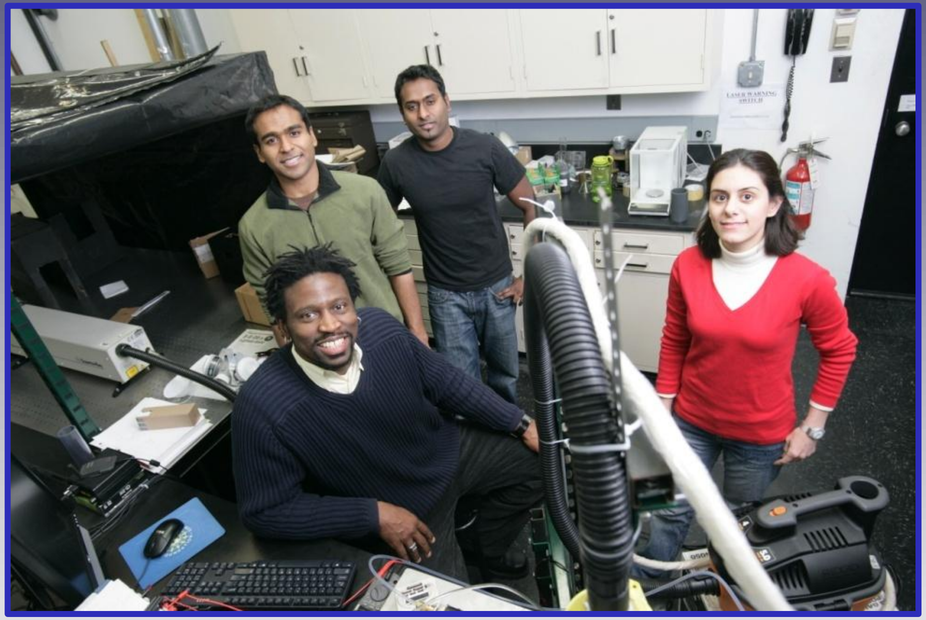
Computational Modeling of the Electrohydrodynamics Influencing Trace Mercury Adsorption within Electric Utility Electrostatic Precipitators



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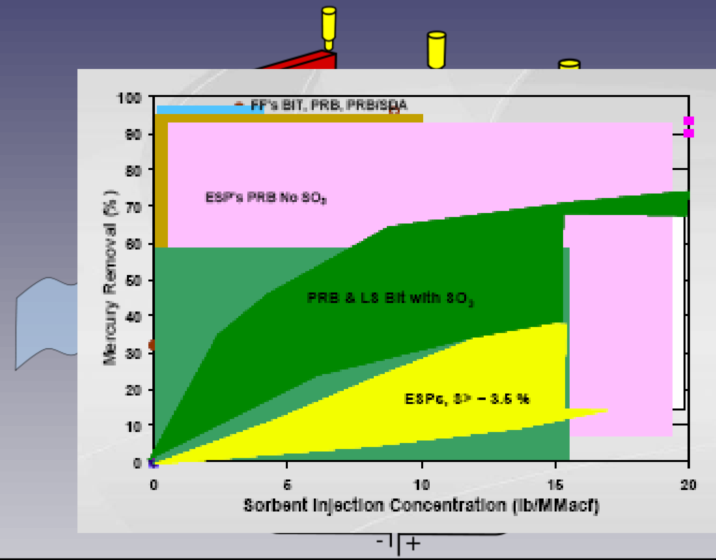
Mercury (Hg) Emissions Control

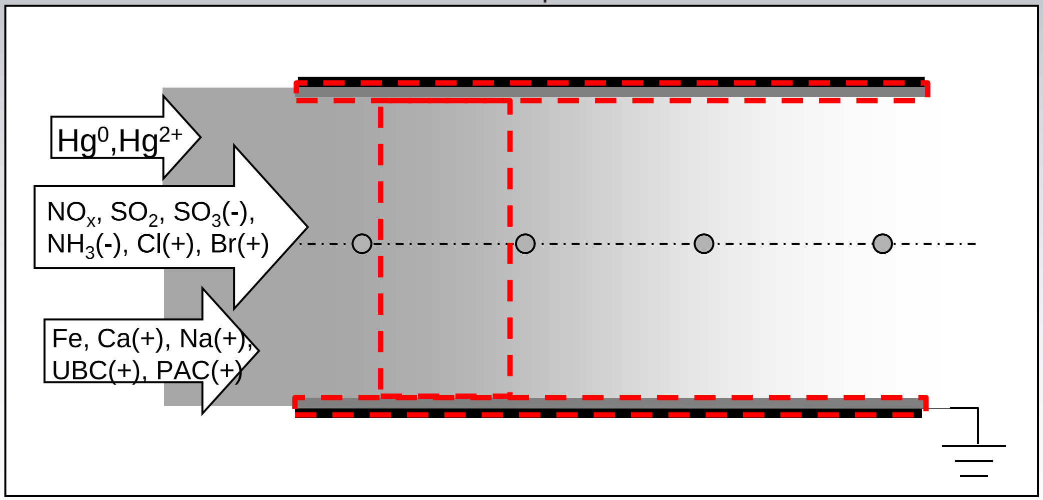
Sjostrom (2007)

- Hg emissions primarily originate from coal combustion
- U.S. EPA Mercury and Air Toxics Standard (MATS, 2013); ~90% RE
- UNEP Minamata Global Mercury Treaty (2013)
- Leading Hg control technology is injecting powdered activated carbon (PAC). PAC adsorbs Hg and is removed with ash in PMCD.
- By country, 70-99+% of coal-fired power plants use electrostatic precipitators (ESPs) for PM control

Hg Capture by PAC w/in ESPs Demonstrated but Poorly Understood

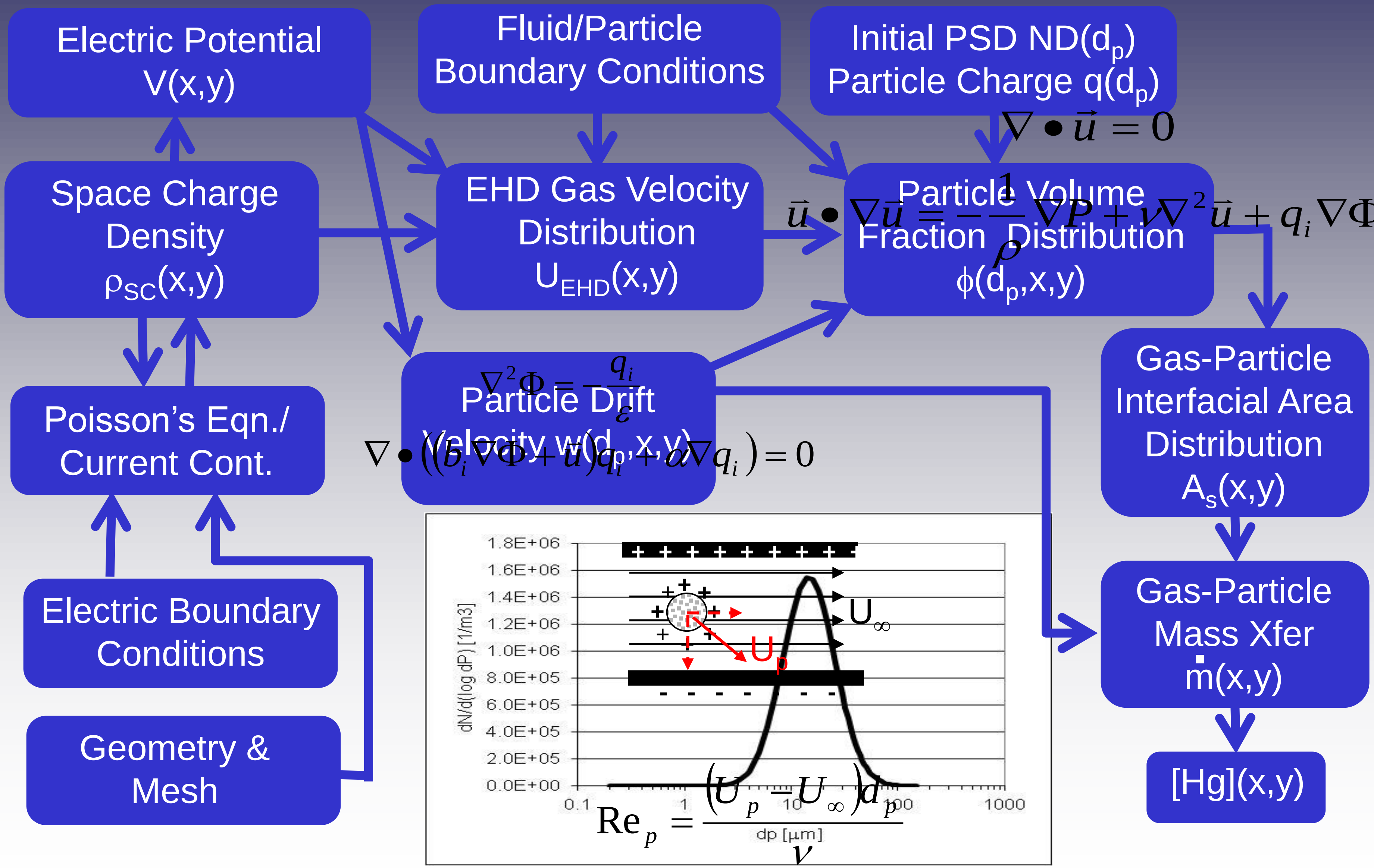
- Ion and charged particle flows w/in ESPs can induce electrohydrodynamic (EHD) phenomena & add complexity
- Low (ppb) Hg concentrations, flue gas & fly ash composition inhibit Hg removal
- Mass transfer fundamentals and full-scale data suggest at least two Hg removal mechanisms:
  - In-flight (suspended PM)
  - Wall-bounded (collected dustcake)





$\nabla \bullet \vec{u} = 0$

Computational Methodology



$$\nabla \bullet \vec{u} = 0$$

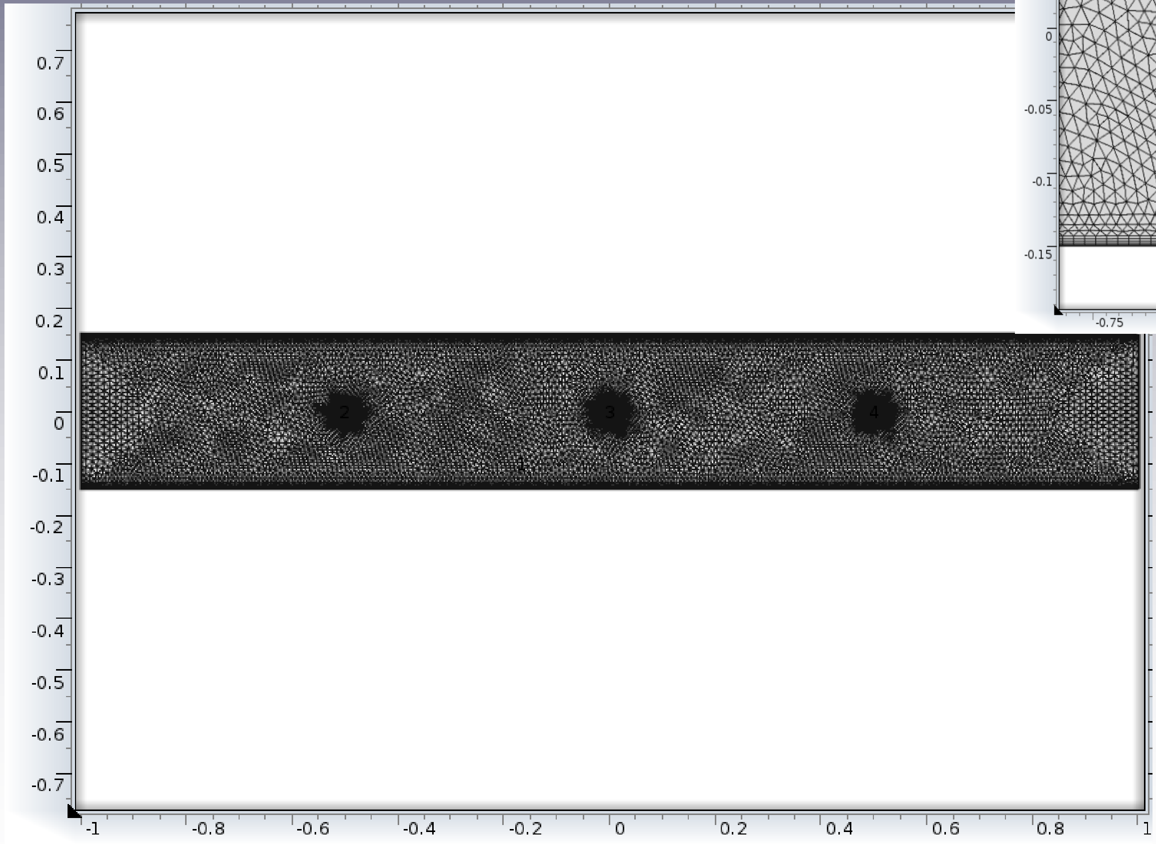
$$\vec{u} \bullet \nabla \vec{u} = -\frac{1}{\rho}\nabla P + \nu \nabla^2 \vec{u} + q_i \nabla \Phi$$

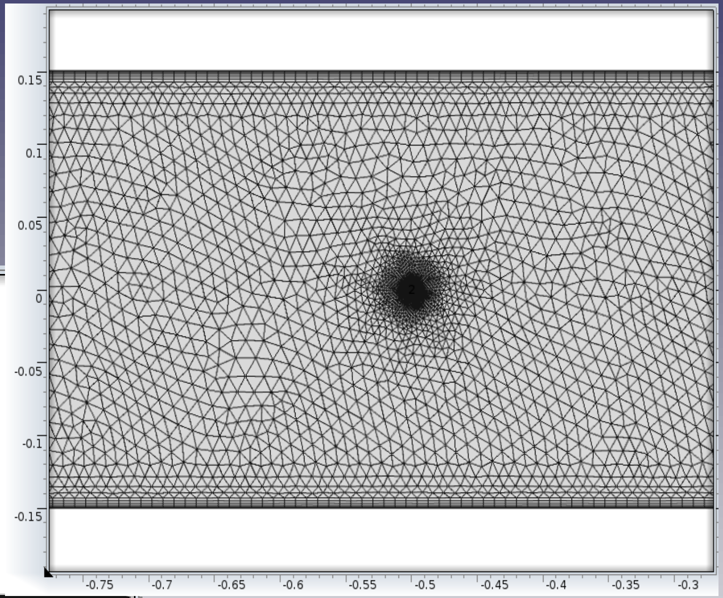
$$\nabla^2 \Phi = -\frac{q_i}{\varepsilon}$$

$$\nabla \bullet \left(\left(b_i \nabla \Phi + \vec{u} \right) q_i + \alpha \nabla q_i \right) = 0$$

$$\mathrm{Re}_p = \frac{\left(U_p - U_\infty \right) d_p}{\nu}$$

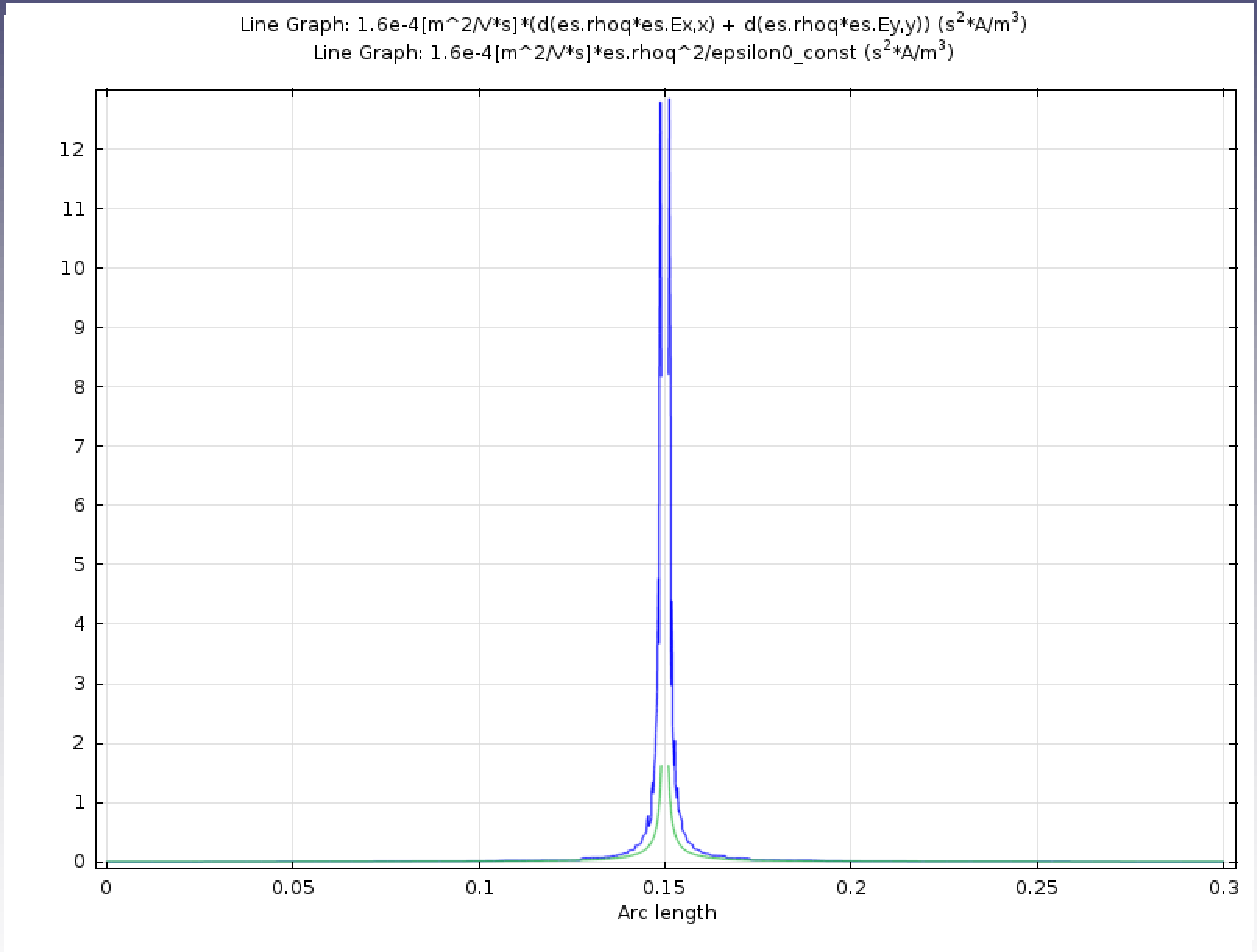
Computational Mesh





Electric Conservation Equations

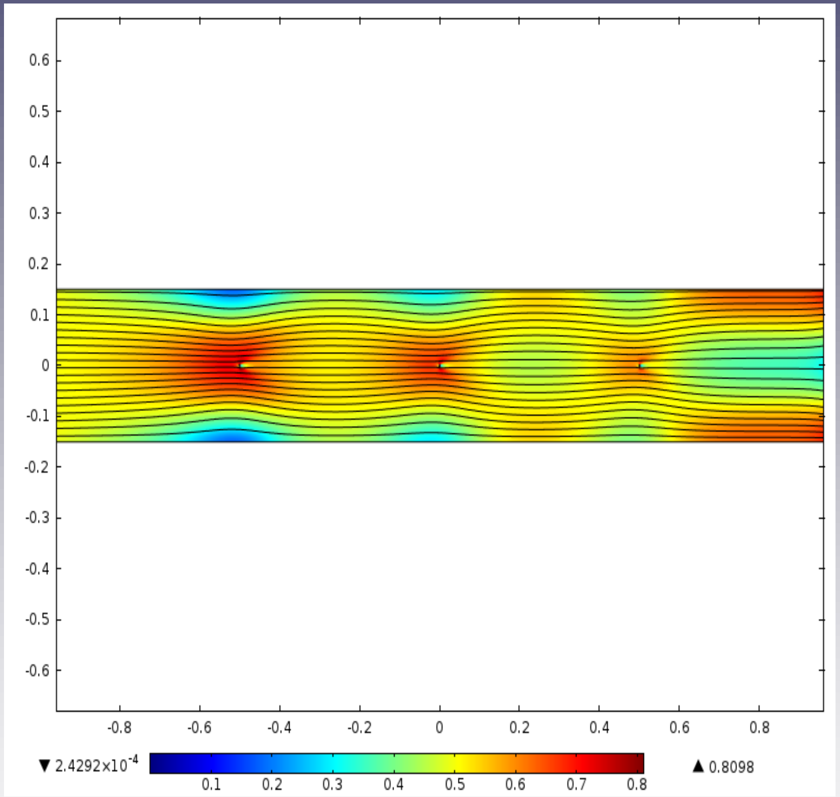
Poisson's Equation, Current Continuity



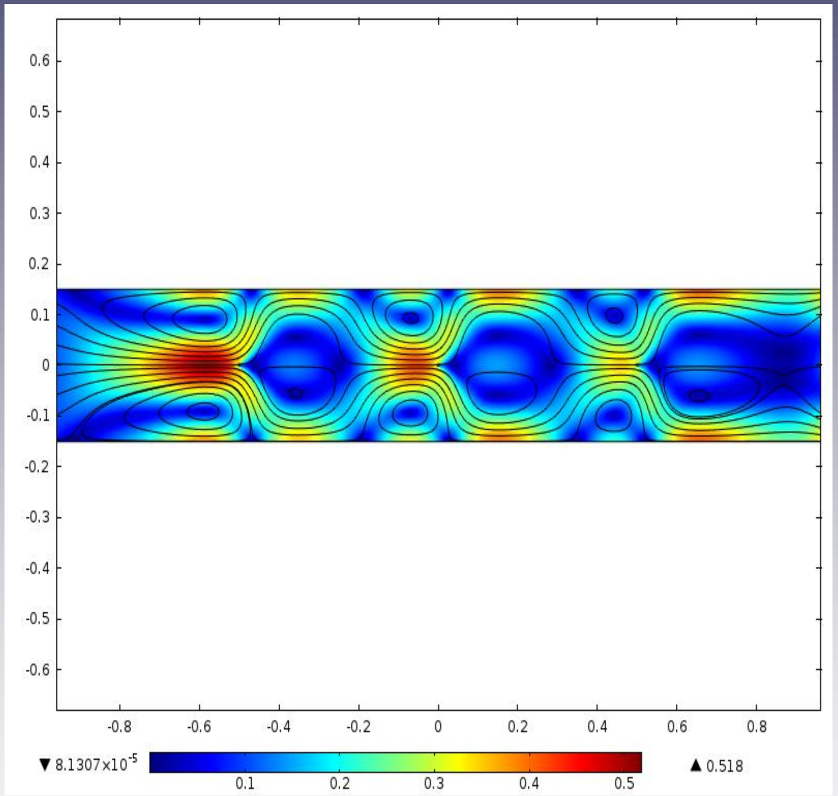
Flue Gas Streamlines & Velocity Color Maps

Low and High EHD Effect

Lo EHD effect



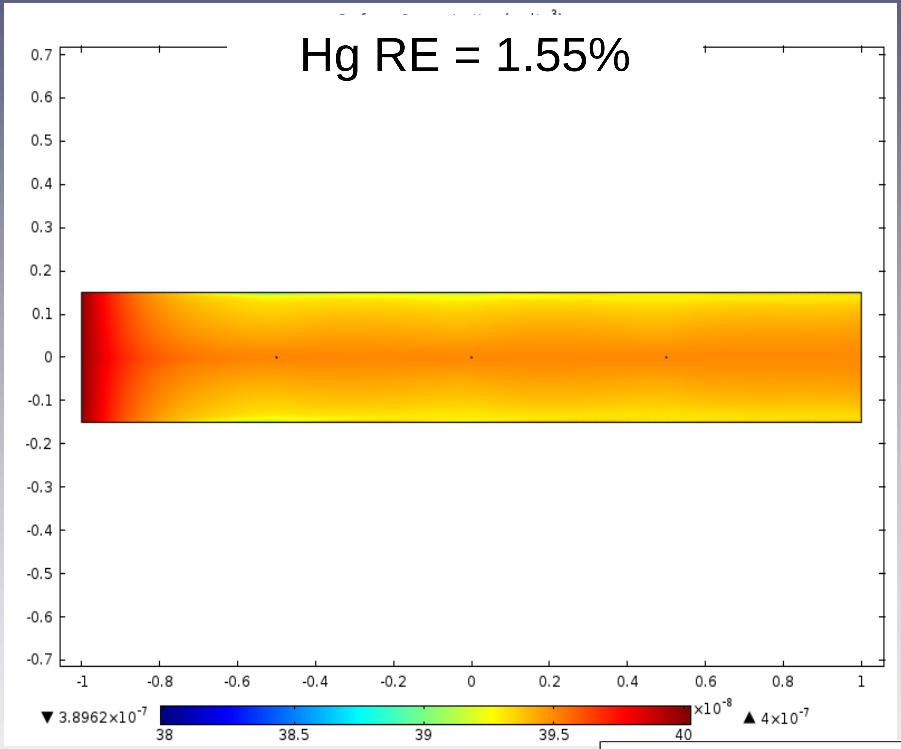
Hi EHD effect



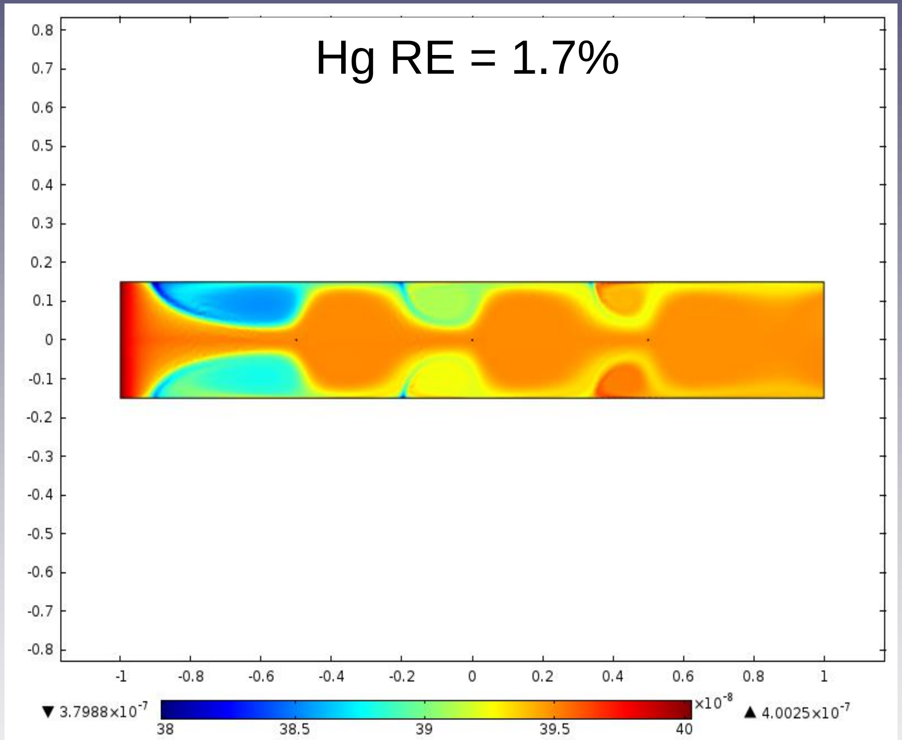
Composite In-flight Hg Adsorption (1.5-150 μm)

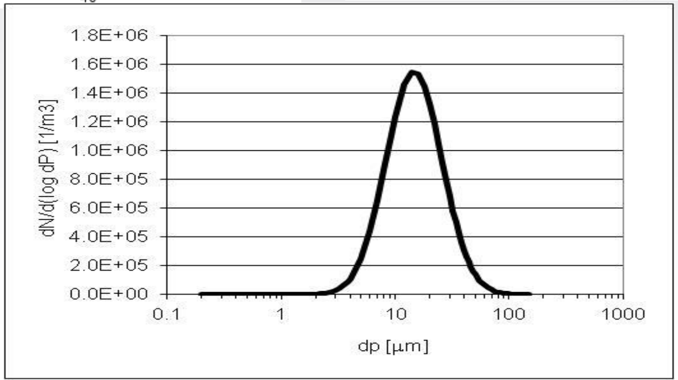
PAC Injected at 6 lbs/MMacf (0.098 g/m^3)

Lo EHD effect



Hi EHD effect

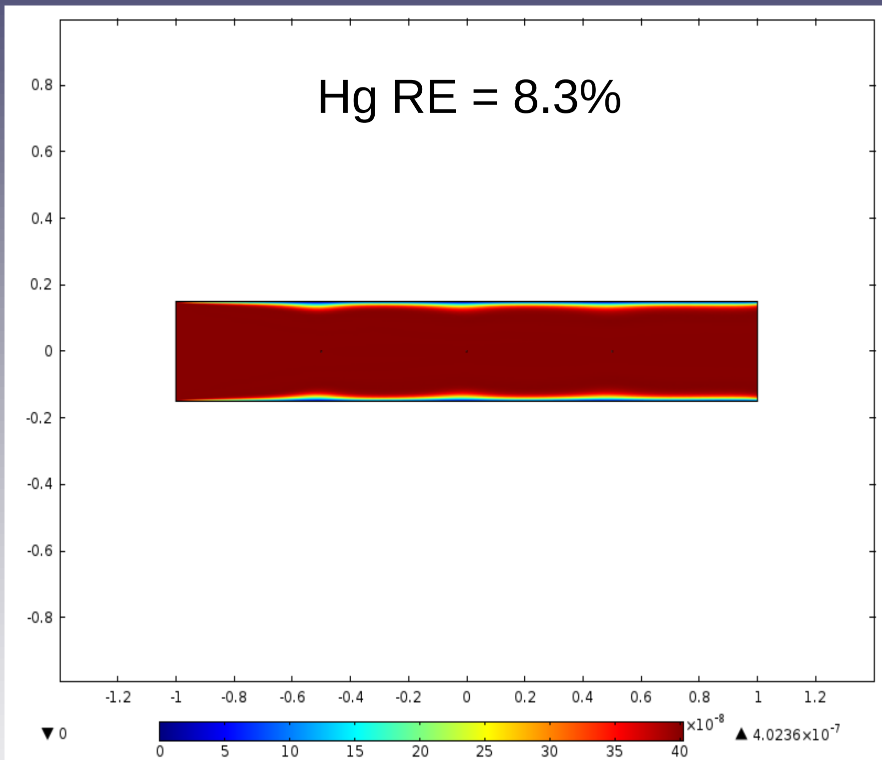




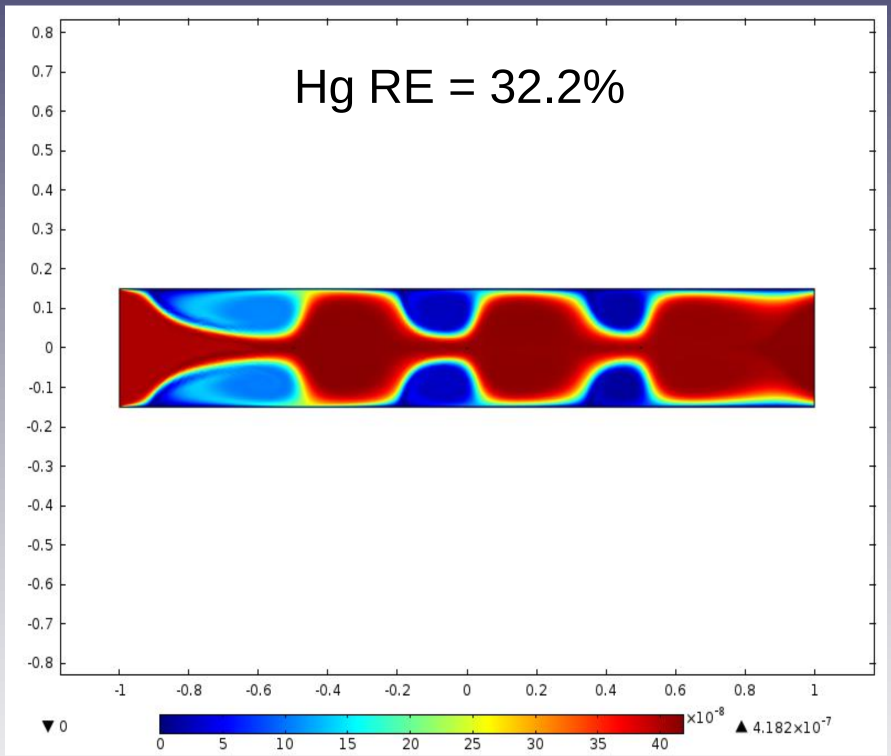
Wall-Bounded Hg Adsorption

Collection Electrode Dustcake Acts as Perfect Mercury Sink

Lo EHD effect



Hi EHD effect



Conclusions

- Opportunities exist to exploit EHD for combined Hg and PM control within ESPs through:
  - Modified ESP design and/or operation
  - Modification of sorbent electrical properties
- Next steps include:
  - Add chemical kinetic Hg adsorption mechanism
  - Re-entrainment of PM during electrode cleaning

Thank You!
Questions?

This work would not have been possible without COMSOL^{TM} Multi-physics simulation suite.

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