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**Combustion Sources** 





Residential Hot Water Boiler

**Experimental** 

Isokinetic withdrawal from stack Dilution Ratio = 44Relative Humidity = 40%Residence Time = 18 sPM<sub>2.5</sub> samples collected on multiple Teflon coated borosilicate fiber filters Target loading: 2 mg organic carbon 12 hours of sampling required over 3 days

No.6 HFO (residual) Research Tunnel Furnace (large utility scale boiler)

## Analytical Methodology

Filter samples spiked with recovery standards and extracted with  $CH_2CI_2$ . Solvent exchanged to hexane. Column fractionated on 5% deactivated silica F1 (hexane) has saturated hydrocarbons

F2 (1:1 cyclohexane/acetone) has aromatic hydrocarbons

Analyzed by GC-MSD (SIM mode)

HP 5890/5970 or Agilent 6890/5973





sources. and alkylnaphthenes. properties of fuels. composition.

Results

also observed. difficult.

For hopanes and steranes, the geological source of the material is a stronger determinant of the profile obtained than the combustion source. For PAH, the No.6 HFO profile shows some similarity to the LDGV profile, but at a much lower intensity.

PM Composition (wt%)

> No.6 HFO SO<sub>4</sub> 36% OC 6.6% EC 0.3%

No.2 LFO SO<sub>4</sub> 40% OC 7.9% EC 7.1%

Balance: ash, bound water, organic associated hydrogen

# Chemical and Physical Characterization of Particulate Matter Emissions from Stationary Combustion Sources

Stack gases were sampled using a dilution sampling technique



These compounds account for less than 0.03% of the organic carbon emissions from these

Alkane CPI: 0.94-1.10 as expected for fossil fuel combustion.

Alkane distribution shifted to higher MW as compared to fuel due to cracking of branched alkanes

Hopanes and steranes not abundant in No.2 LFO, but found in No.6 HFO due to distillation

Hopanes and steranes are sparse in PM from both sources. Compounds found reflect fuel

Only low MW PAH found in No.2 LFO. PAH found in No.6 HFO span the range of MW. PAH sparse in PM from both No.2 LFO and No.6 HFO.

Retene is a tracer for wood combustion but found in PM from both sources. Suspect it is present in the combustion air and passes through the burner unaffected. Found in No.2 LFO in trace amoun

## Comparison to Mobile Source Emissions

Source apportionment profiles obtained by normalizing to organic carbon emission rate.

- For alkanes, the No.6 HFO profile shows some similarity to LDGV emissions.
- The diesel vehicle alkane profile shows contributions from both fuel and lubricating oil while the gasoline vehicle alkane profile shows contributions from lubricating oil only. Evidence of cracking is

Evidence of similarities exists between stationary and mobile source profiles for hopanes and steranes, but the amount of material present in the stationary source samples made detection



Introduction

Dilution sampling also offers the opportunity to investigate the number concentrations of particle emissions from these sources. Ultrafine particles are being recognized as a potential health hazard. Measurements on stationary combustion sources are virtually non-existent. The conditions under which the particles are diluted and cooled will to some extent affect the composition of the particles and the mass emission rates obtained.

![](_page_0_Picture_47.jpeg)

Instrumentation Particle size distributions: SMPS: TSI 3936, Long DMA with TSI 3025A CPC (Size range 14.8 - 673 nm) Total number concentration: TSI 3022 CPC (15nm 90% efficiency,  $10^7$  #/cm<sup>3</sup>)

**Comparison to Mobile Source PM Emissions** Heavy Duty Diesel Particles: Trimodal 3-30 nm (90% of N), 30-500 nm (90% of M), >1 m mechanically generated debris Light Duty Gasoline Particles: Trimodal 3-20 nm (90% of N), 30-200 nm (90% of M), >1 m mechanically generated debris

![](_page_0_Figure_50.jpeg)

![](_page_0_Figure_51.jpeg)

Mobile Source emissions are one of the largest sources of organic fine particulate matter. To be able to accurately perform source apportionment modeling and to understand the relative magnitudes of different sources in a region, accurate source emission profiles are required for all significant emission sources in a given region. Conventional stationary source PM sampling methods are inappropriate for obtaining source emission profiles because PM samples are collected under stack conditions and do not allow condensation of semivolatile material onto the particulate matter. The PM collected does not represent the PM found in emissions as they exit into the environment, are cooled and diluted. Dilution sampling methods applicable to stationary sources are under development by a number of different groups in North America. The US EPA has a conditional test method for dilution sampling from stationary sources (EPA CTM 39). Canadian National Pollutant Release Inventory will soon require particulate matter emissions to be determined using dilution sampling methods.

## Experimental

Stack gases sampled using dilution sampling technique Isokinetic withdrawal from stack and number emission rates. Boiler fueled with a No.2 fuel oil (0.2% S). Burner operates with 15-20% excess air.

# Effect of Increasing Relative Humidity

Particles grow (GMD increases) Number Distribution broadens (GSD increases) Particles larger than 25 nm grow (hygroscopic) Particles smaller than 25 nm and larger than 100 nm do not change (non-hygroscopic) Largest particles likely from excess combustion air

Number emission rate decrease Coagulation.

Small change in distributions from

![](_page_0_Figure_62.jpeg)

Dilution Ratio, Relative Humidity and Residence Time varied to observe effect on particle size distributions (Number and Mass)

S	Dilution Ratio = 40							
	Residence Time = 30 s							
due to		Ν	lumber Distri	Mass Distribution				
	Relative Humidity	GMD	GSD	Emission Rate	GMD	GSD		
1 40% to 70% RH.	(%)	(nm)	(nm)	(#/cm <sup>3</sup> )	(nm)	(nm)		
	70	27.6	1.39	3.17.E+08	46.3	2.02		
	40	27.4	1.39	3.10.E+08	48.7	2.18		
	9	24.4	1.34	3.89.E+08	44.1	2.36		

## Effect of Increasing Residence Time

Particles grow (GMD increases). Number distribution broadens (GSD increases) 0.3s distribution is bimodal. Distributions become unimodal due to coagulation. Accumulation mode increases, nucleation mode decreases. Number emission rate trend likely due to CPC sensitivity. Particles smaller than 15 nm are not efficiently detected.

Dilution Ratio = 40								
	Relative Humidity = 40%							
	Number Distribution			Mass Distribution				
Residence Time	GMD	GMD GSD Emission Rate		GMD	GSD			
(s)	(nm)	(nm)	(#/cm <sup>3</sup> )	(nm)	(nm)			
0.3	19.8	1.22	1.75.E+08	36.2	2.83			
18	23.9	1.36	2.68.E+08	42.2	2.16			
30	27.4	1.39	3.10.E+08	48.7	2.18			
60	28.8	1.40	2.25.E+08	51.2	2.12			

## Effect of Increasing Dilution Ratio

Particles are smaller (GMD decreases). Smallest particles survive longer.

Number distribution narrows (GSD decreases).

ess particle growth due to coagulation and condensation.

Number emission rate trend likely due to CPC sensitivity. Particles smaller than 15 nm are not efficiently detected.

Relative Humidity = 40%								
Residence Time = 60 s								
	N	lumber Distril	Mass Distribution					
Dilution Ratio	GMD	MD GSD Emission Rate		GMD	GSD			
	(nm)	(nm)	(#/cm <sup>3</sup> )	(nm)	(nm)			
25	33.2	1.44	2.35.E+08	59.6	2.03			
39	28.8	1.40	2.25.E+08	51.2	2.12			
59	24.6	1.34	2.06.E+08	48.0	2.53			