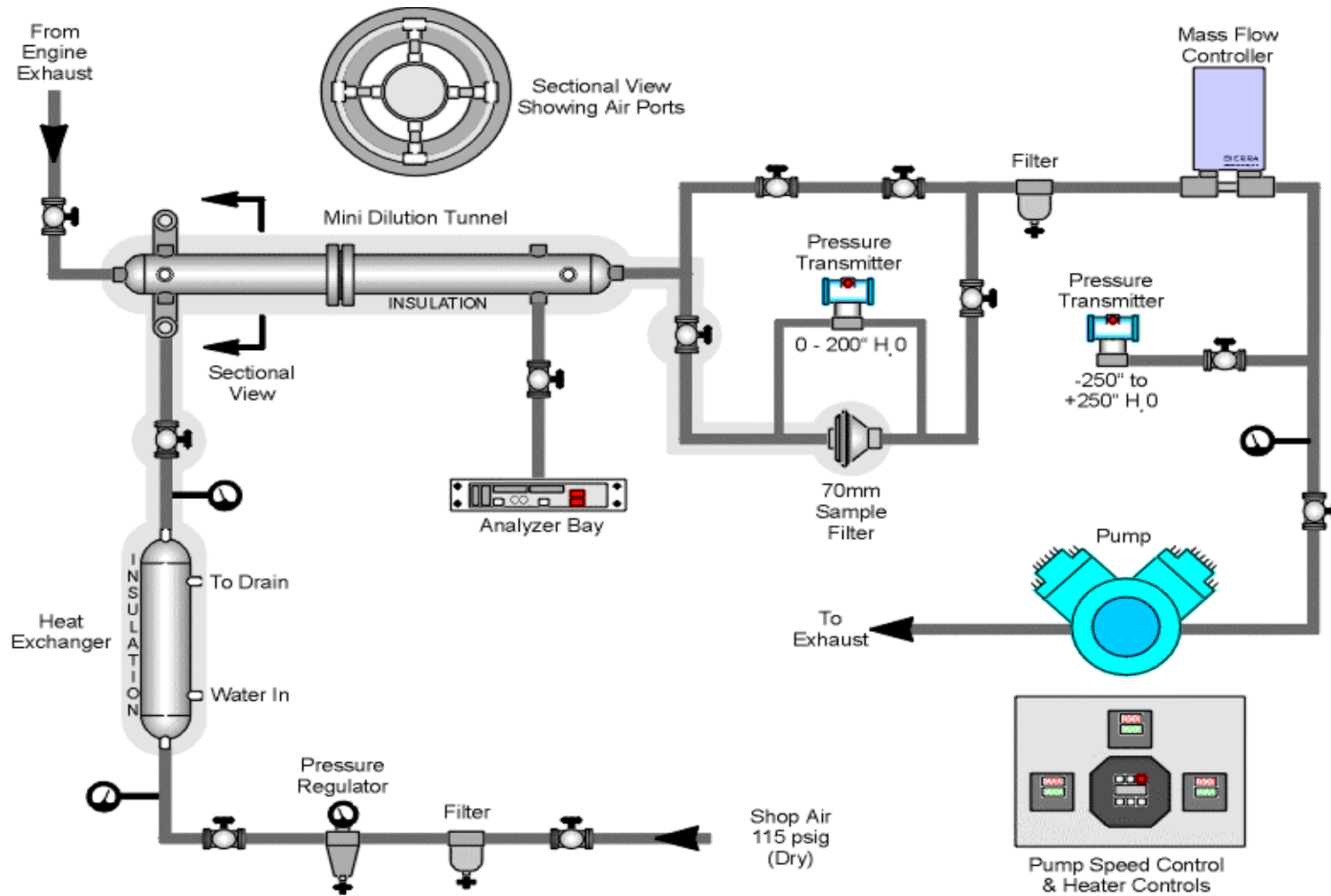
- **ENGINE OPERATING CONDITIONS:**
  - **ENGINE CONDITION 1 LOW SPEED/NO LOAD**
    - 12 rps, 2 bar BMEP, 0 kPa Boost
  - **ENGINE CONDITION 2 INTERMEDIATE SPEED/INTER. LOAD**
    - 24 rps, 8 bar BMEP, 54 kPa Boost
  - **ENGINE CONDITION 3 INTERMEDIATE SPEED/HIGH LOAD**
    - 24 rps, 16 bar, 125 kPa Boost
  - **ENGINE CONDITION 4 HIGH SPEED/HIGH LOAD**
    - 36 rps, 12 bar, 160 kPa Boost
- **EXHAUST SAMPLE WAS DRAWN INTO A MINI-DILUTION TUNNEL (“SECONDARY-DILUTION TUNNEL” TYPE SYSTEM) THROUGH A HEATED LINE**
- **EMPLOYED AN SMPS WITH ULTRA-FINE CPC (TSI MODEL 3025)**

# **DILUTION SYSTEMS**

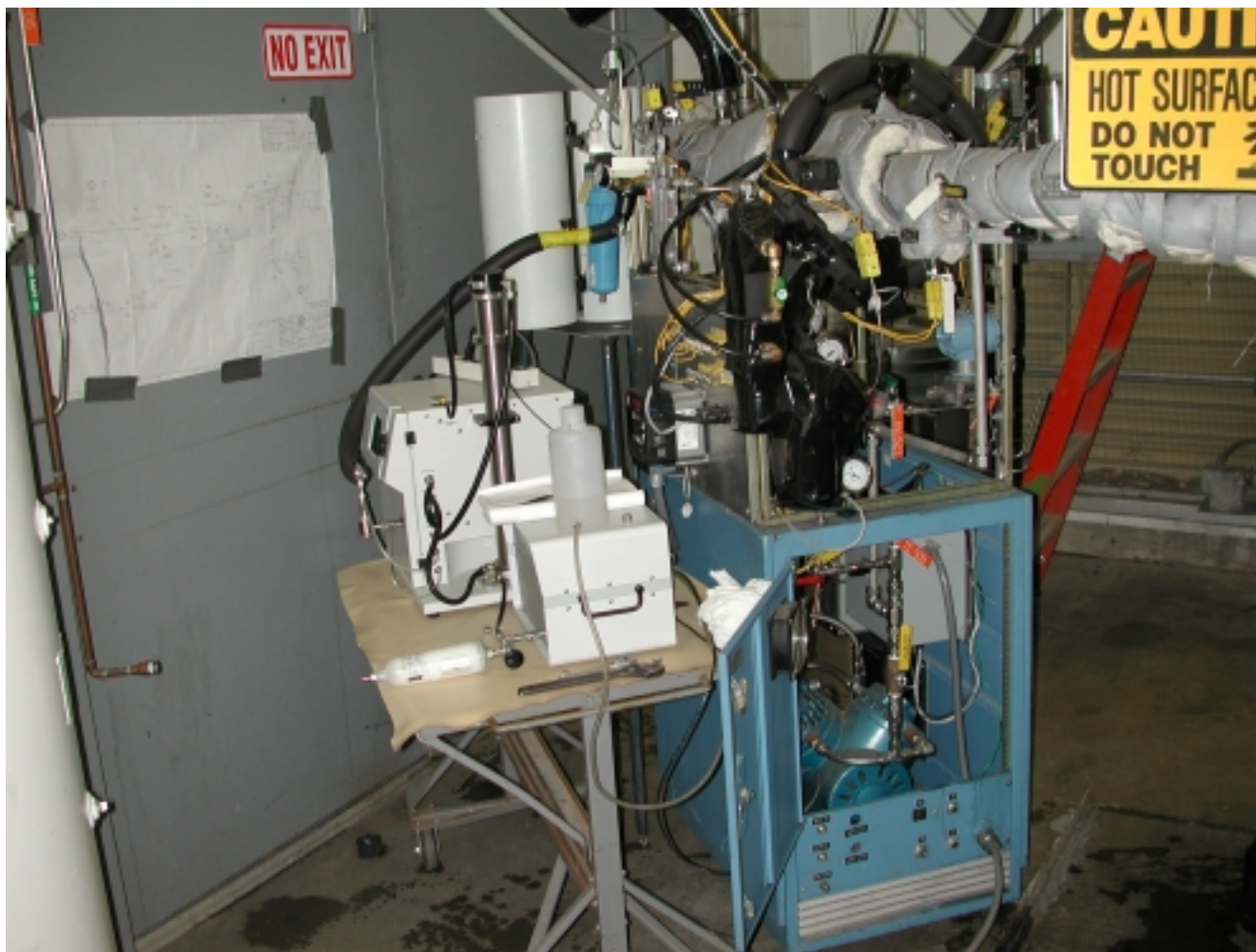
- **“SECONDARY-DILUTION TUNNEL” TYPE**
- **AIR-EJECTOR/CRITICAL FLOW ORIFICE (CFO) TYPE**
- **CAPILLARY/VENTURI TYPE (BROCKMAN et al.,1984)**
- **ROTATING DISK TYPE (HUGLIN et al., 1998)**



# SCHEMATIC OF THE DILUTION TUNNEL



# MINI-DILUTION TUNNEL AND SMPS



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## FUEL AND LUBRICANT SULFUR CONTENT

FUEL/LUBE	SULFUR
D2	343 ppm
FT	0
HSL	4500 ppm
LSL	280 ppm

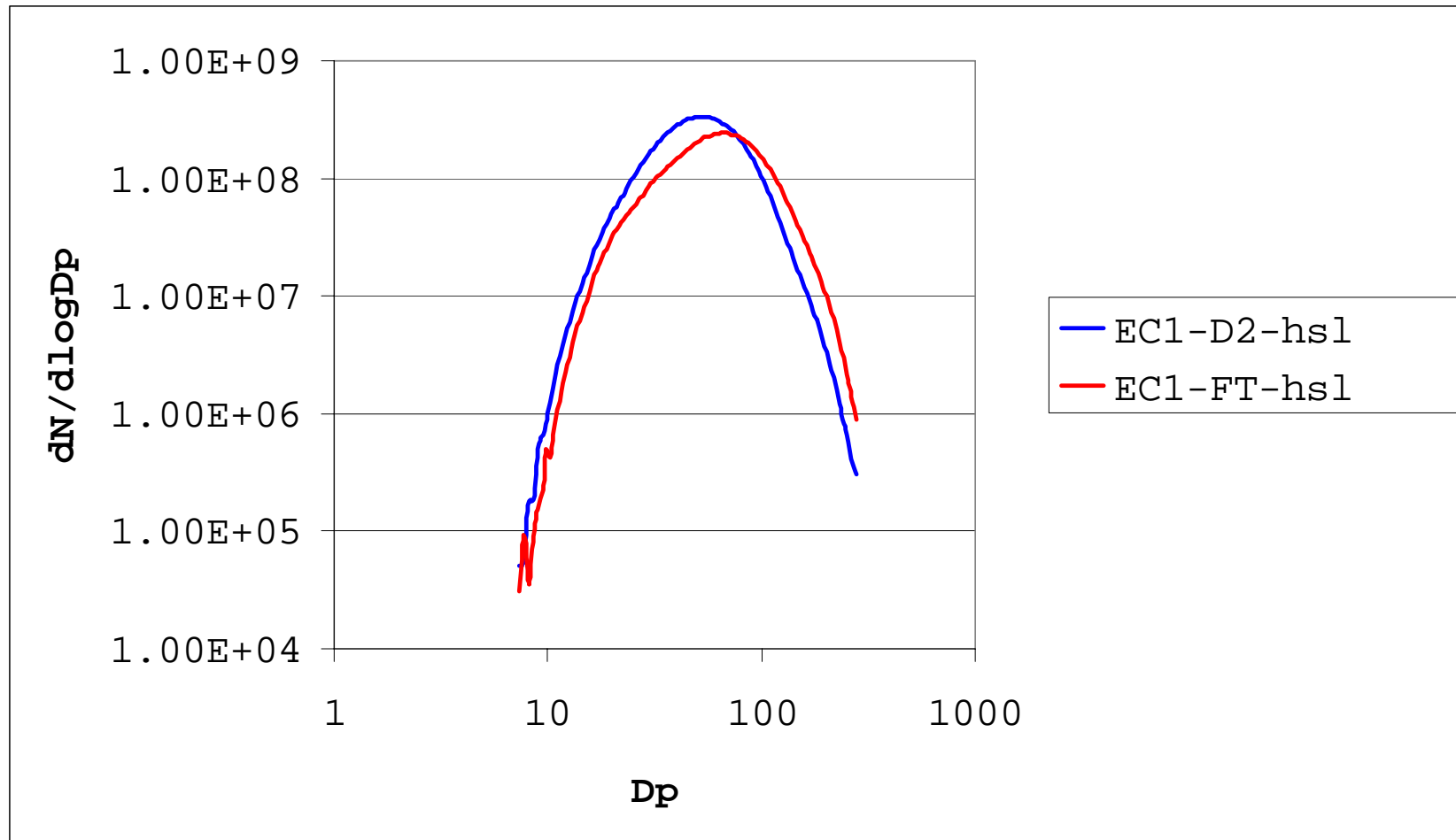


## TEST MATRIX

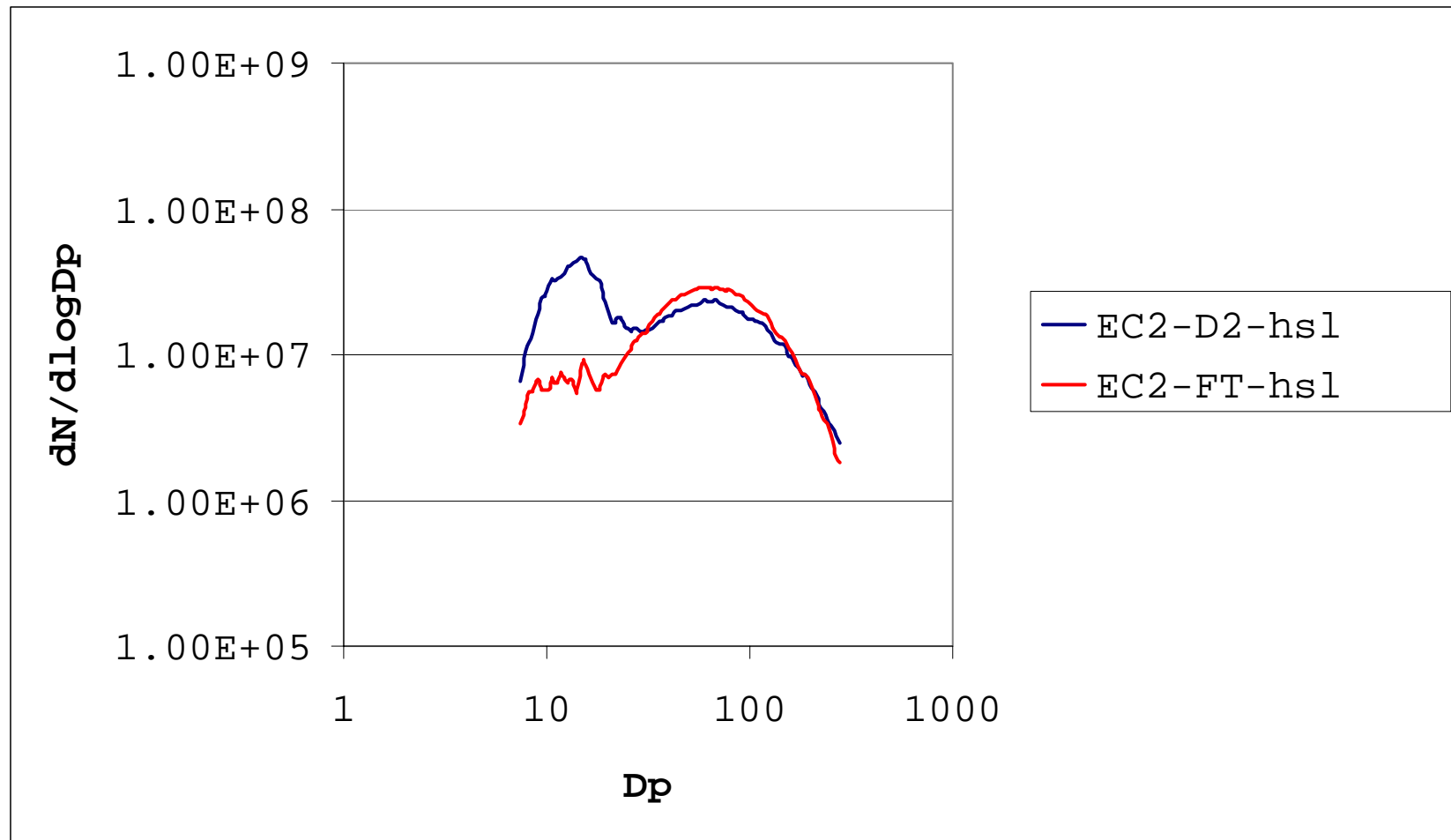
E.C.	LUBRICANTS	FUELS
1	HSL	FT, D2
1	LSL	FT, FT343,D2
2	HSL	FT, D2
2	LSL	FT, FT15, FT50, FT120, FT343, FT2000, D2
3	HSL	FT, D2
3	LSL	FT, FT343,D2
4	HSL	FT, D2
4	LSL	FT, FT15, FT50, FT120, FT343, FT2000, D2



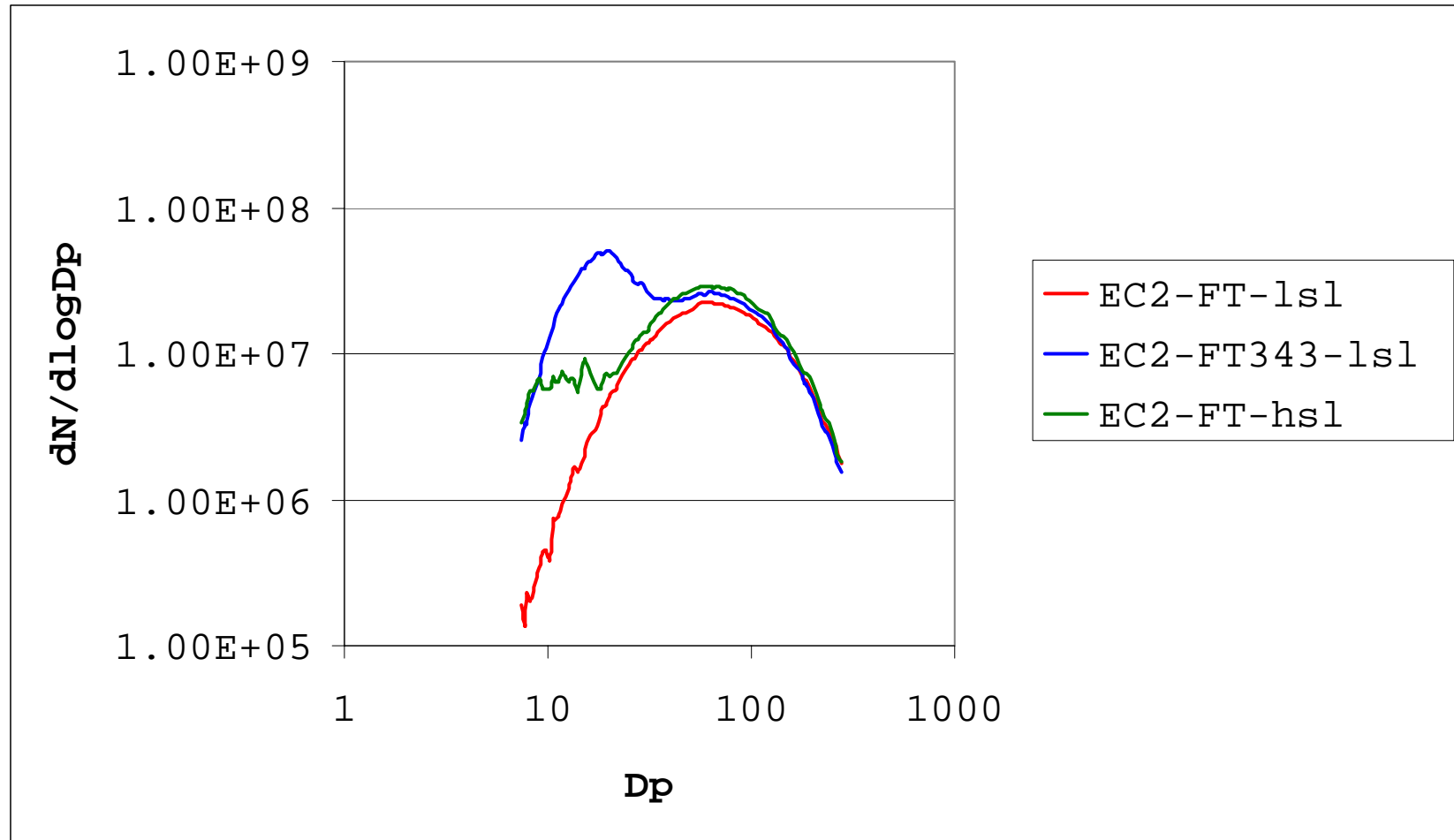
## EC-1 (Low Speed/Low Load) HIGH SULFUR LUBE, D2 vs. FT



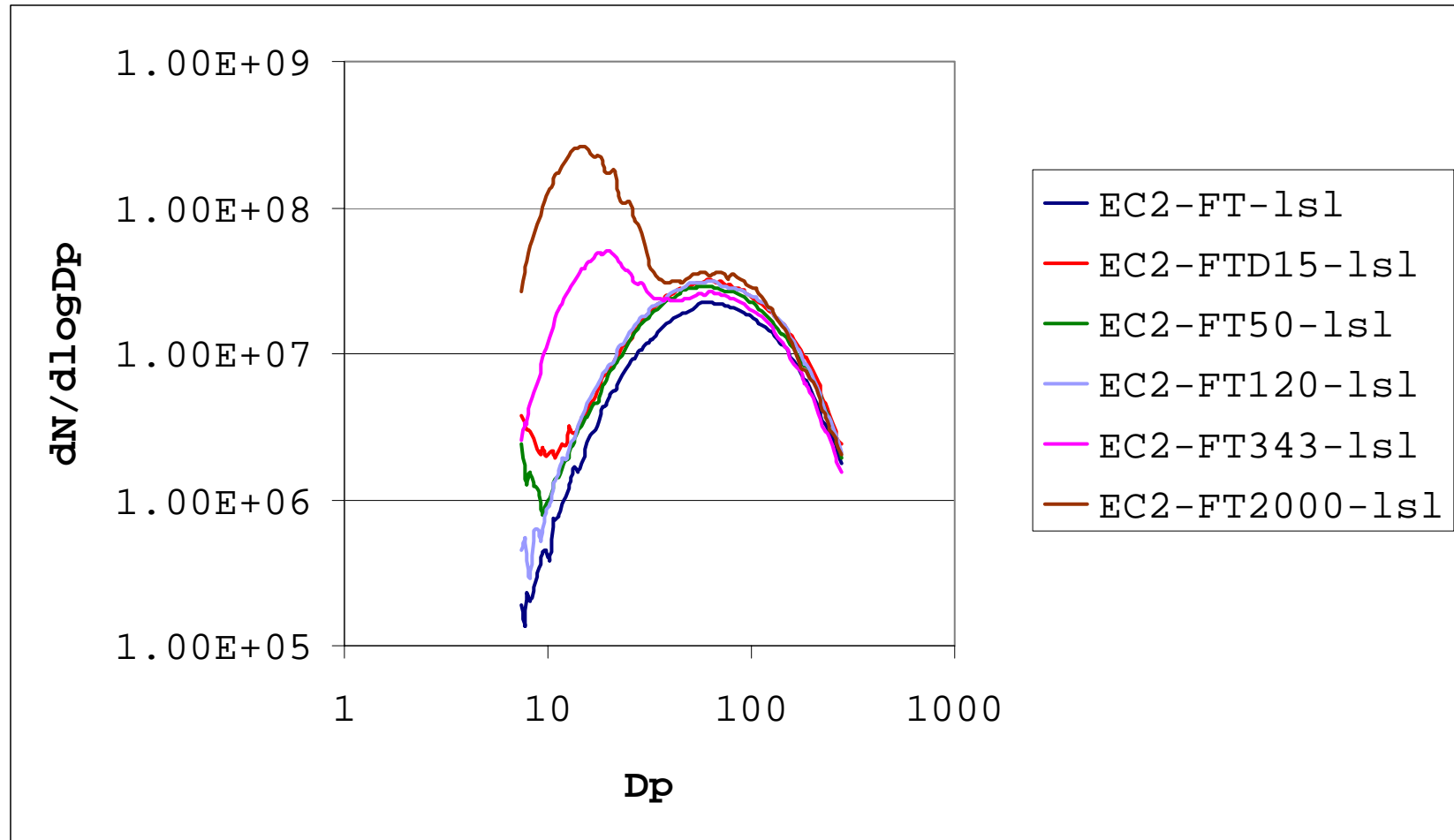
## EC-2 (Intermediate Speed/Intermediate Load) HIGH SULFUR LUBE, D2 vs. FT



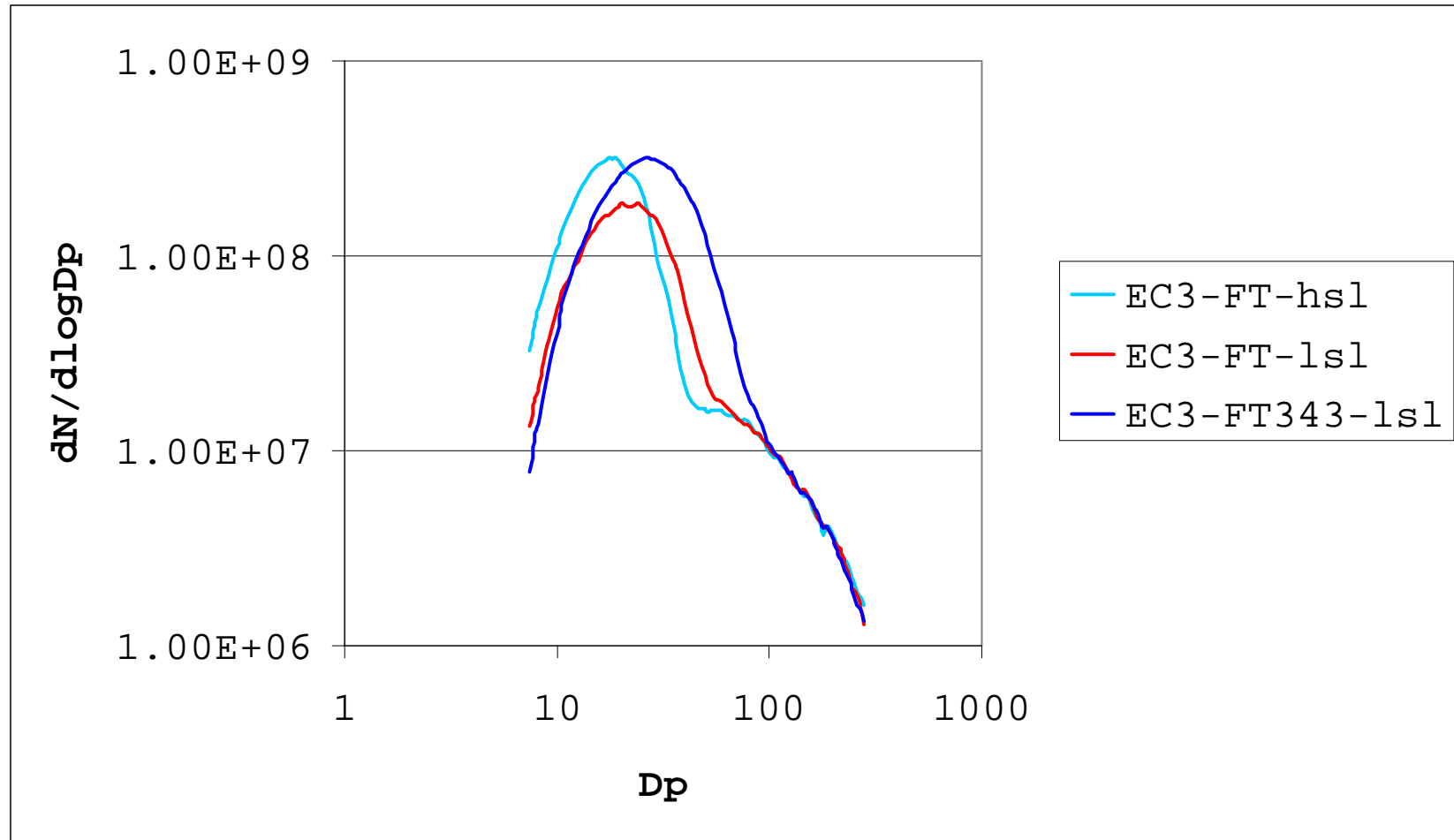
## EC-2 (Intermediate Speed/Intermediate Load) HIGH AND LOW SULFUR LUBE, FT



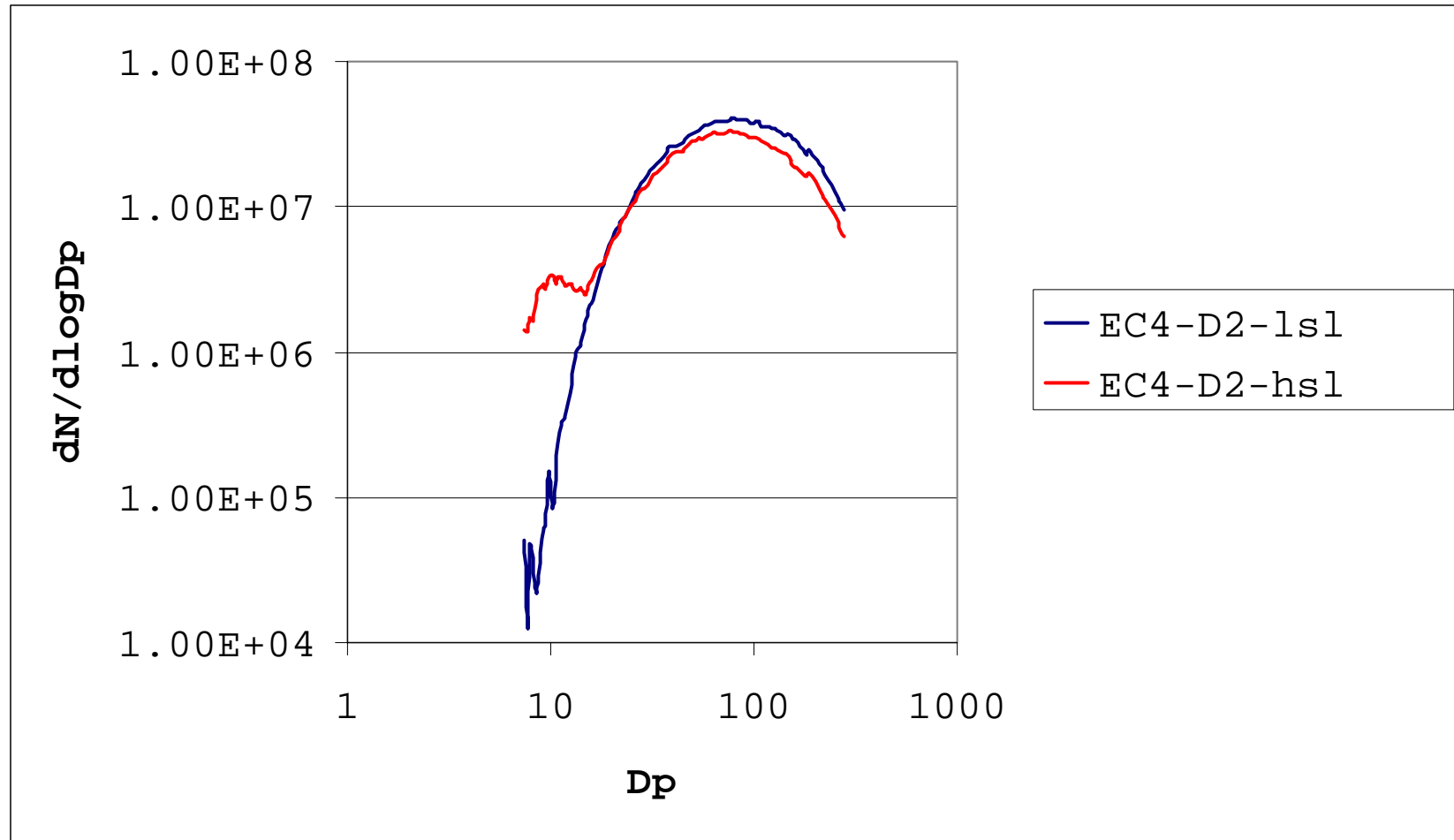
## EC-2 (Intermediate Speed/Intermediate Load) LOW SULFUR LUBE, FT – DOPED



## EC-3 (Intermediate Speed/High Load) HIGH AND LOW SULFUR LUBE, FT

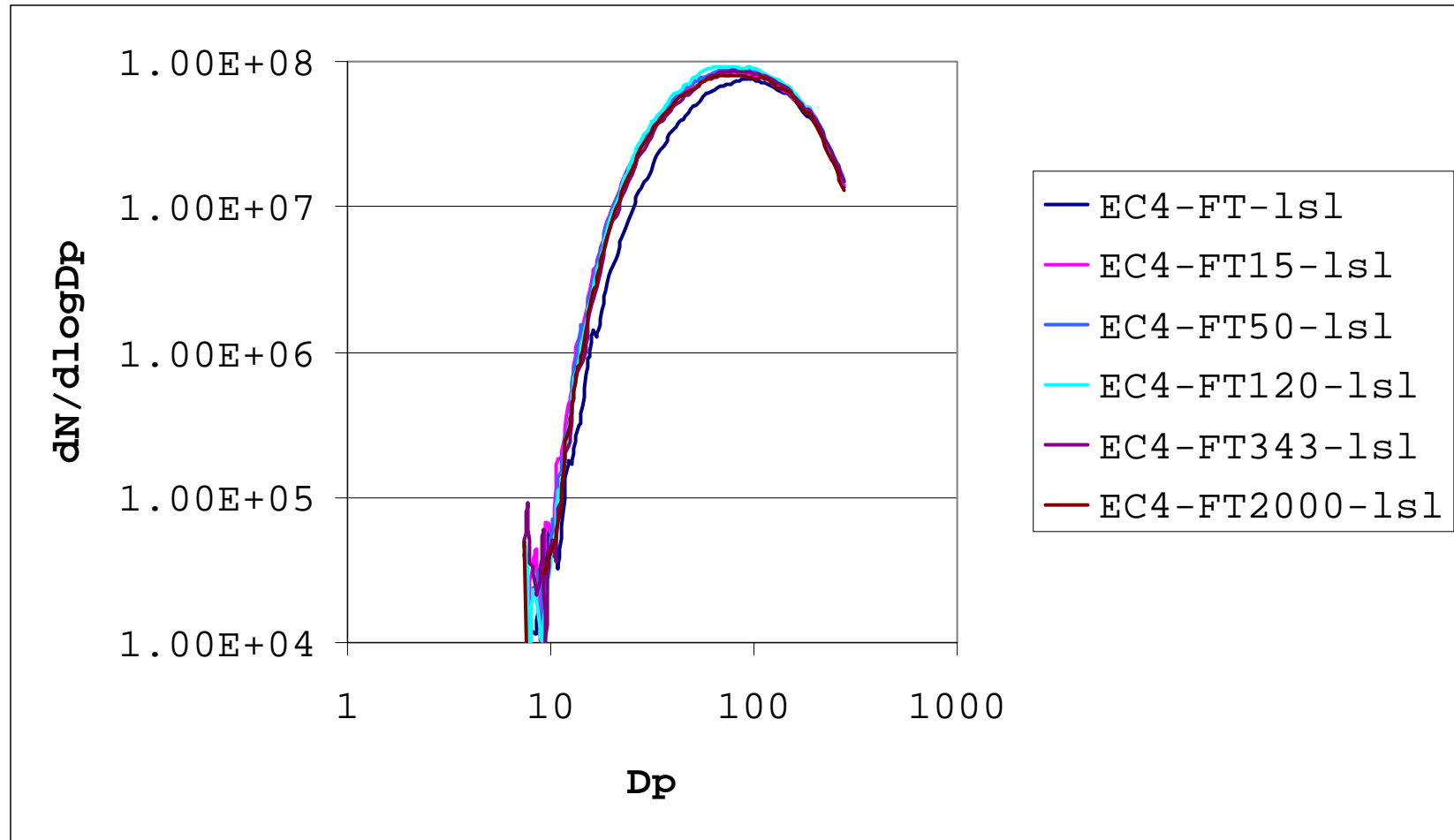


# EC-4 (High Speed/High Load) HIGH AND LOW SULFUR LUBE, D2





# EC-4 (High Speed/High Load) LOW SULFUR LUBE, FT – DOPED



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## **CONCLUSIONS**

- **REDUCING FUEL SULFUR LEVELS ALONE MAY NOT BE AN ANSWER TO REDUCING NANOPARTICLE CONCENTRATIONS IN DIESEL EXHAUST EMISSIONS.**
- **LUBE OIL SULFUR LEVELS AND ADDITIVE PACKAGES DO HAVE A PROFOUND INFLUENCE ON SIZE DISTRIBUTIONS AND CONCENTRATIONS OF PM EMISSIONS.**
- **NANOPARTICLES ARE GENERATED AS A RESULT OF HIGHLY COMPLEX INTERACTIONS BETWEEN FUEL AND LUBE OIL HYDROCARBON CHEMISTRY AND SULFUR CONTENT, ENGINE OPERATING MODES, THE EXHAUST DILUTION SYSTEM ITSELF (IN ADDITION TO DILUTION CONDITIONS).**

# **ACKNOWLEDGMENTS**

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- **CTC**



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