Center of Excellence for Aerospace Particulate Emissions Reduction Research

Plume Processing of Soot Aerosol in a Jet Engine Exhaust

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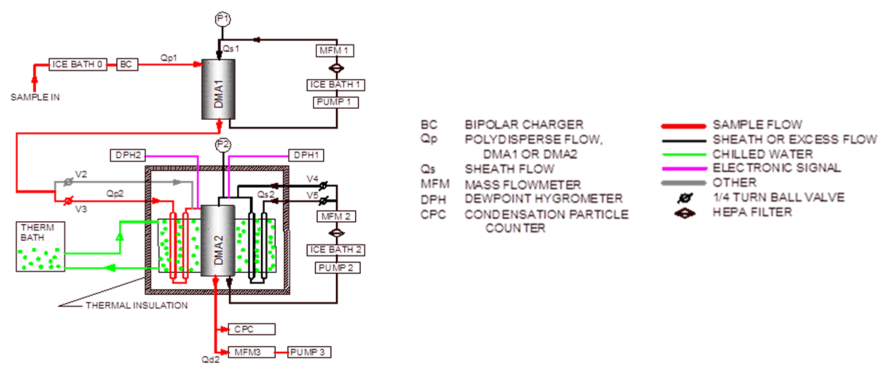
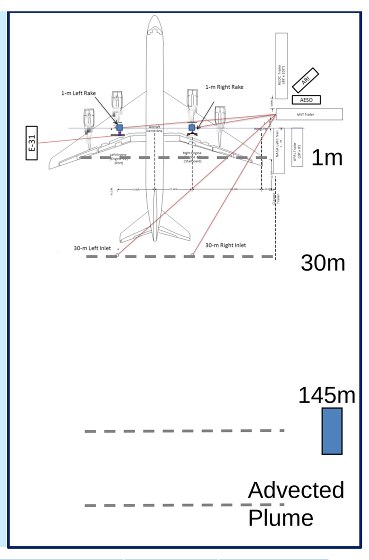
Introduction

- Volatile materials in exhaust condense onto soot particles and nucleate new particles.
- Useful metrics: SMF (Soluble Mass Fraction) and VMF (Volatile Mass Fraction)
- Use deliquescence measurements to quantify SMF.
- Use volatility measurements to quantify VMF.
- Explore SMF & VMF variation with distance in plume.



Project AFFEX-2

OBJECTIVE
Perform static aircraft engine testing using Hydro-treated Renewable Jet (HRJ) and other fuels to determine effects on engine performance and emissions.
APPROACH
Utilize the NASA DC-8 aircraft with CFM 56 engines at the Dryden Operational Facility in Palmdale, CA to perform emissions testing using various alternative fuels and a JP-8 reference fuel, and obtain gaseous, solid, and aerosol samples for analysis at 1, 30, and 145 meters downstream of the aircraft engine exhaust.



Fuels Studied	JP8	HRJ (Beef Tallow)	HRJ – JP8 Blend	FT (CTL)	FT+THT

Differences in fuel properties, especially fuel aromatic content and fuel sulfur content can influence PM Emissions

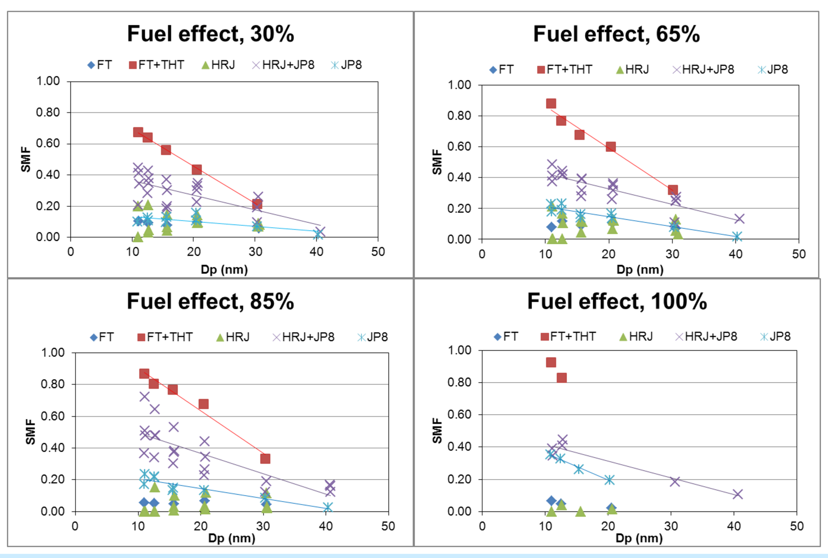
Methodologies for VMF and SMF

VMF Methodology
- Measure the total and non-volatile size distributions.
- Take the non-volatile size distribution and calculate what it's size distribution would become, when it gets coated with volatile material, assuming that that the non-volatile particles collect a volume of volatile material proportional to their surface area, with proportionality constant b. b is the object of the measurement.
- Adjust b to minimize the difference between the GMD for the modeled total size distribution and that for the measured total size distribution.
- Use b to calculate a Volatile Mass Fraction, VMF.

$vmf_i = \rho_v b x_i^2/[(\pi/6)\rho_s x_i^3 + \rho_v b x_i^2]$
ρ_s = Soot density
ρ_v = Density of volatile material

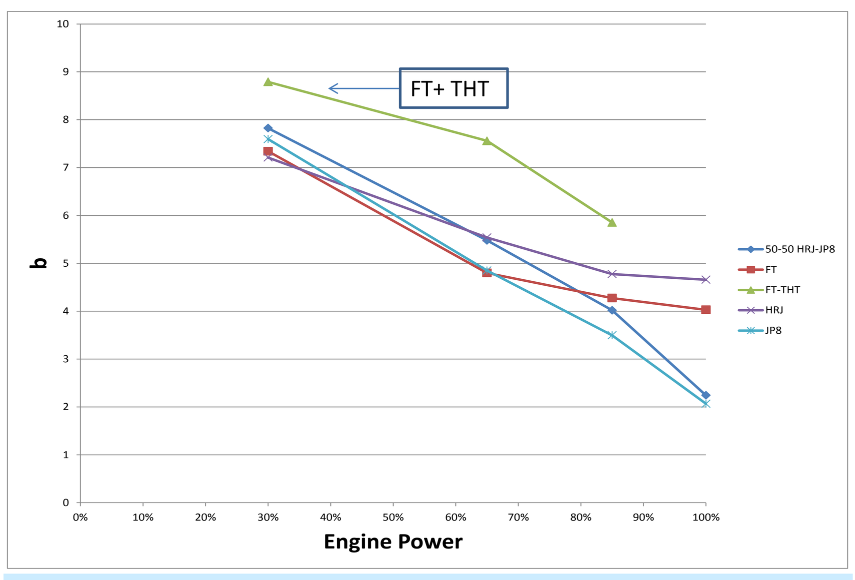
SMF Methodology
- Measure dry diameter.
- Measure wet diameter, (86% RH)
- SMF = (sol mass)/(tot mass)
- Calculate critical supersaturation (assuming soluble material sulfuric acid)

Soluble Mass Fraction (SMF) 145m



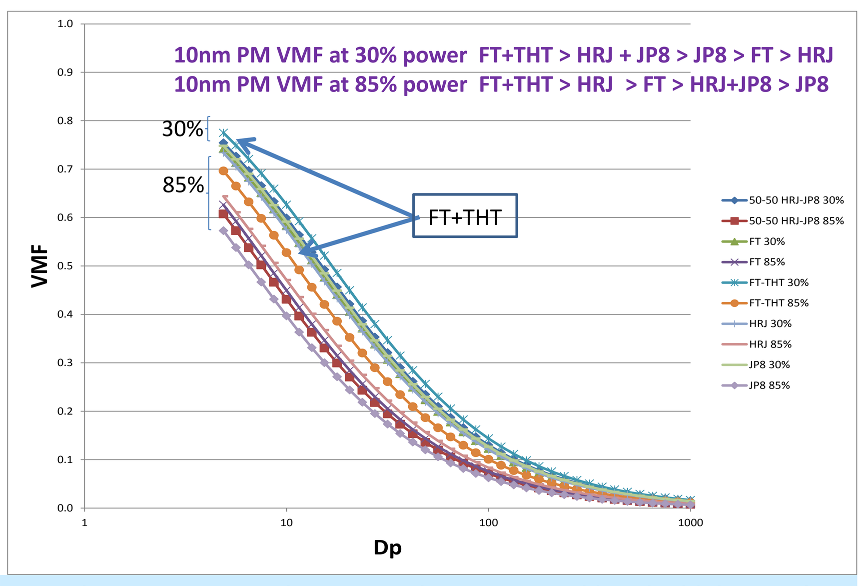
SMF increases with fuel sulfur content and engine power condition, and decreases with particle diameter

VMF Studies Proportionality Constant (b) vs Engine Power

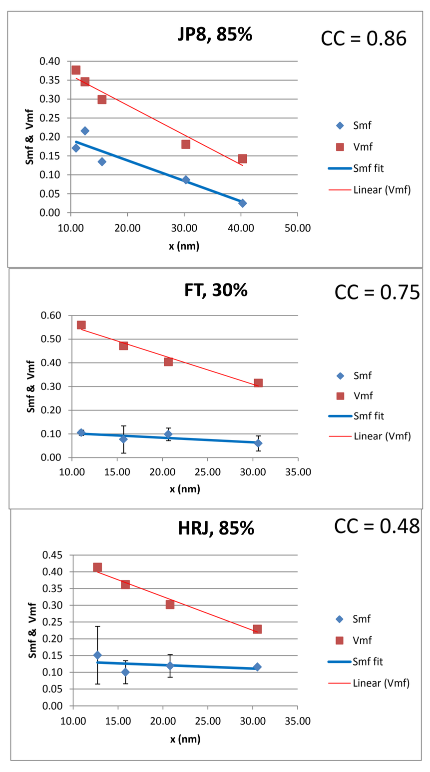


FT+THT has highest propensity for collecting volatile material, as evidenced by largest b value for the fuels studied.

VMF vs Particle Diameter

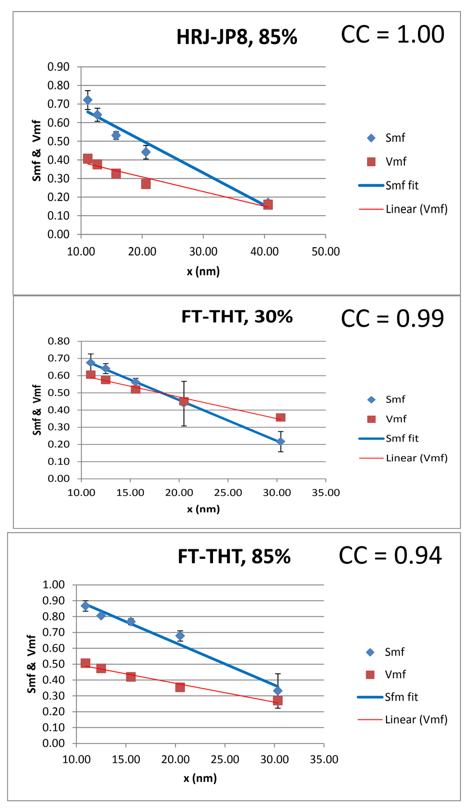


VMF increases as engine power decreases and has its highest value for the FT+THT mixture.



Comparing SMF and VMF as a function of particle diameter for lower sulfur fuels

For fuels with lower sulfur content their VMF values are found to be greater than SMF. This indicates that not all volatile material is water soluble, for the fuels with lower sulfur content. The CC values are correlation coefficients and reflect confidence in the linear fits to the data.



Comparing SMF and VMF as a function of particle diameter for higher sulfur fuels

For fuels with higher sulfur content their SMF values are found to be greater than VMF. The CC values are correlation coefficients and reflect confidence in the linear fits to the data.

Correlation Summary

Fuel	Pwr%	Correl Coef
JP8	30	0.64
	85	0.86
HRJ	30	1.00
	85	0.48
FT	30	0.75
	85	0.27
HRJ-JP8	30	0.73
	85	1.00
FT-THT	30	0.99
	85	0.94
	Weighted Avg	
		0.97

Conclusions

- SMF can be measured via deliquescence.
- VMF can be measured via thermal desorption.
- SMF is found to
  - Increase with fuel sulfur content and engine power.
  - Decrease with particle diameter.
- VMF increases with decreasing engine power and hence longer residence time in plume.
- The FT+THT fuel has the highest propensity for collecting volatile material in the plume, with HRJ coming next. The ordering of the other fuels changes with engine power.
- For low sulfur fuels
  - VMF > SMF
  - Not all volatile material is water soluble.
- For high sulfur fuels
  - SMF > VMF
  - SMF and VMF are highly correlated.

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