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Electrostatic Removal of Diesel Particulate Matter

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Exposure to DPM in Mines

Very common in mines and construction sites from vehicles and machinery.

Health effects seen in miners (Stayner *et al.*, 1998)

Picture from www.cdc.gov

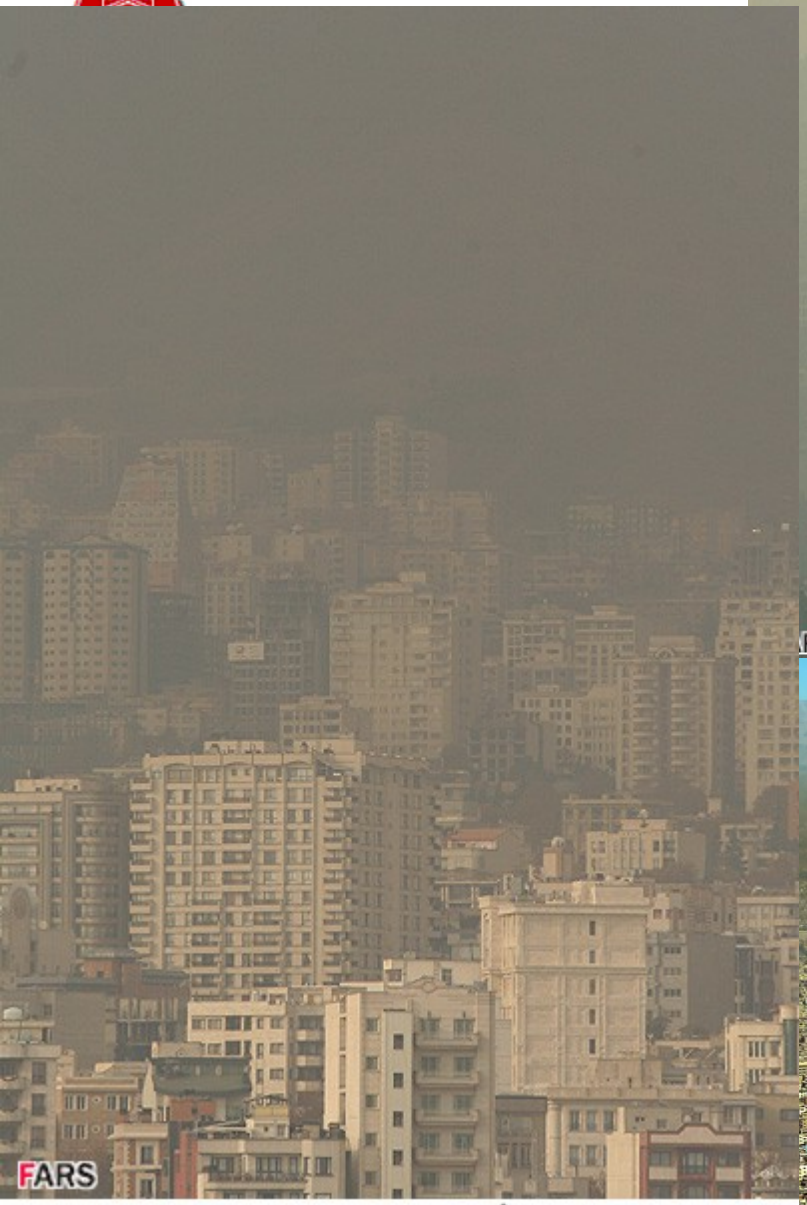
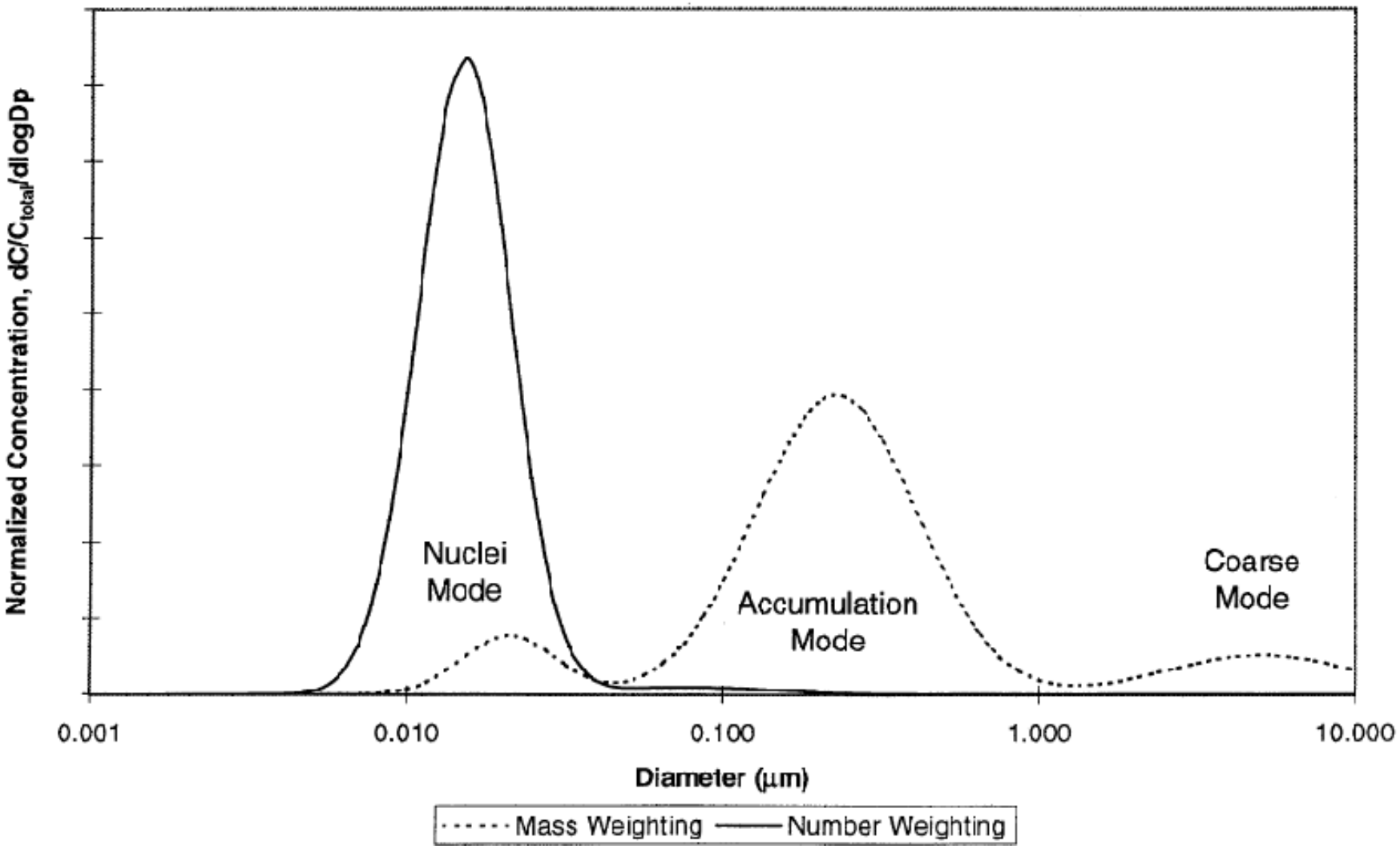


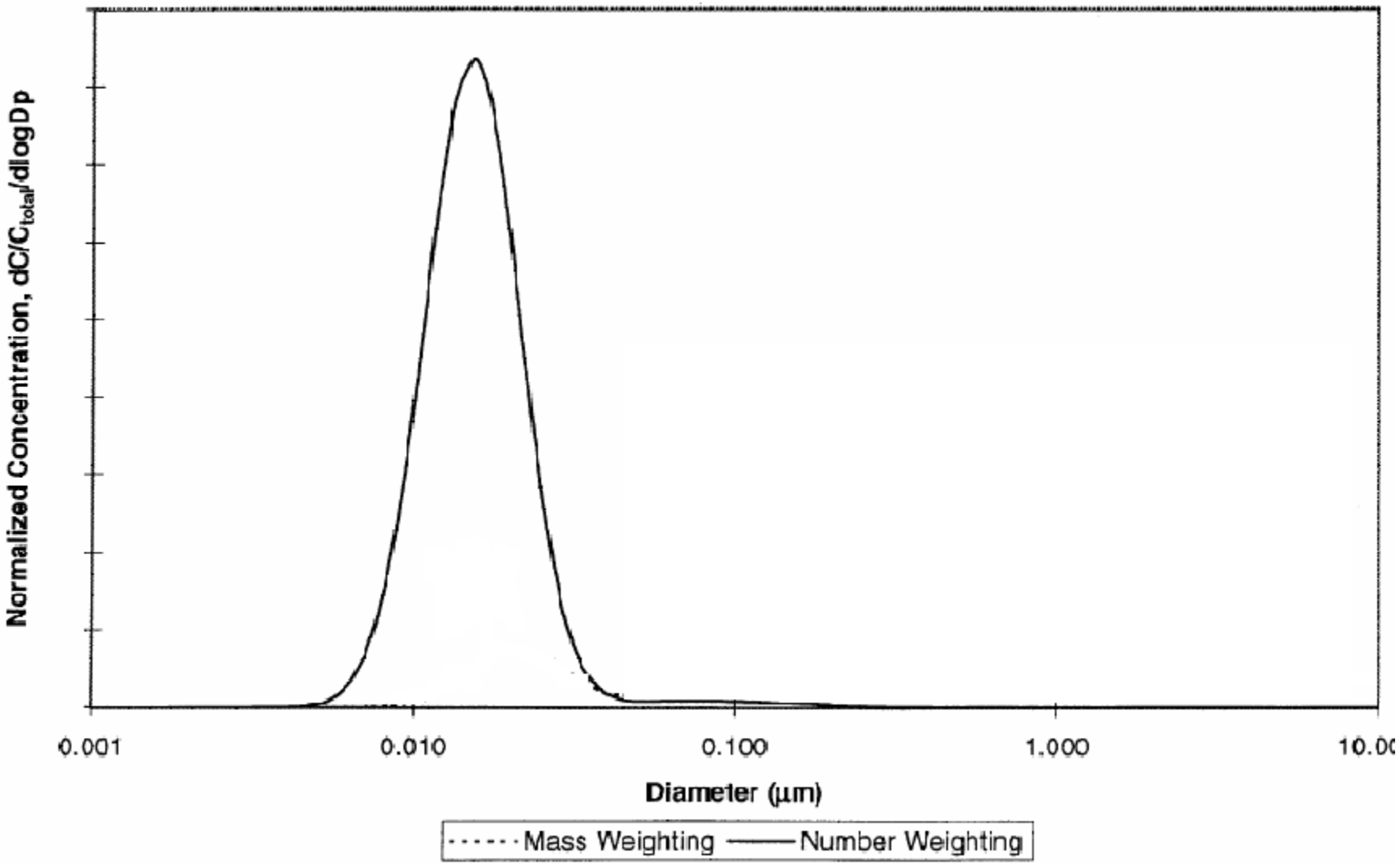
photo : Ghader agheli

FARS NEWS AGENCY

DPM Size Distribution



DPM Size Distribution



DPM Removal Methods--DOC

Diesel Oxidation Catalysts (DOC)

- Mainly removes HC (50-90%)
- Removes 30-40% of DPM on average

Advantage

Does not need maintenance

Disadvantages

Low removal efficiency

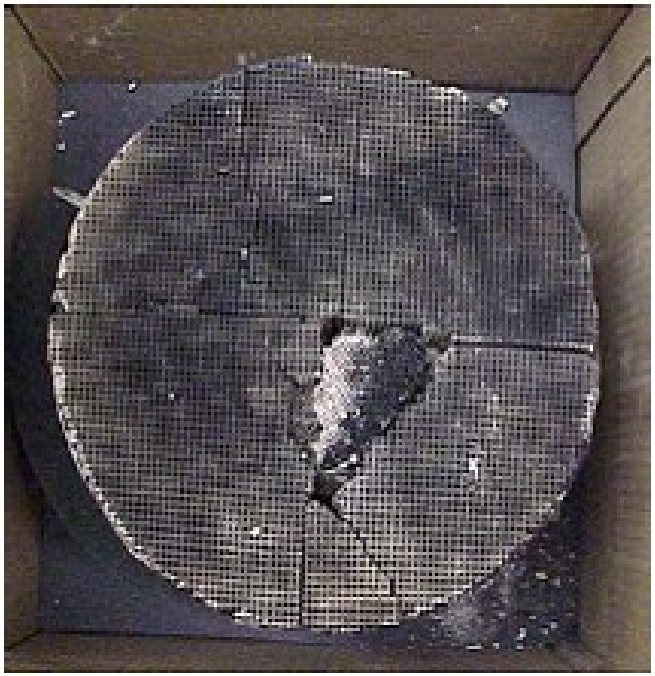
Converts SO_2 into SO_3

Costs an average of 2,000$

Diesel Particulate Filters (DPF)

Hi Temp - Melting

Temp Gradients - Fracture



Bunting *et al.*, 2002

Alternative DPM Removal Methods

- **Electrostatic Precipitators**
  - **Invented in 1907**
  - **Used in industry for a century**
  - **Low pressure drop**
  - **High efficiency**
- **Previous studies on diesel have never been commercialized**
  - **Faulkner, 1981**
  - **Masuda, 1983**
  - **Farzaneh, 1994**
  - **Saiyasitpanich, 2007**

Research Objectives

- **Determine the fundamental electrical properties of small-scale ESPs**

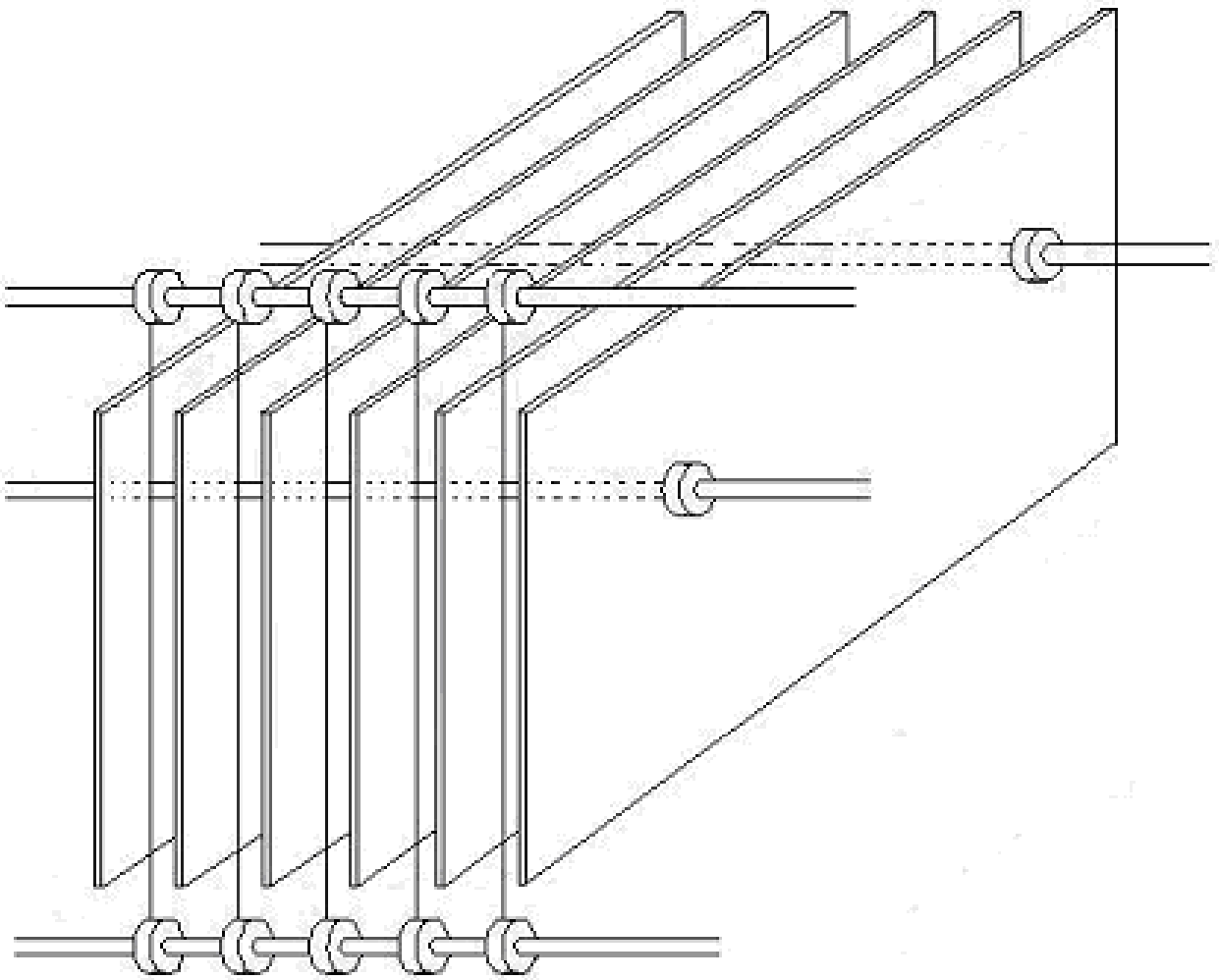
- **Measure the mass and number removal efficiencies of the small-scale ESP as a function of ESP design parameters and engine's operational condition.**

Introduction/Research Objectives

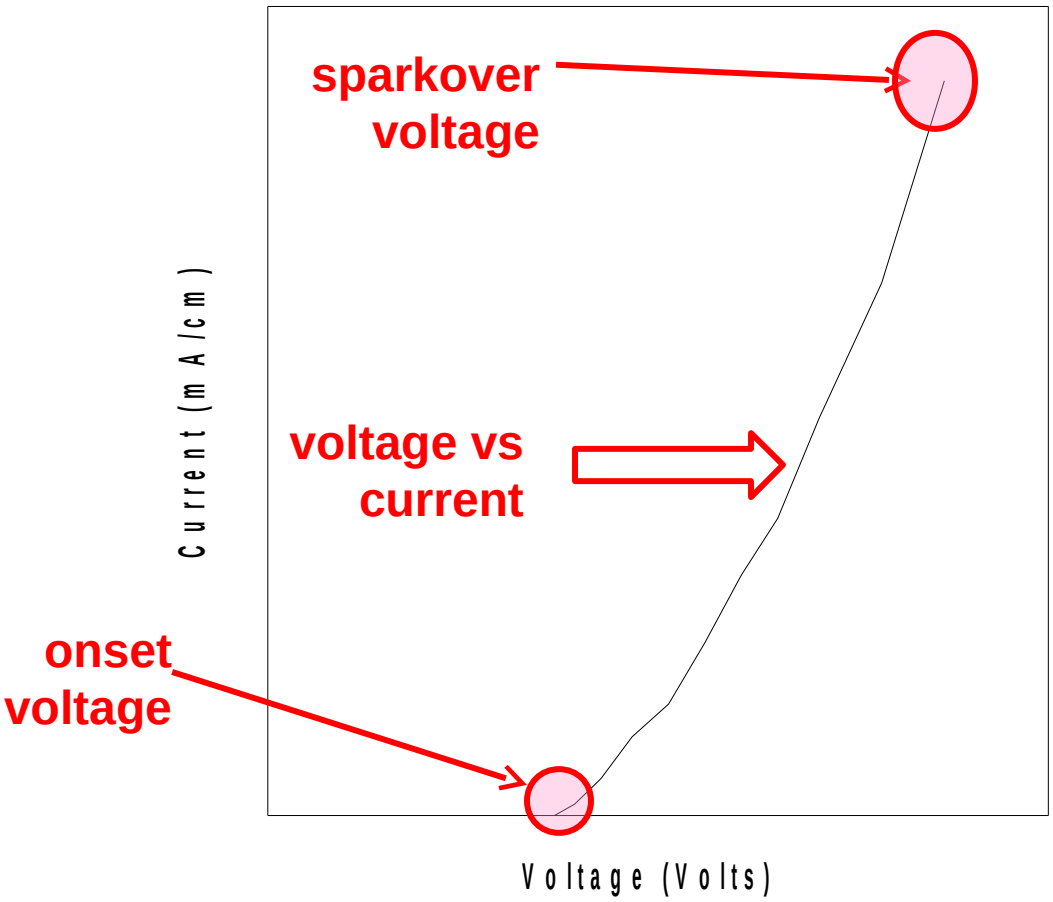
Fundamental Electrical Properties

DPM Removal Efficiency of a small-scale ESP

Conclusions



Big Picture


sparkover voltage
voltage vs current
onset voltage
Current (mA/cm)
Voltage (Volts)

Voltage versus Current

$$V = V_0 + aE_0\left[\left(\sqrt{1+\left(\frac{2ib^2}{KE_0^2a^2}\right)}\right) - 1 - Ln\left(\frac{1+\sqrt{1+\left(\frac{2ib^2}{KE_0^2a^2}\right)}}{2}\right)\right]$$

***V*: Applied voltage**

***i*: Current per length of wire**

***K*: Ion mobility**

***b*: Wire-to-plate distance**

a: Wire diameter

E_0: Onset electric field

***V0*: Onset voltage**

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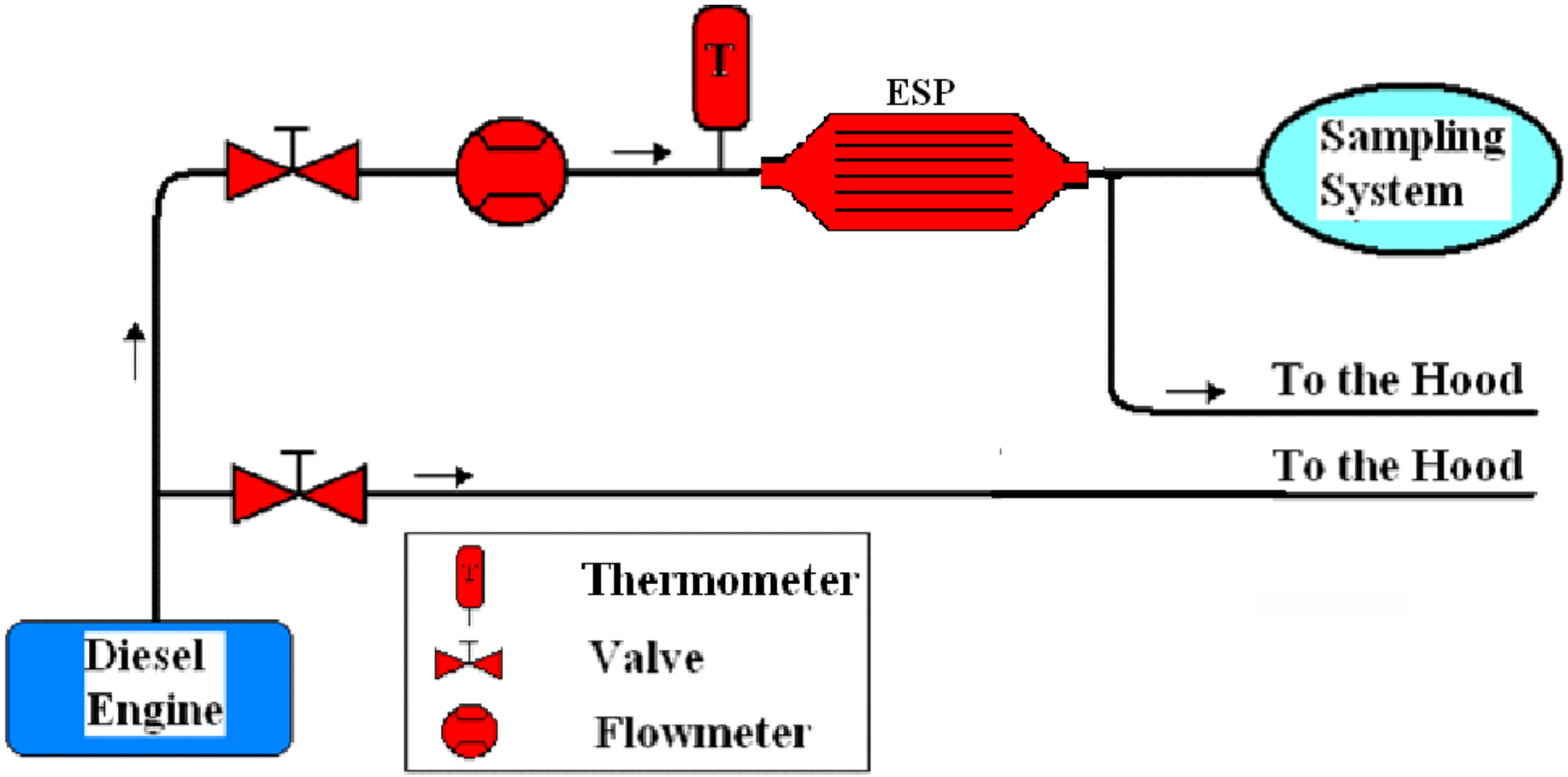
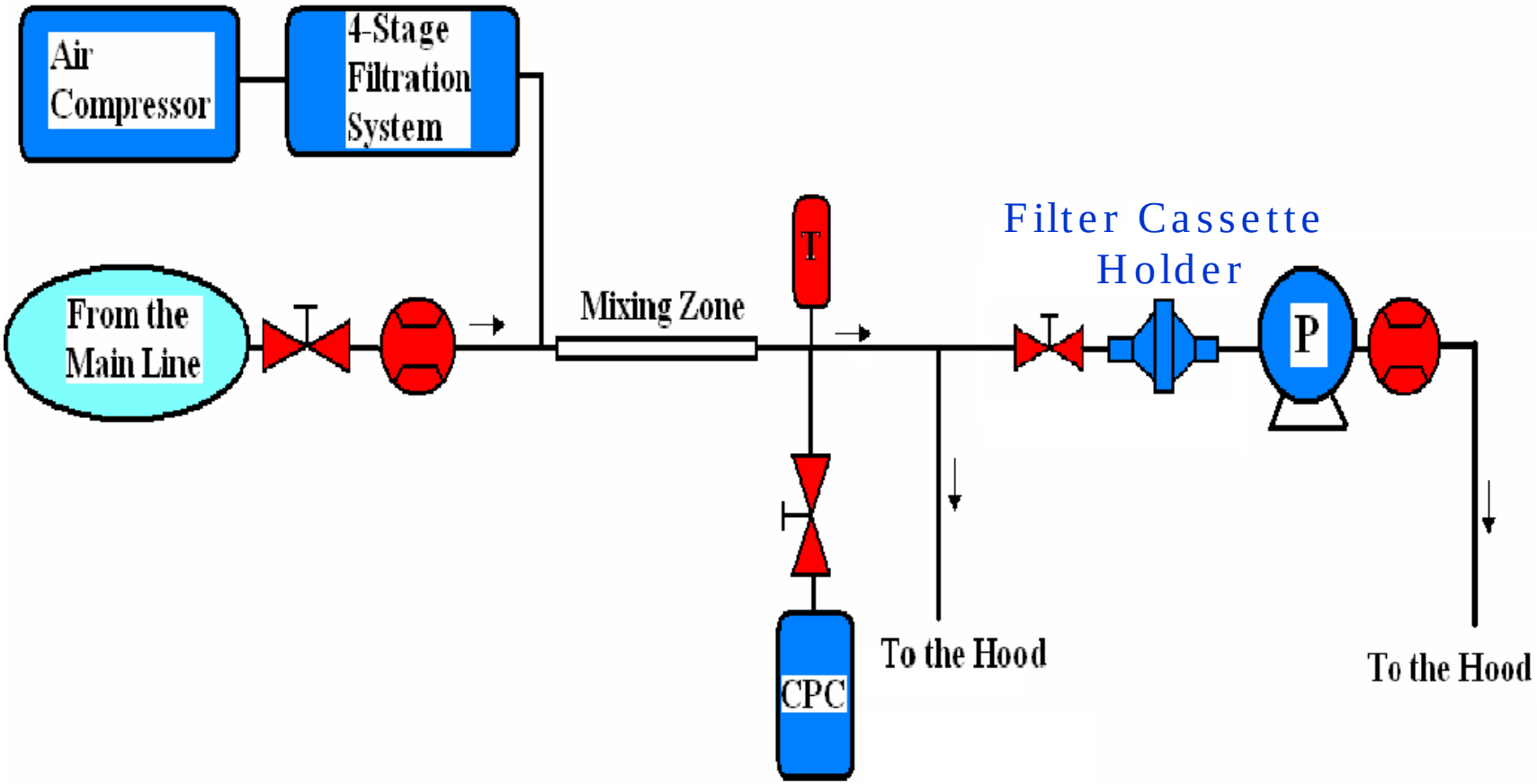
Diesel Particulate Generation System




EXIT
Diesel Generator
ESP

Sampling and Analysis System



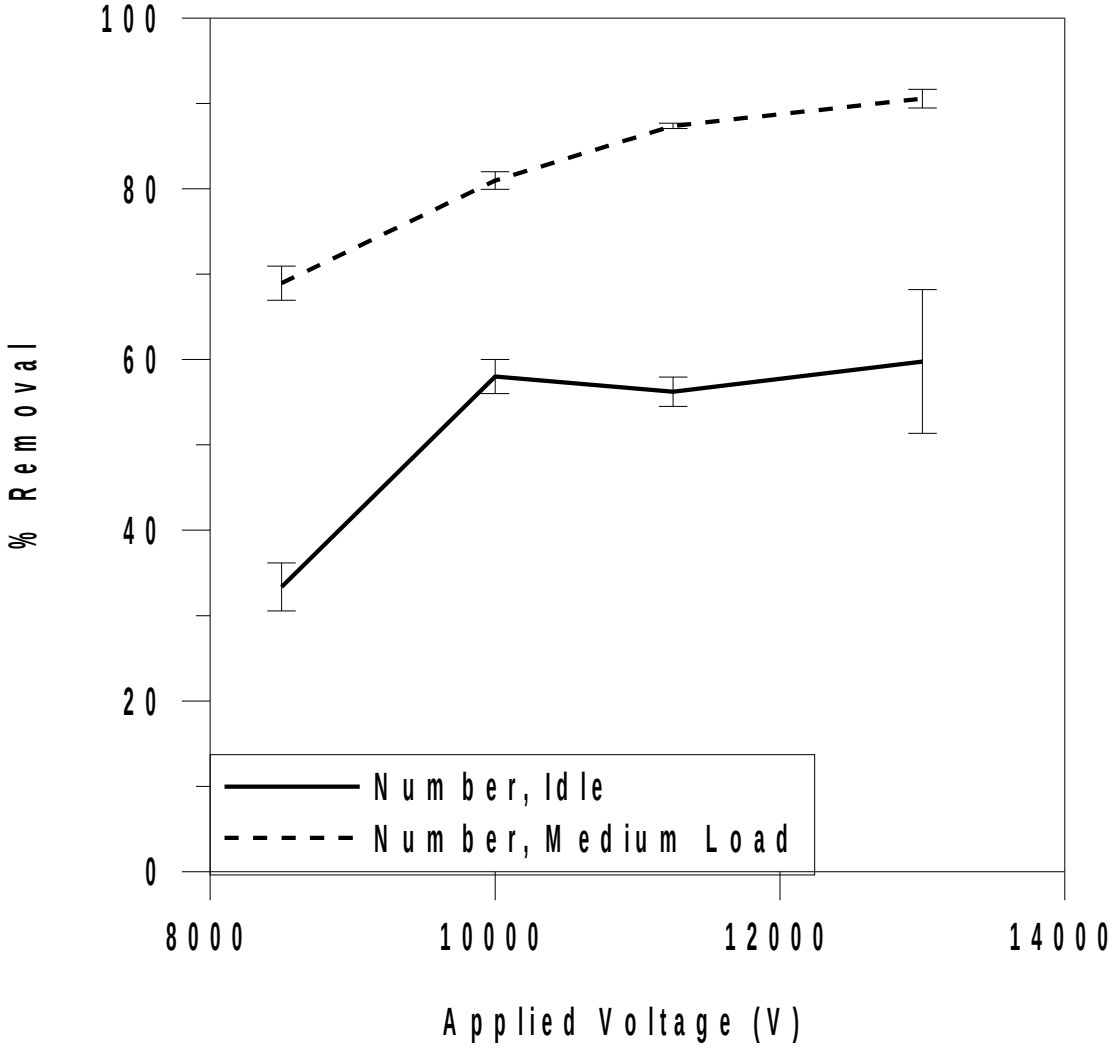
Different Engine/Fuel Conditions

- Idle vs. Medium Load vs. High Load
- Low Sulfur vs. Ultra Low Sulfur Diesel
  - Idle and Medium Load
- Alternate ESP Design

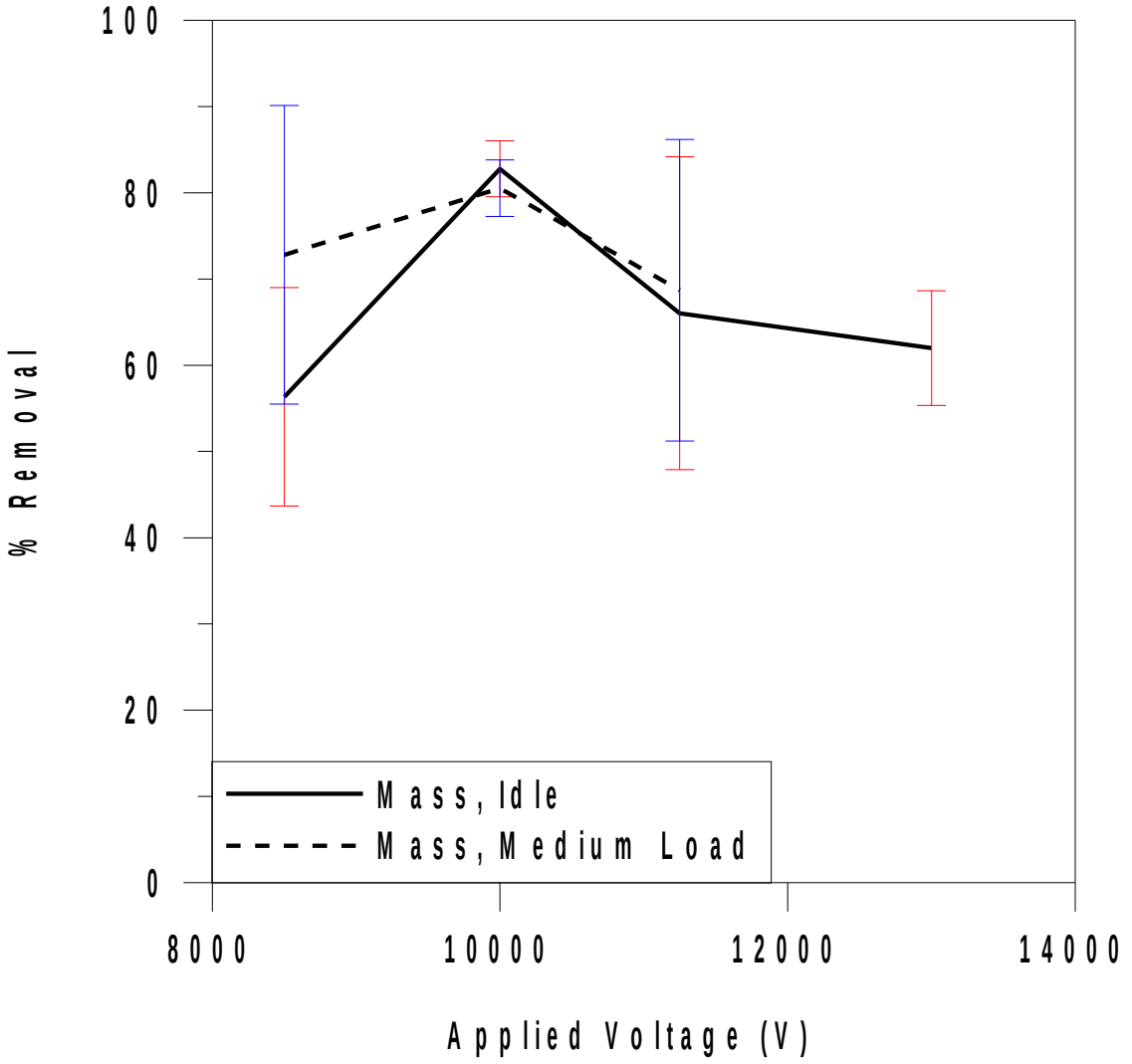
Idle vs. Medium Load Experiments

- Mass and number removal efficiencies were measured when
  - The engine was running idle
  - The engine was running at medium load
- BC mass with the ESP off and ESP on was measured for both load conditions
- Low Sulfur Diesel (LSD) were used in these experiments

Number Removal Efficiency



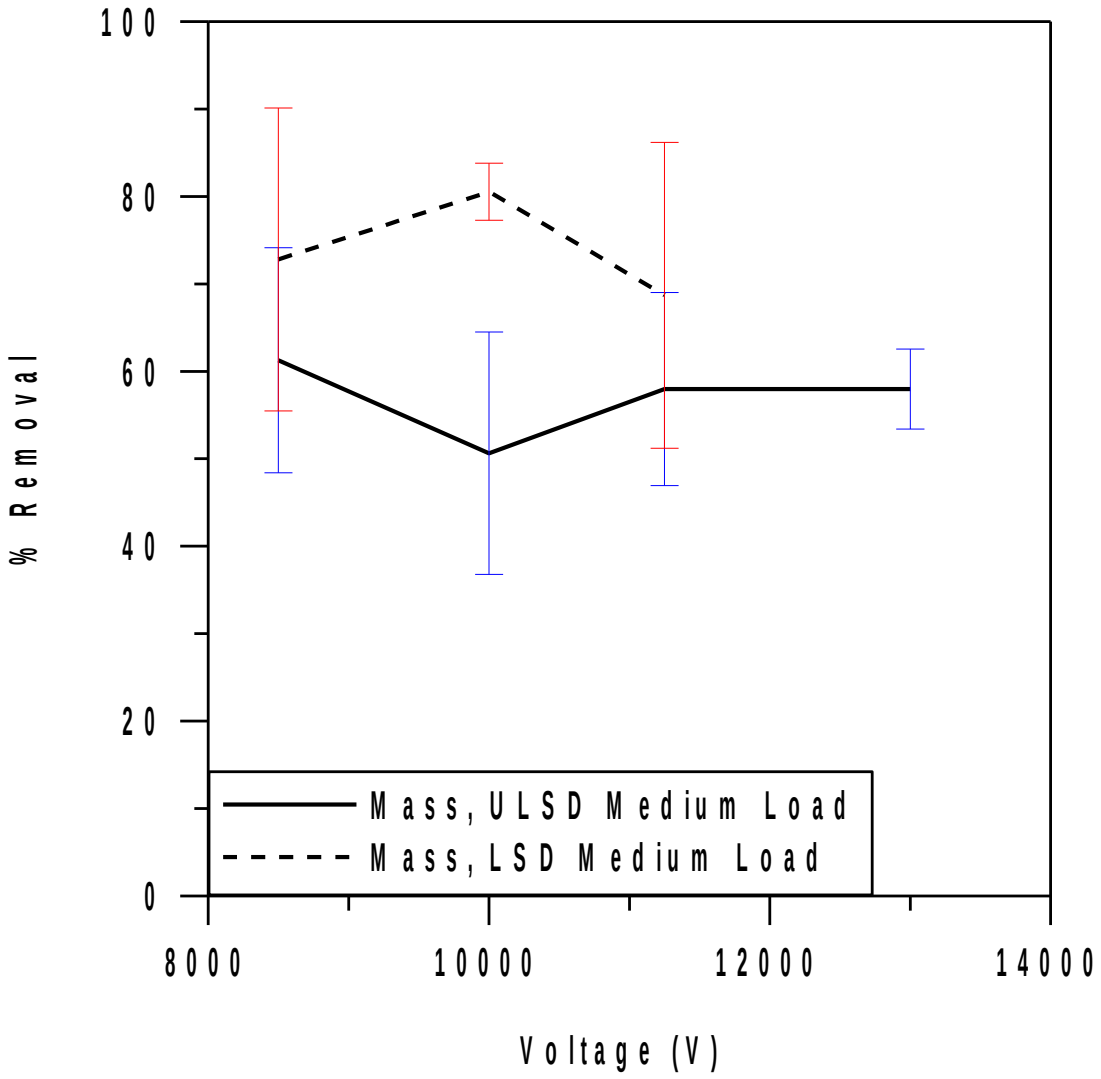
Mass Removal Efficiency



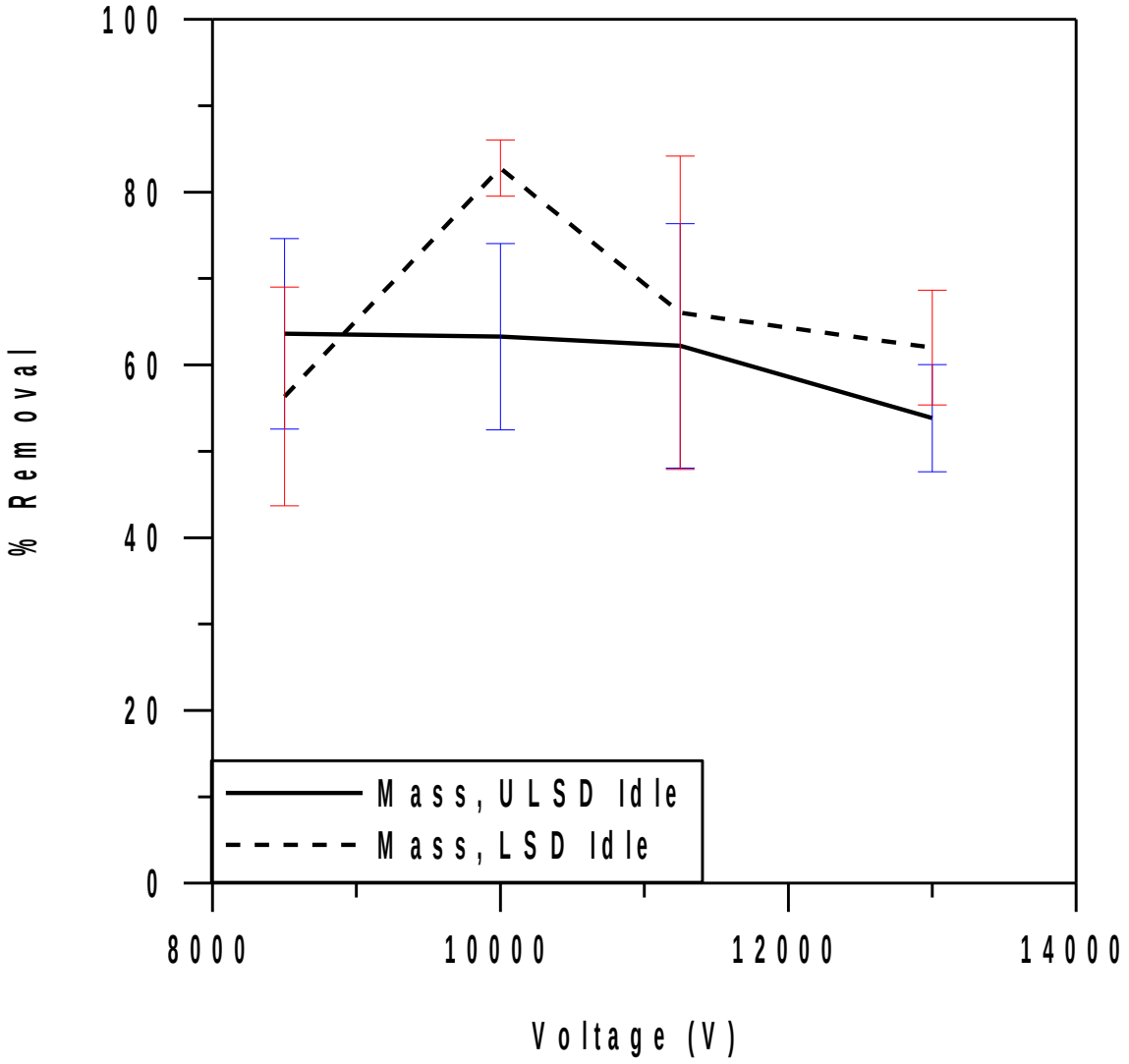
LSD vs. ULSD Experiments

- Tests were run with LSD and ULSD at two different load conditions:
  - The engine was running idle
  - The engine was running at medium load
- BC mass with the ESP off and ESP on was measured for both load conditions
- Sulfur content of the fuel:
  - 550 ppm for LSD
  - 16 ppm for ULSD

Mass Removal Efficiency: LSD vs. ULSD



Mass Removal Efficiency: LSD vs. ULSD



Conclusions

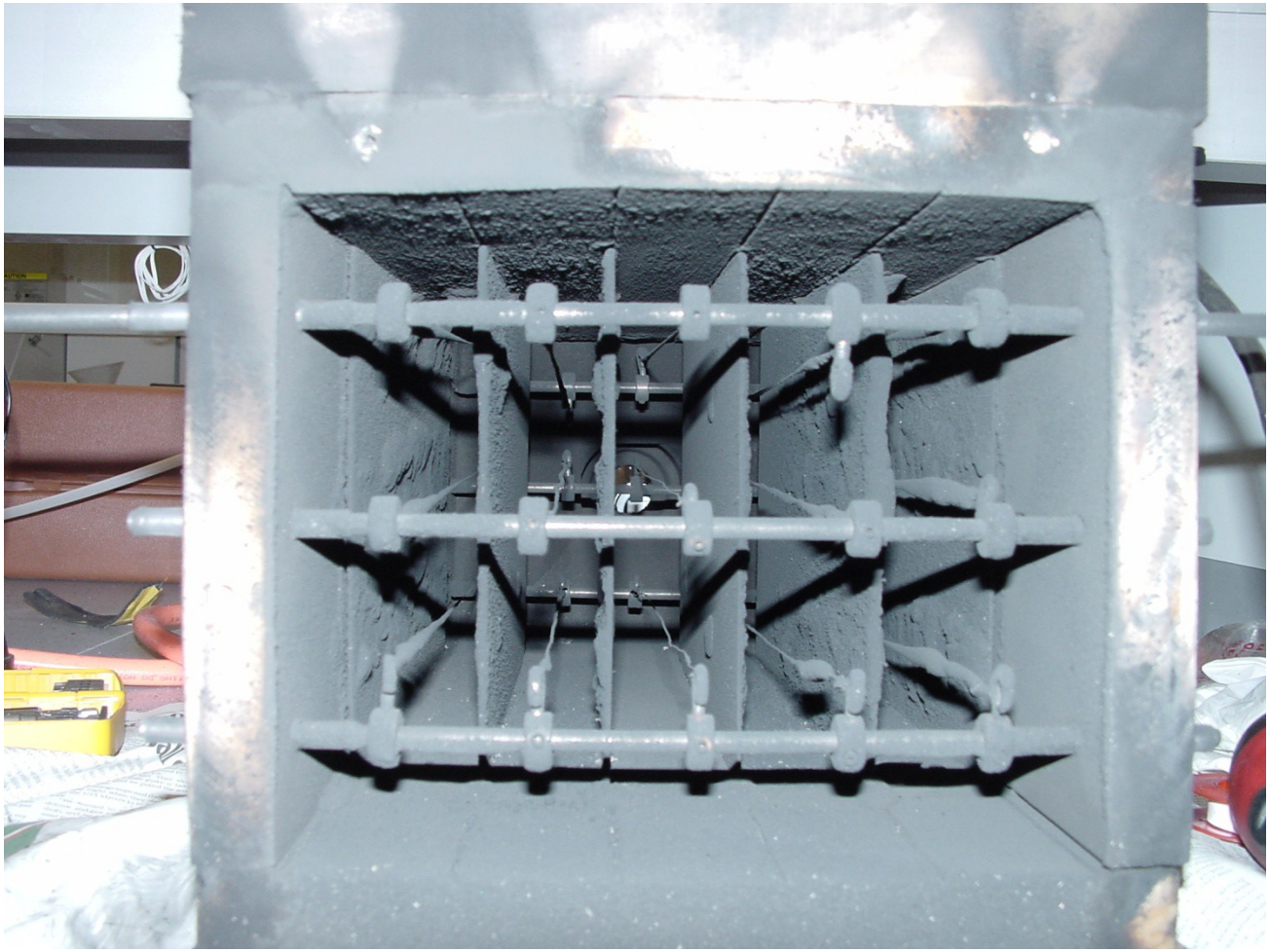
- The ESP can remove 60 to 90 percent of the particles
- Number removal efficiency is much higher when there is a medium load on the engine compared to idle conditions.
- Mass removal efficiency is almost the same for both load conditions.

Conclusions

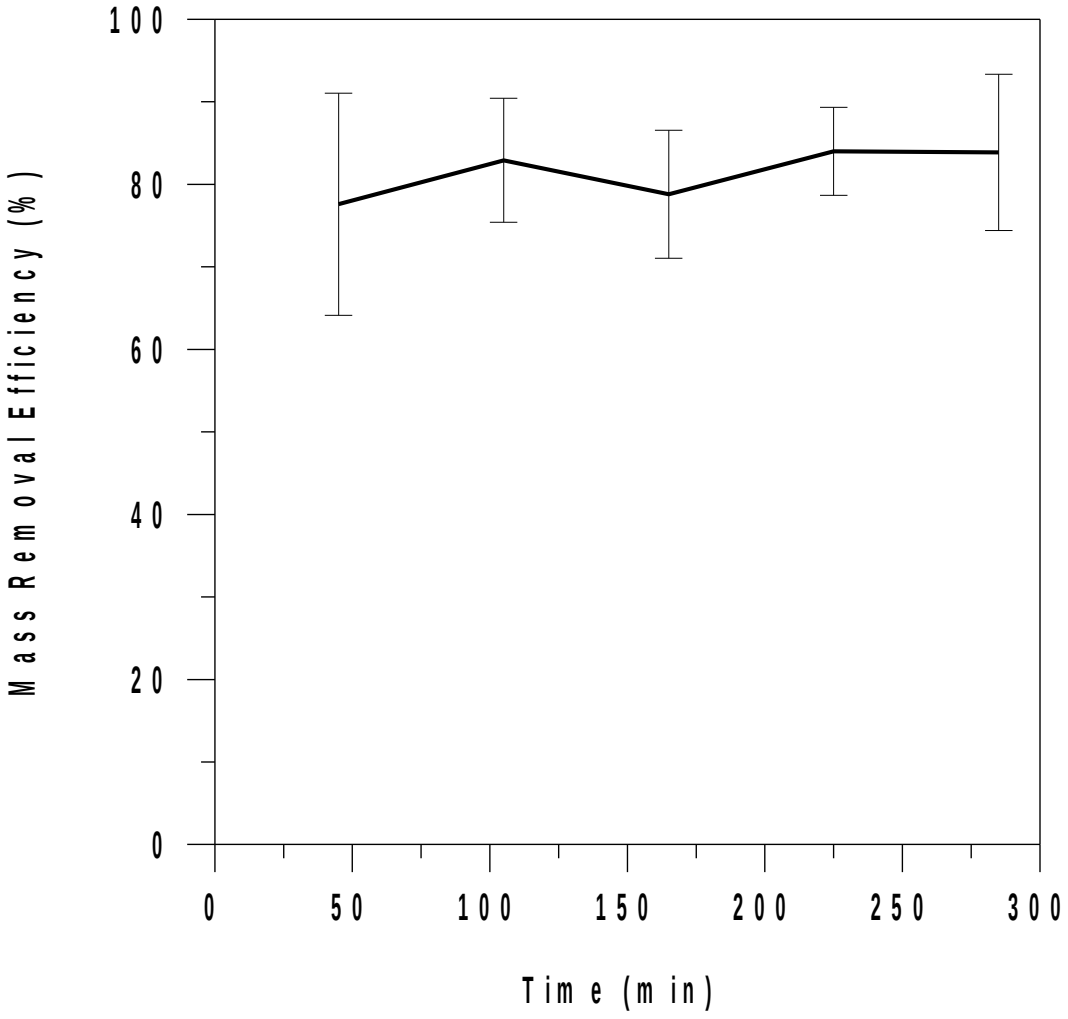
- **ESP removed 60 percent of the mass for ULSD and up to 80 percent for LSD for both load conditions.**

- **At medium load, ESP's performance with LSD fuel is better than ULSD. However, at idle load, performances are not significantly different**

A New Design for the ESP



Longer-term Tests: New Design



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Conclusions-DPM Removal Efficiency

Tests at different loads with LSD showed that:

- **The ESP reached 90% number-based efficiency and 80% mass-based efficiency at medium load**
- **Mass-based efficiency reached a maximum of 80% at idle load. Number-based efficiency was 60%.**

Mass-based tests with different types of fuels showed that:

- **Efficiency of the ESP at medium load was around 15% more with LSD than ULSD**
- **At idle load, the efficiencies were not significantly different**

Conclusions-DPM Removal Efficiency

A new design of the ESP with wires parallel to the flow was tested. The results showed that:

- This ESP could reach 80% mass-based and number-based efficiency. Mass-based efficiency dropped by 20% after applying load.
- The ESP worked for 12 hours with no need for cleaning and an average of 80% mass-based efficiency with 20 watts power consumption.
- Current production significantly dropped after 10 hours of operation. Probably due to corona dissipation which was caused by soot deposition.

Acknowledgement

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