PARTICLE GENERATOR FOR ENGINE EXHAUST SIMULATION

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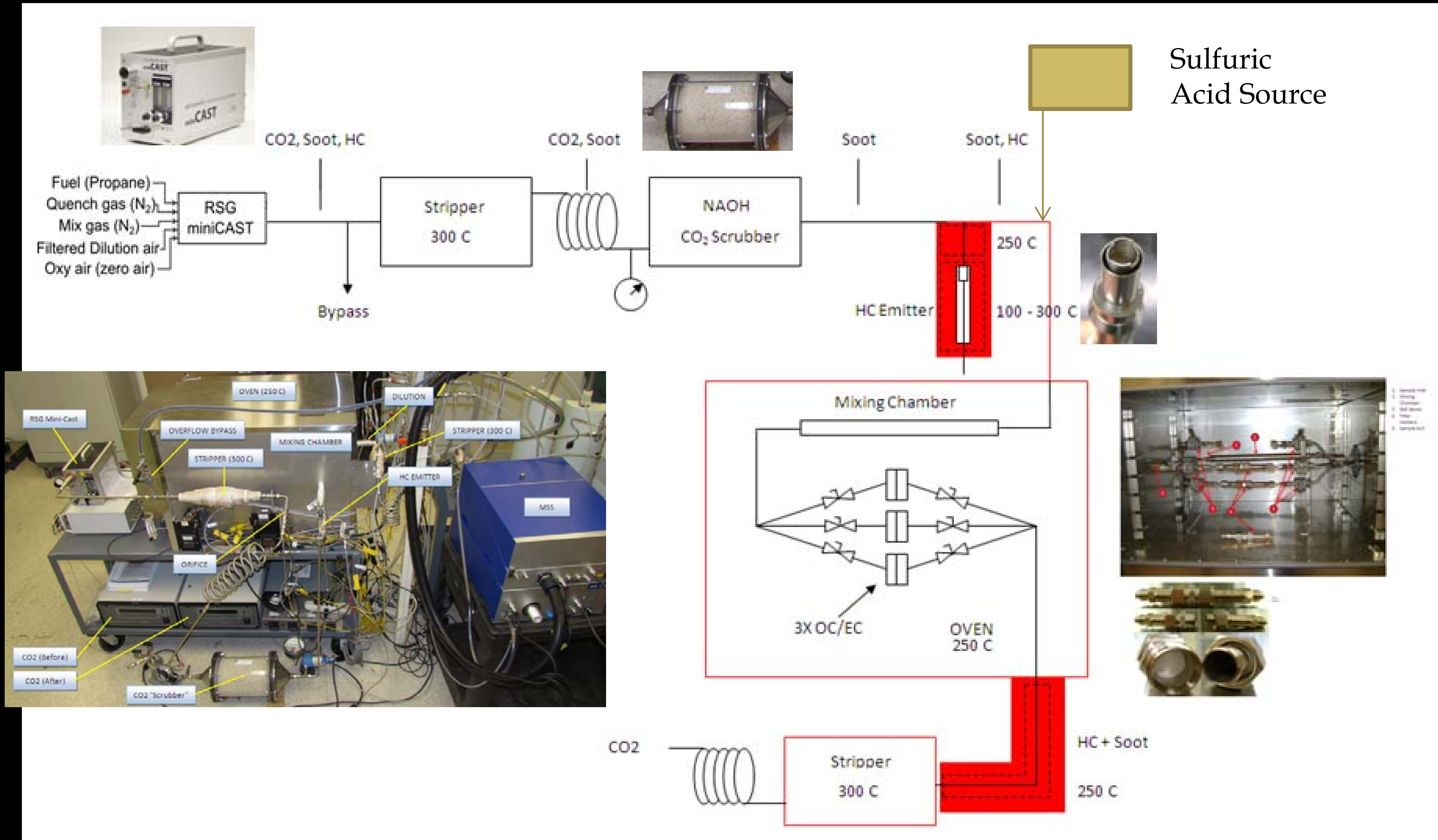
Objectives

- This is work in progress. The objective is to develop a laboratory particle generator that can simulate engine exhaust aerosol and be used for PM research and development to assist in better understanding:
  - Gas/PM phase partitioning
  - Gas/PM phase transport & losses in sampling systems
  - Filter negative/positive artifacts
  - Particle nucleation and growth
  - Particle instrument performance and accuracy
  - Modeling using COMSOL and OpenFoam
  - Consideration of future standards related to different metrics such as particle mass and/or number
  - Other research elements

PM Generator
(Housed in SwRI Nanoparticle Laboratory)

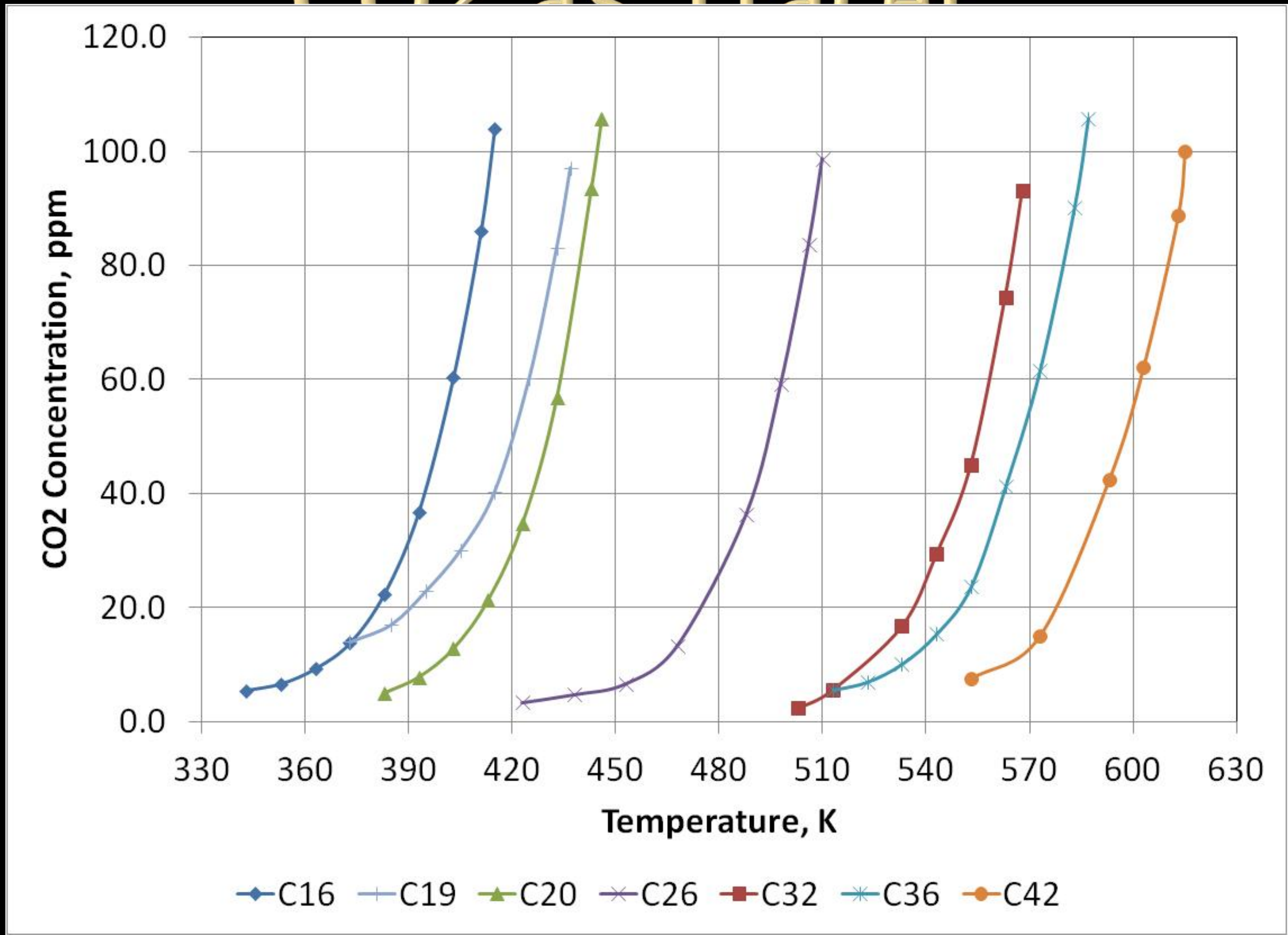


Elemental Carbon + Hydrocarbons (C1-C42) + H_2SO_4

Features

- Elemental Carbon or Soot
  - Min-CAST + Catalytic Stripper
- HC Source
  - Developed a HC generator
  - Controlled C16 to C42 (alkanes for now but flexible to add any other compounds)
  - Concentration range: 0 to 100 ppmC
  - CO2 for hydrocarbon detection
- Sulfuric Acid Source
  - SO2 + catalytic stripper + H2O
  - Concentration range: 0 to 100 ppm
  - SO2 for H_2SO_4 detection
- Other Sources like ammonia and can be easily added

Generating Different Hydrocarbon Profiles & Using CO2 as Tracer



HC Mass Concentration Range from 0 to ~ 60 mg/m^3

HC Recovery Using CO_2

	Measured	CO2-Based	% Difference
	mg/m³	mg/m³	
C16	16.74	17.20	2.7%
C20	28.82	29.85	3.6%
C26	29.45	29.50	0.2%
C32	34.95	34.66	-0.8%
C36	31.48	29.82	-5.3%
C42	26.45	21.62	-18.3%

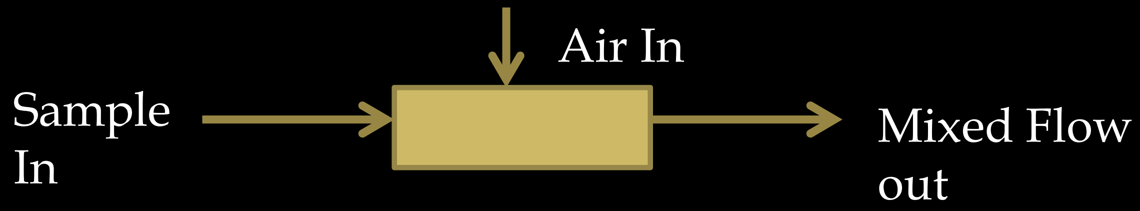
Measured: Weight Difference before and after

CO2-Based: Based on CO2 Measurement Downstream of Catalytic Stripper

HC was transported at 250°C
Catalytic Stripper was operated at 300°C
The system seems to suggest losses of C42 at temperature of 250°C

Normal Alkanes Nucleation in Simple Tee Diluter

- Problem Statement:
  - In our earlier work, we had several publications on the effect of dilution conditions on particle formation and growth:
  - We indentified :
    - Dilution ratio, dilution air temperature, residence time, relative humidity, transfer tube temperature as playing a major in effecting total particle number and size
  - We did not investigate the effect of diluter design on particle formation and growth in a systematic way
- The goal of these activities is to look at various diluter designs to study particle nucleation and growth starting with simple Tee diluter (aided with modeling)

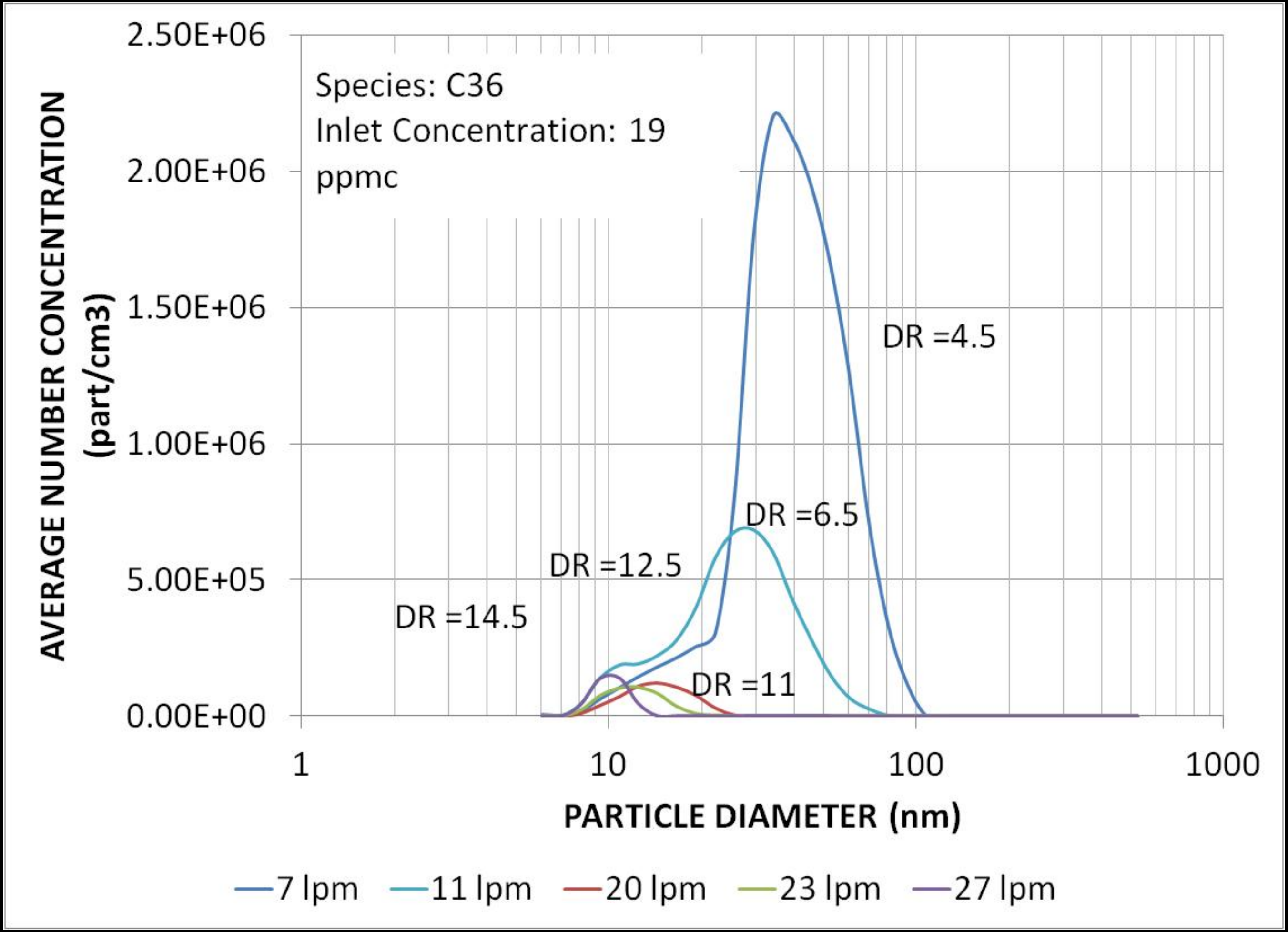


Normal Alkanes Nucleation

- Ei-, Do-, Hexa-cosane (C20, C22, and C26) did not nucleate and grow using the following parameters:
  - Saturation pressure ratio of ~2000
  - Sample Temperature 250C
  - Dilution air temperature 25C
  - Dilution Ratio 4.5 to 14.5
- Only Dotria- and Hexatria-contane (C32 and C36) nucleated and grew, but required **extremely high saturation pressure ratio**

Example of C36 Nucleation at Various Dilution Ratios

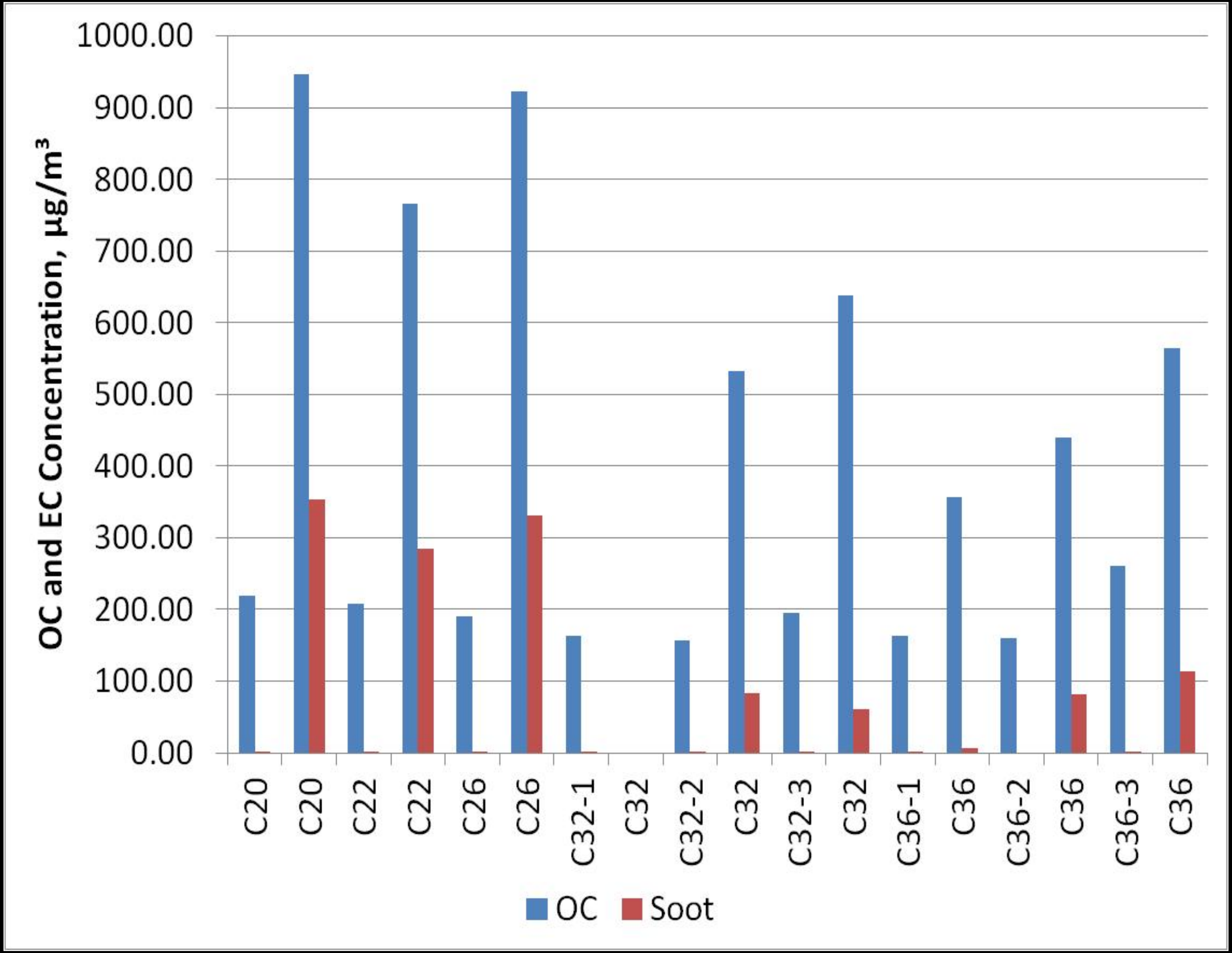
- It takes an extremely high saturation pressure ratio to nucleate and grow normal alkanes
- Significant part of the material is lost to the walls of the sampling system.
- The OC recovery after the lowest dilution was about ~8%



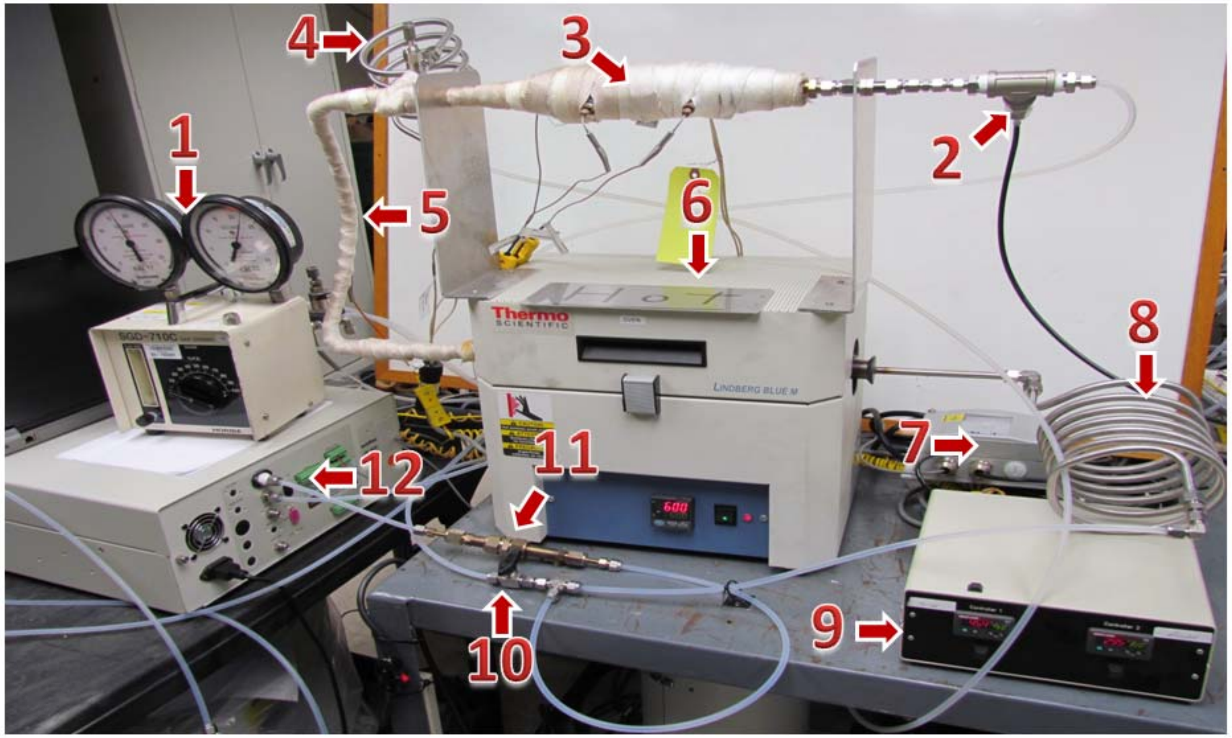
Hydrocarbon Transport in the Presence and Absence of Soot

•Significant HC loss was observed in the absence of soot. Soot acts as a transport mechanism of species

•This poses a challenge to the measurement of toxic compounds emitted from modern engines with DPF in the absence of soot.



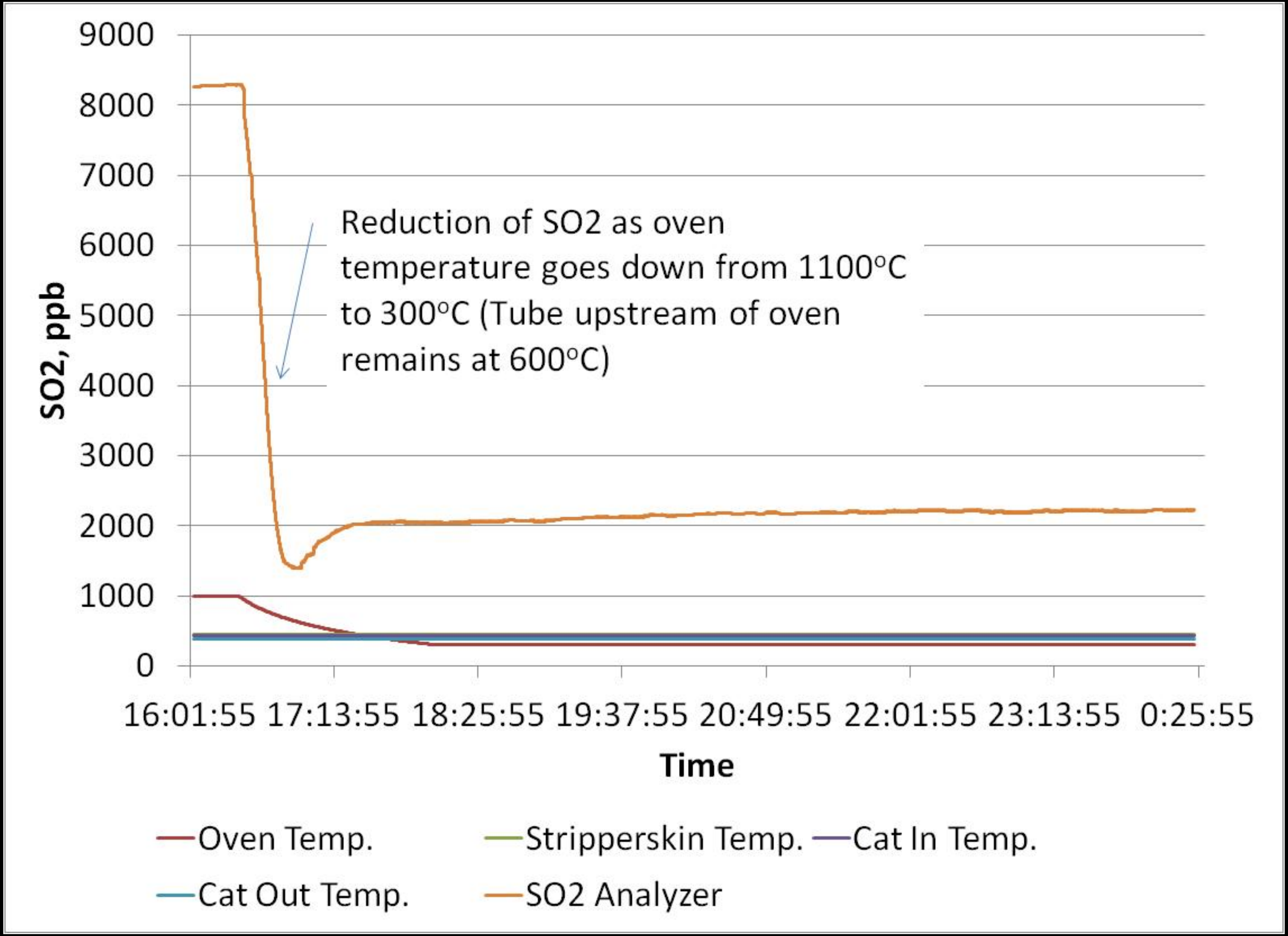
Sulfuric Acid Generation System



1. Gas Divider
2. RH Sensor
3. Catalyst
4. Bypass After Catalyst
5. Heated Tube from Catalyst to Oven
6. Oven
7. RH Analyzer
8. Cooling Coil Oven Out
9. Temperature Control Box
10. Bypass After Oven
11. TX Filter
12. SO2 Analyzer

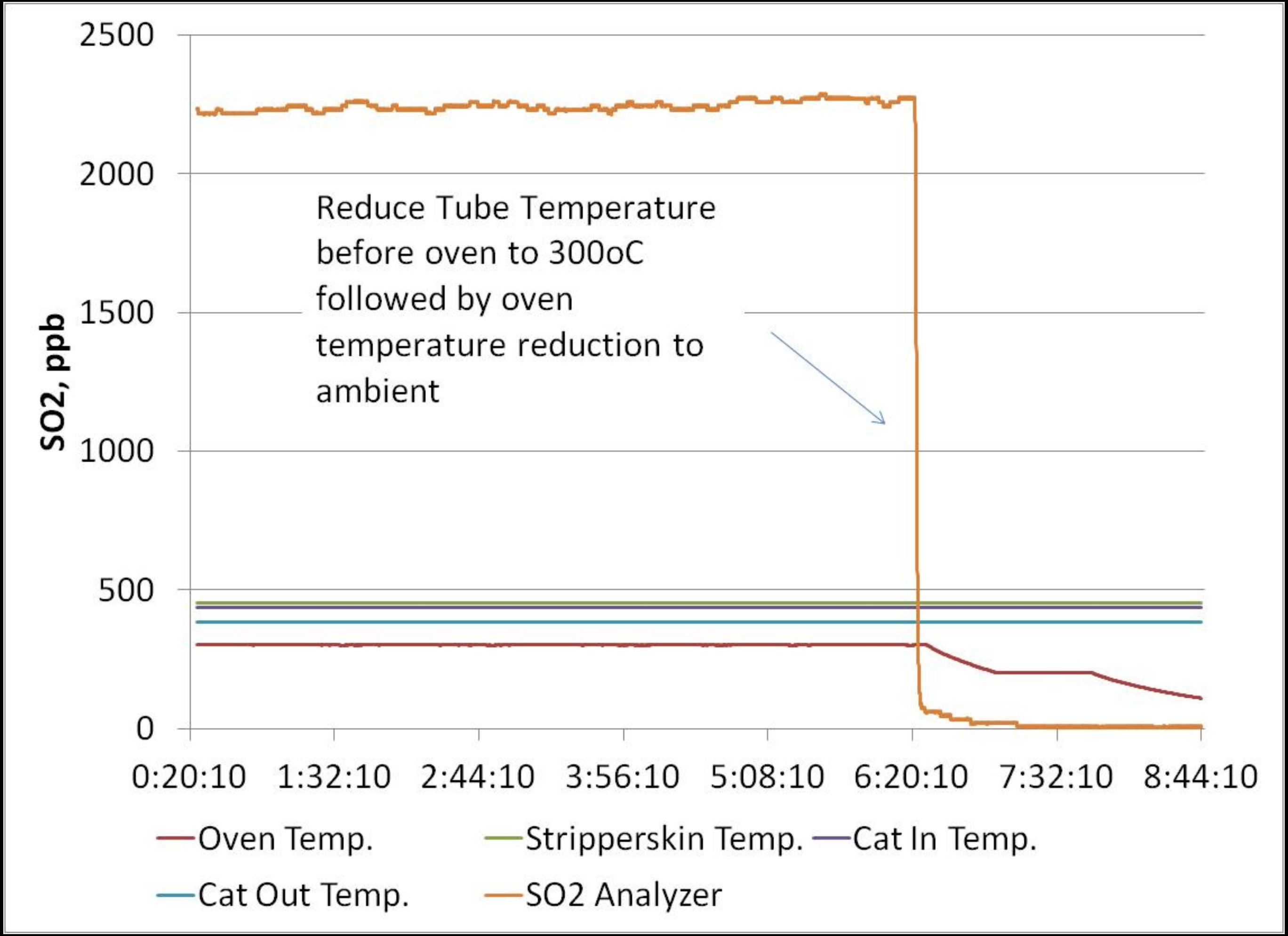
Using SO2 Measurement as Surrogate for SO3

As the oven temperature is reduced, SO2 concentration decreases

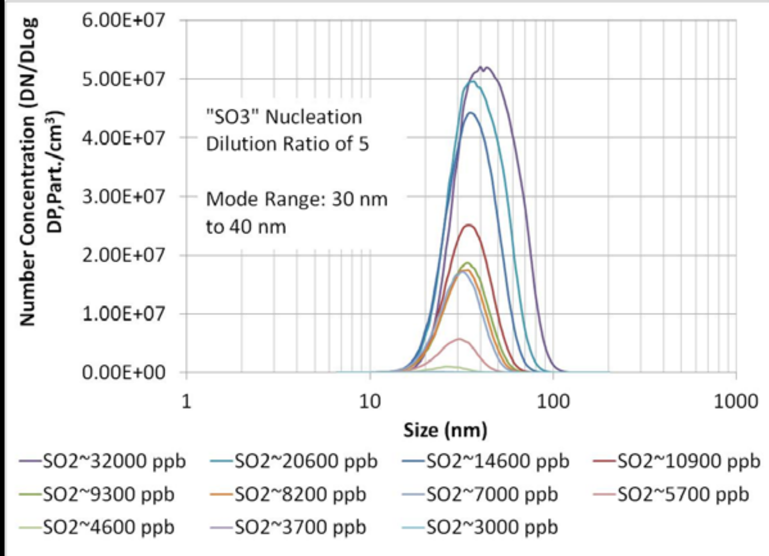


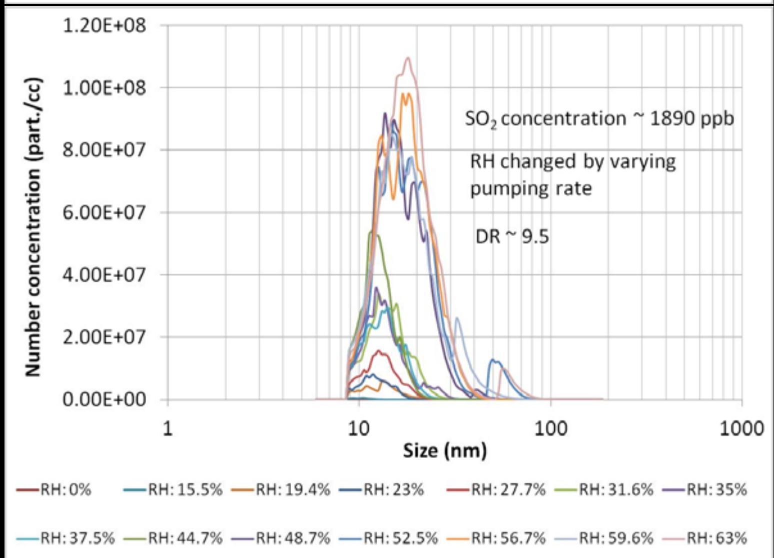
Complete Loss of SO3 with Oven Temperature Down to Ambient

- At 1100°C, we were able to decompose 95% of the SO3 formed
- The literature suggests a temperature of 1250°C is needed for complete decomposition (*Noglik et a., J. of Solar Energy Engineering, 2009)*



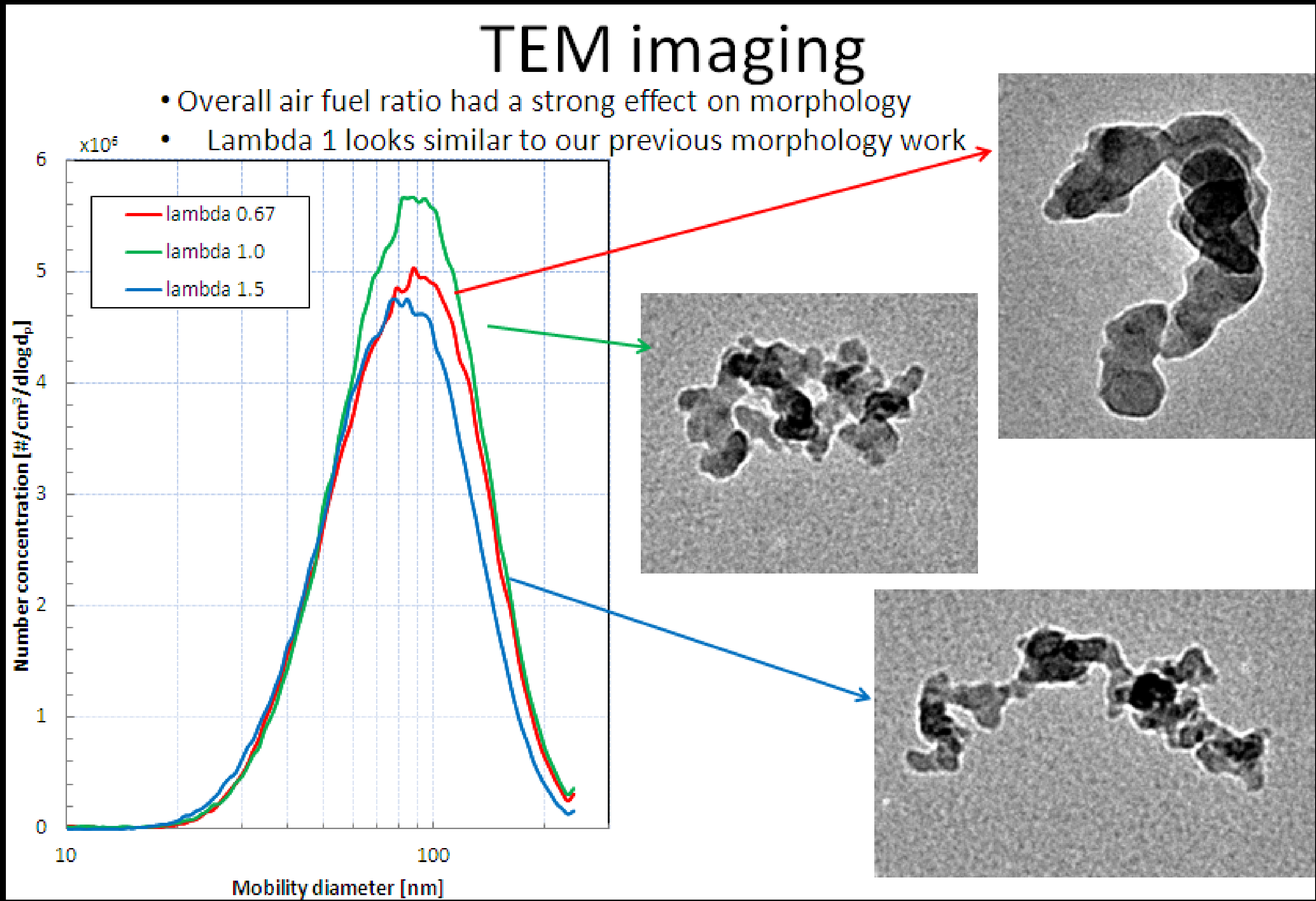
SO_3 or SO_4 and Sulfuric Acid Nucleation





- SO3 or SO4 nucleation produced larger size distributions than that of sulfuric acid
- The increase in water significantly enhanced sulfuric acid nucleation and growth. Even at high concentration, the mode of the distribution on a number basis did not exceed 20 nm. This is what we typically see in engine exhaust nucleation and growth, but the growth is typically via hydrocarbons
- At very high water content (> 16% in exhaust, ~Natural Gas), large mode started to appear, especially on a mass basis.

Different Soot Morphology



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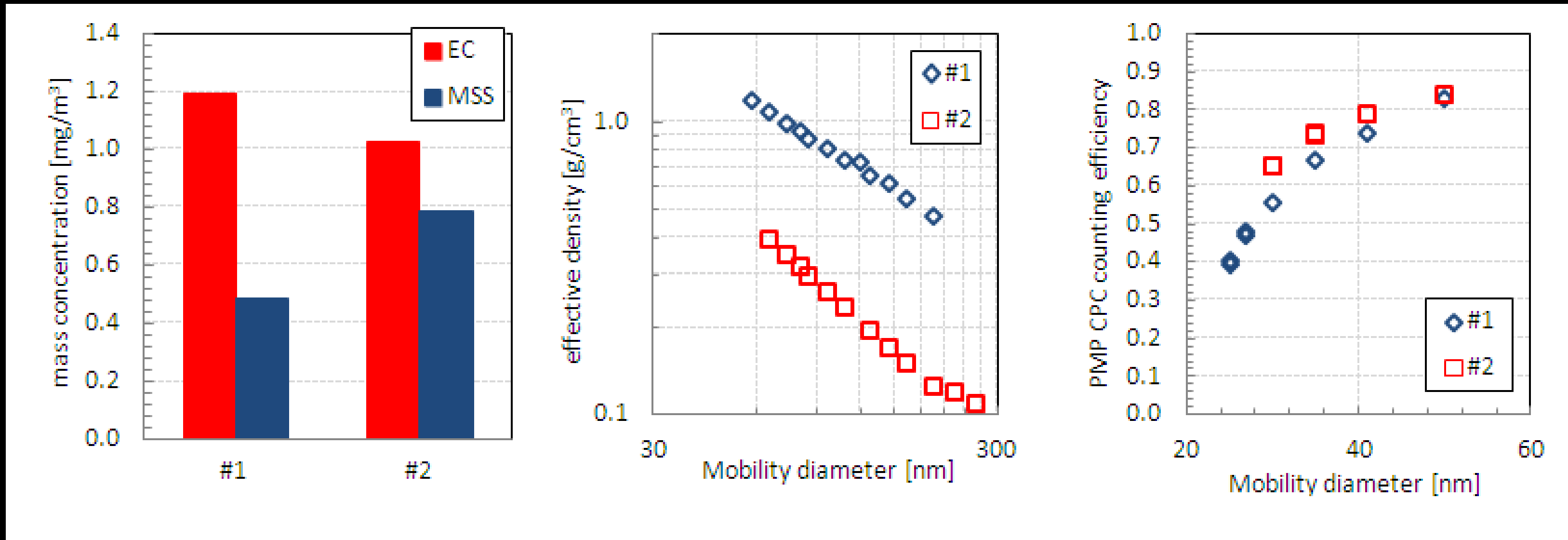
MINICAST AEROSOL CHARACTERIZATION



#1	#2
60 mlpm C_3H_8	60 mlpm C_3H_8
0 mlpm N_2	275 mlpm N_2
1 lpm air	1.85 lpm air
d_g at ~70 nm	d_g at ~80 nm

miniCAST operating conditions had a strong effect on the light absorption, effective density and particle affinity for butanol.

Characterization of Combustion Aerosol Produced by a Mini-CAST and Treated in a Catalytic Stripper
Mamakos, Khalek, Giannelli & Spears, AS&T, vol 47, issue 8, May 2013

Summary

- A "quiet" Particle Generator has been developed to investigate various fundamental processes of aerosol formation and growth
- We have recently added modeling efforts to gain more fundamental insights to the experimental findings
- A final report for 2013 activities will be issued by September 31, 2013
- We expect to continue working with the system in FY2014 , starting October 1, 2013.