AAFEX Fuel Sulfur Experiment and Comparison of AAFEX-I/II PM EIs

Workers Dumping 13 kg Tetra-hydro-thiophene into 2500 gals FT fuel

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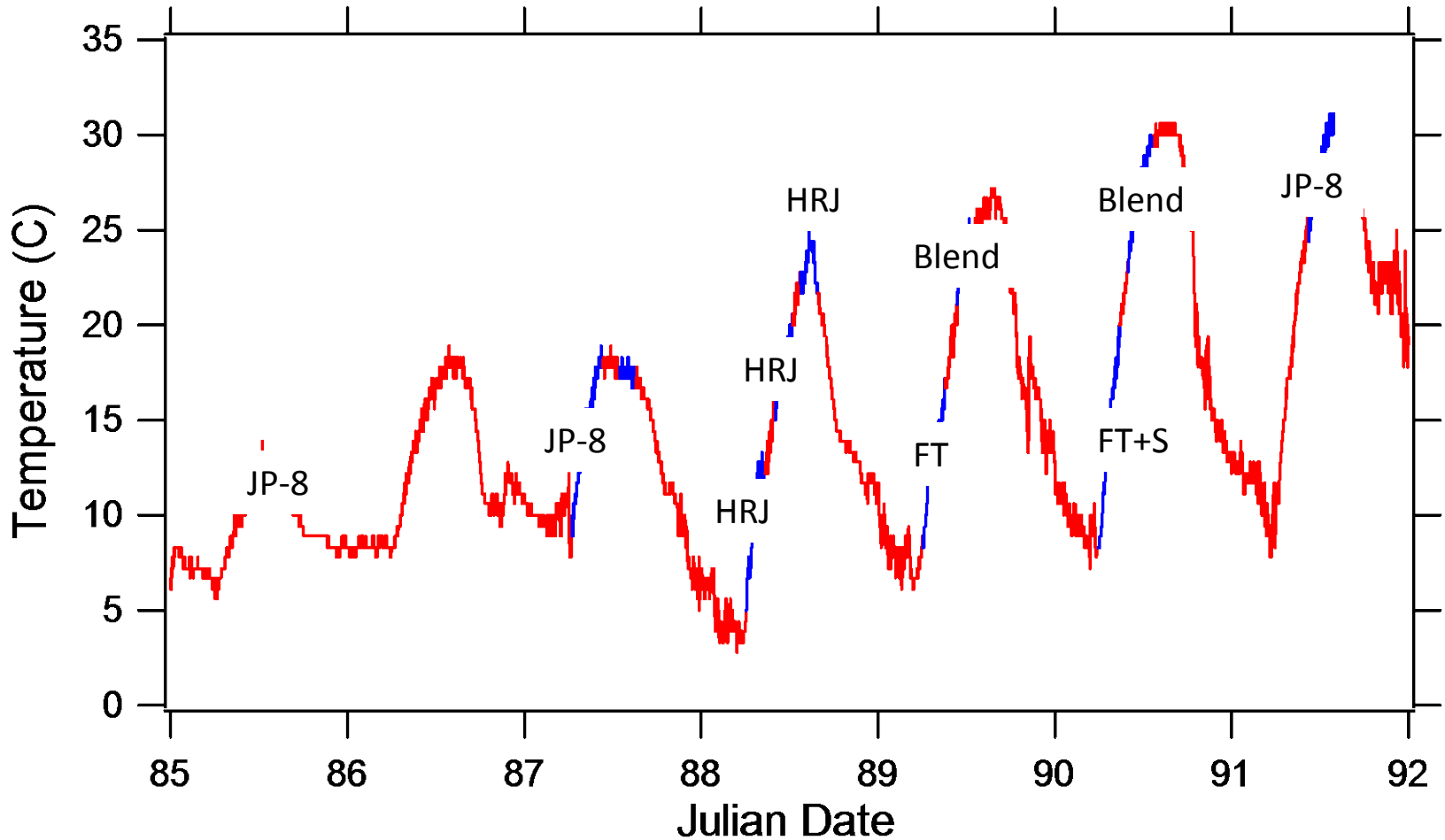
Fuel Characteristics

Test	JP8	HRJ	Blend	FT	FTS
Sulfur Content (ppm Mass)	100	0	200	0	1000
Parafins (% mass)	44	95	69	88	88
Cyclo Paraffins (% mass)	33	5	21	11	11
Normal Paraffins (% mass)	15	15	11	<.2	<.2
Aromatics (% vol)	21.8	0.4	9.8	1.7	2.1
End Point (°C) 300	268	254	264	225	224
Flash Point (deg C)	46	52	46	43	43.5
Density (kg/L)	0.811	0.759	0.783	0.761	0.761
Freezing Point (deg C)	-53	-49	-54	-78.5	-76.5
Hydrogen Content (% mass)	13.5	15.3	14.4	15.0	15.0
Smoke Point	22.0	28.3	29.0	31.5	29.3

Conducted 11 Runs, 30.5 Hours of Testing

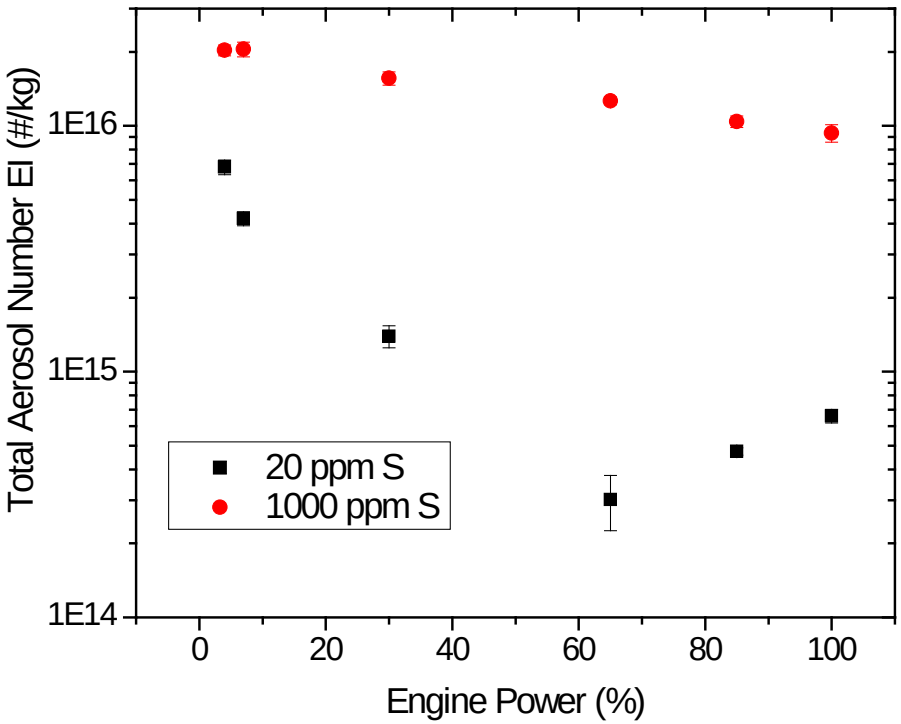
Test Number	Test Date	Times		Test Duration	Engine Fuel		Objective
		Start	End		Left	Right	
1	26-Mar	1420	1530	1.1	JP-8	JP-8	Shakedown
2	28-Mar	0630	1040	4.1	JP-8	JP-8	JP-8 Characterization-Cold
3	28-Mar	1300	1507	2.1	JP-8	JP-8	JP-8 Characterization-Warm
4	29-Mar	0605	0840	2.5	JP-8	HRJ	HRJ Characterization-Cold
5	29-Mar	1004	1225	2.4	JP-8	HRJ	HRJ Characterization
6	29-Mar	1331	1550	2.4	JP-8	HRJ	HRJ Characterization-Warm
7	30-Mar	0605	0910	3.1	JP-8	FT	Fuel S--FT Characterization- Cold
8	30-Mar	1045	1250	2.1	JP-8	Blend	HRJ/JP-8 Blend Characterization
9	31-Mar	0555	0850	3	JP-8/FT+S	FT+S	Fuel S--FT + S Characterization- Cold
10	31-Mar	1000	1330	3.5	JP-8	Blend	HRJ/JP-8 Blend Characterization/E-31
11	1-Apr	1030	1445	4	JP8 & Blend	JP8 & Blend	JP-8 Characterization/E-31 Tests

Temperature Context for Test Runs

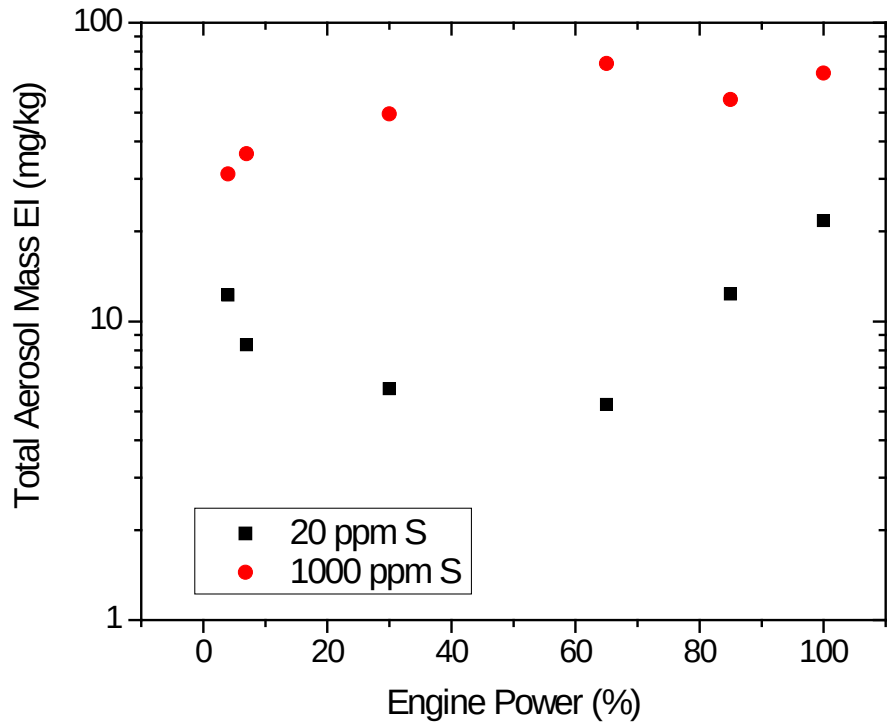


Temperatures 5 to 10 C warmer than during AAFEX-II, less volatile aerosol formation

Sulfur Plays Significant Role in Regulating Volatile PM

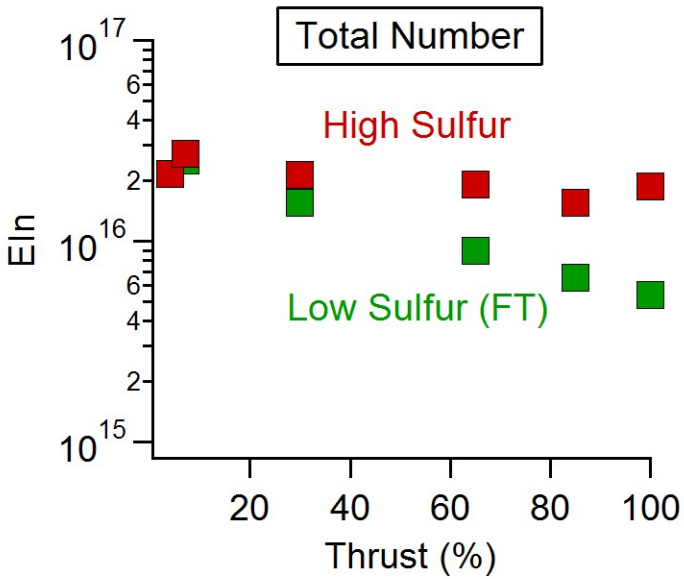


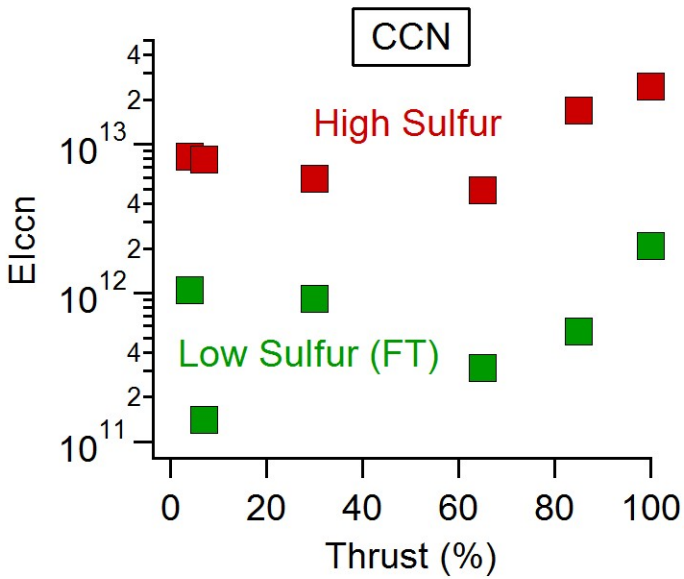
Relatively high ambient temperature suppressed volatile formation, but difference still profound

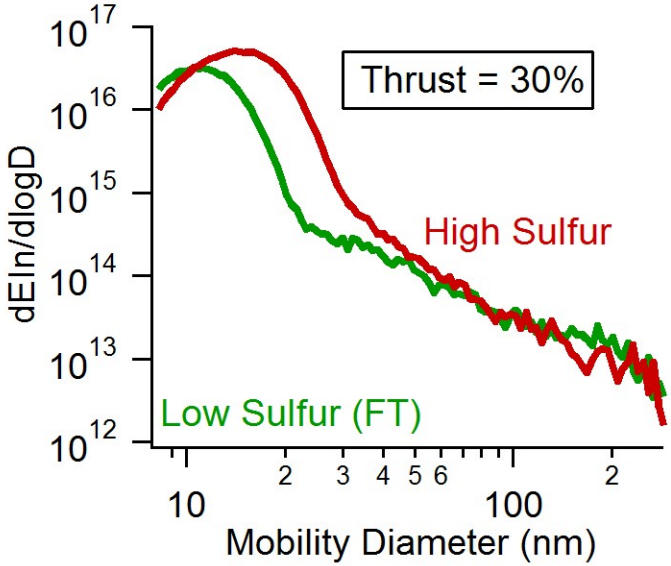


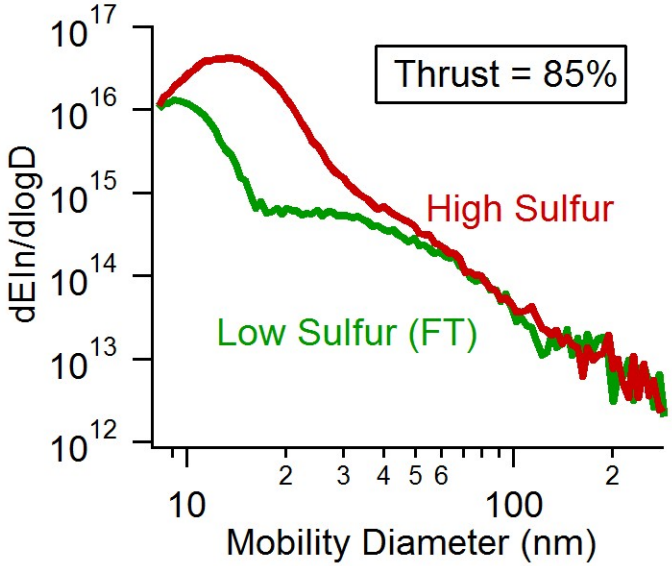
40 mg/kg ~ 1% S(IV) conversion to S(VI)

Sulfur Effects Particle Size and Solubility

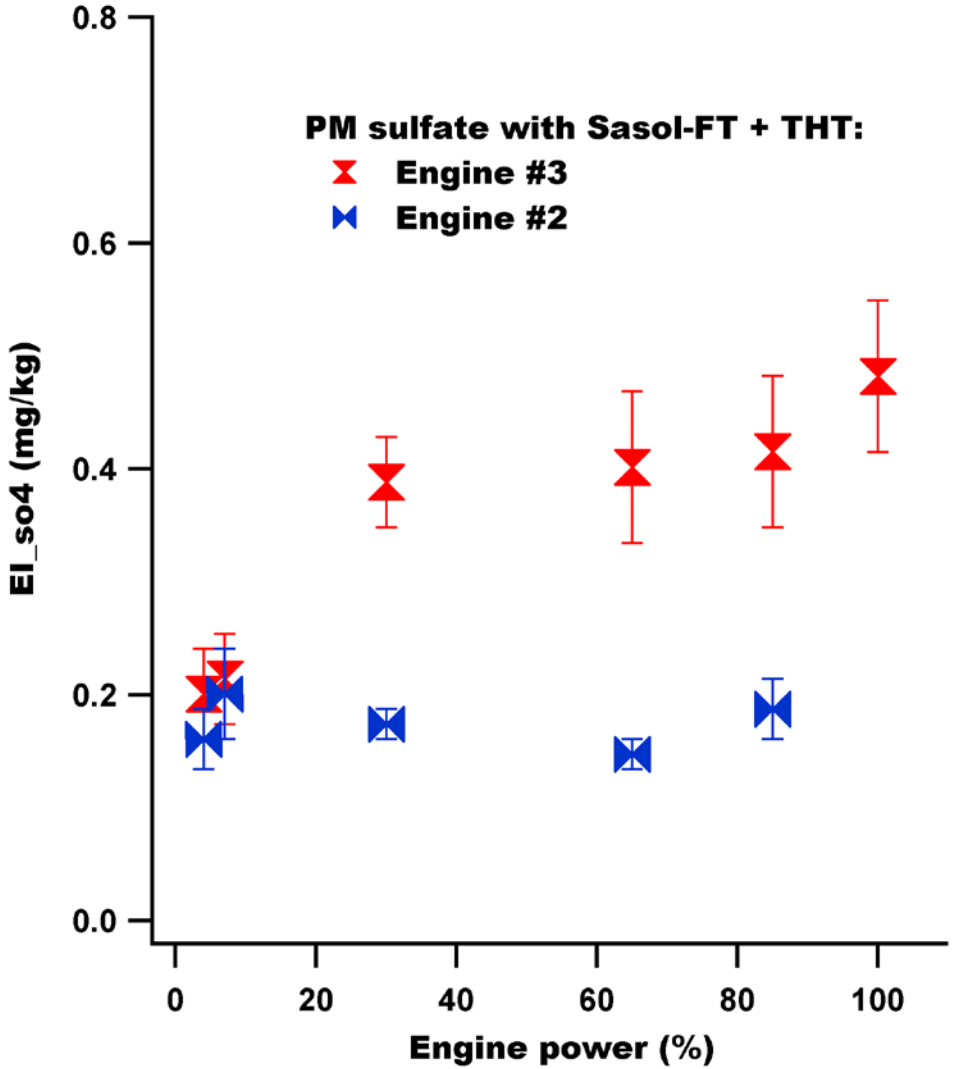






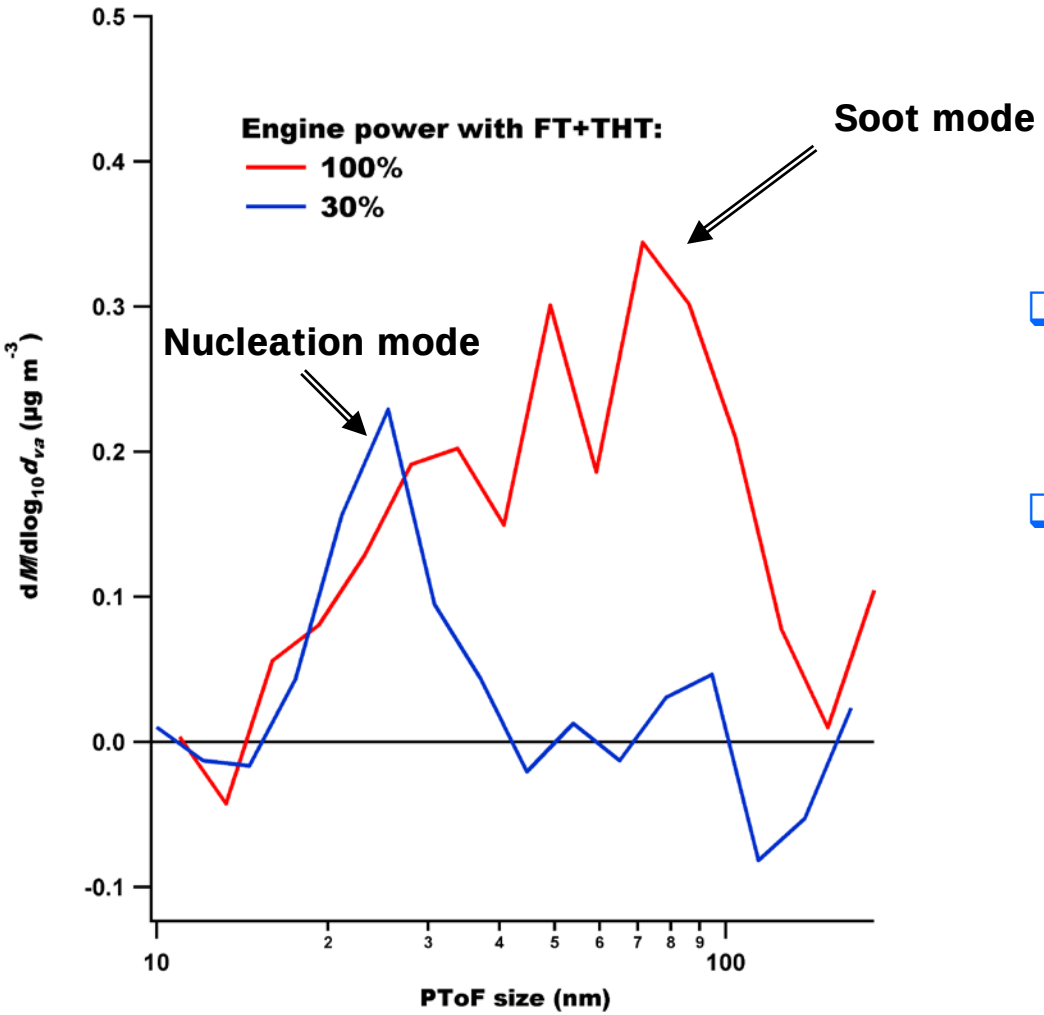


JP8 vs FT Fuel with THT



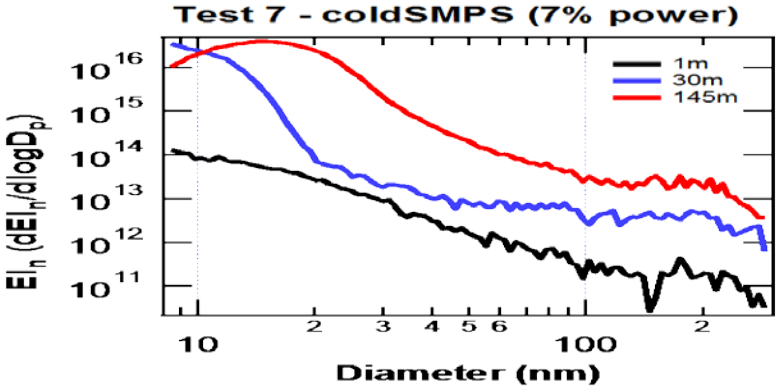
- Adding sulfur-containing compound in FT fuel increase emission index of sulfate PM except for idle condition
- The increase is not very sensitive to engine power

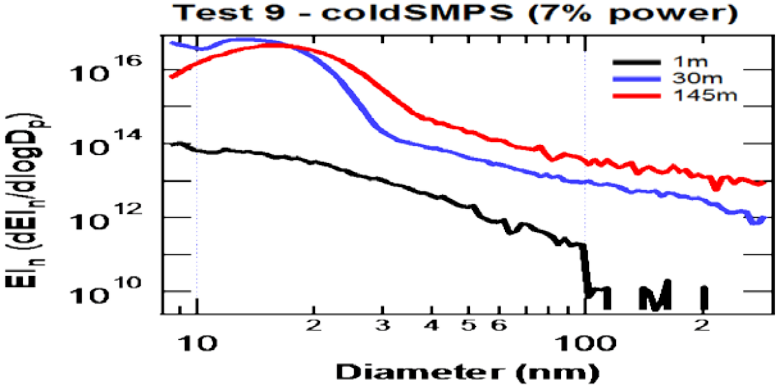
Particle Size from FT Fuel with THT

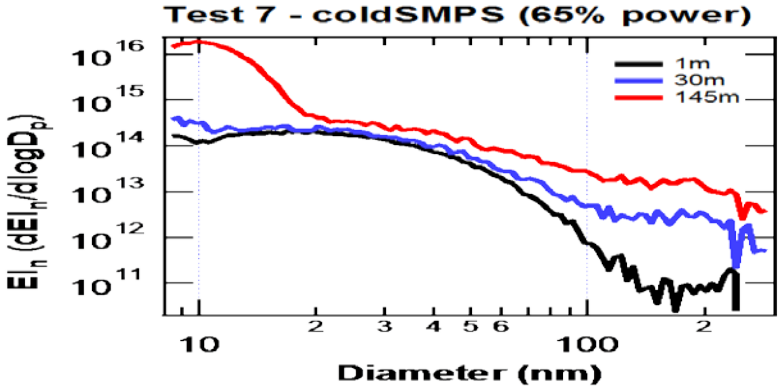


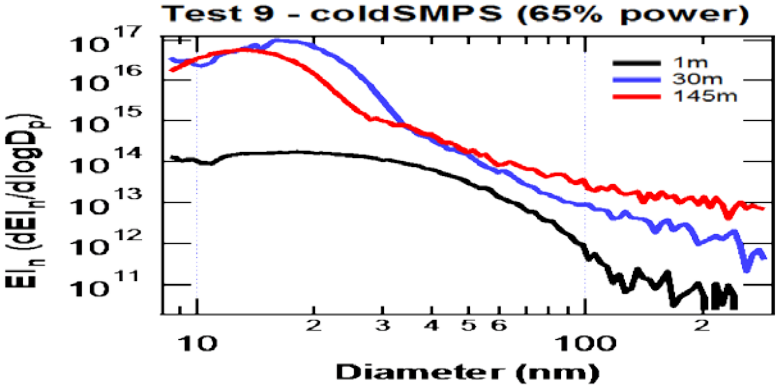
- At high power (100%), sulfate PM exists at both nucleation and soot mode particles
- At low power (30%), sulfate is predominantly present at nucleation mode

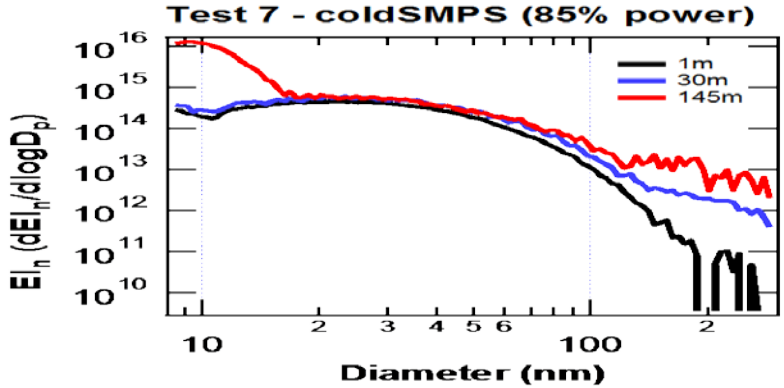
Nucleation Mode Evident Even when Sulfur <20 ppm

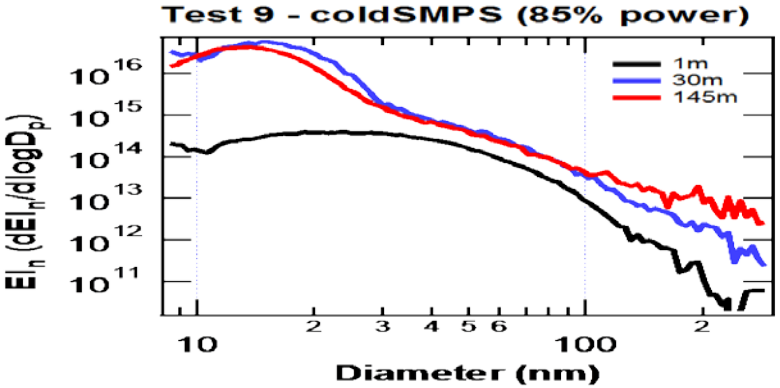












Are PM Measurement Consistent Between Tests?

APEX-1, May 2004 (Hot Weather)

- Number EI, TSI 3022
- Volume EI/GMD, SMPS/TSI 3010
- Measurements on right inboard engine only
- JP-8 only

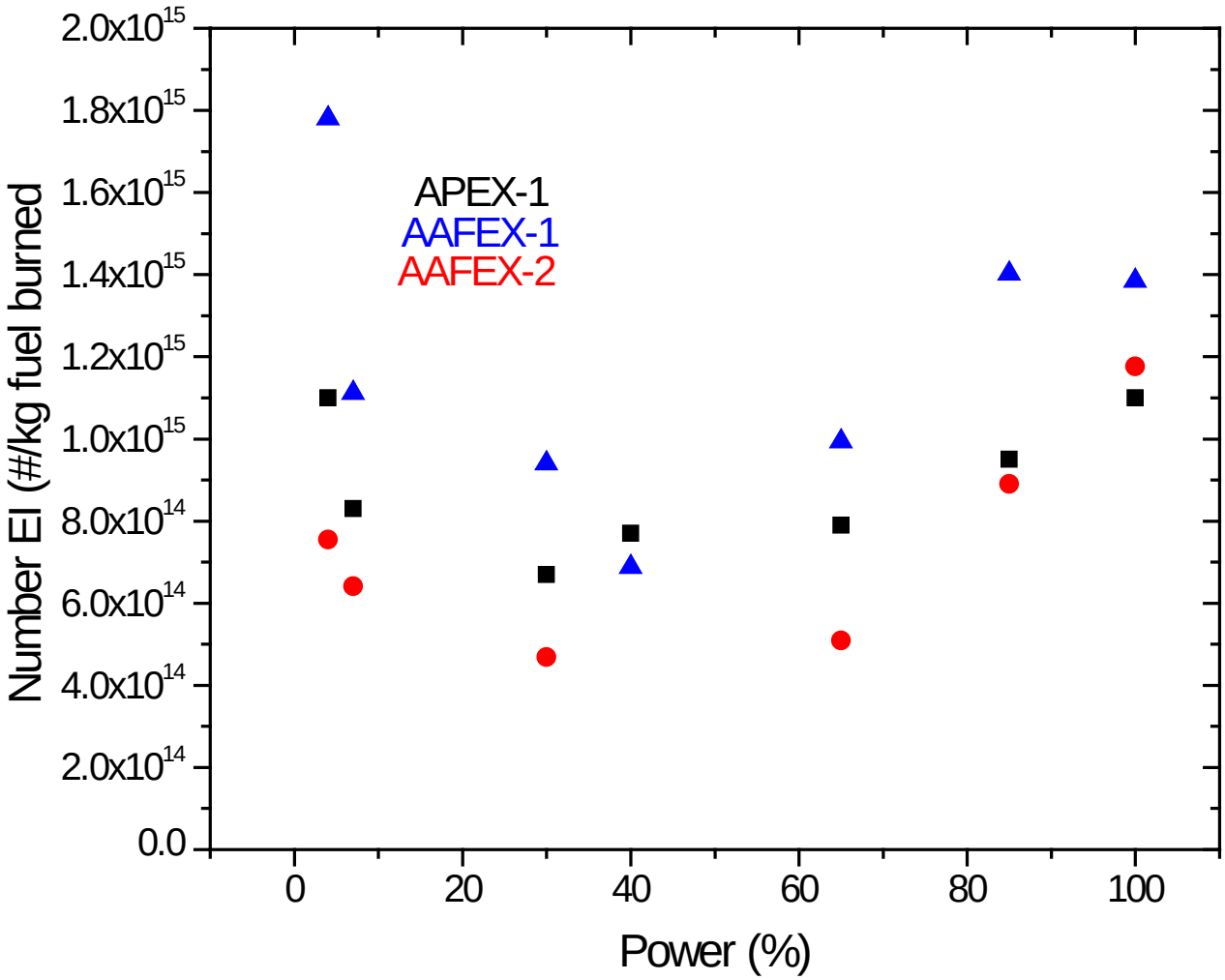
AAFEX-1, January 2009 (Cold Weather)

- Number EI, TSI 3775; Nonvolatile TSI3022
- Volume EI/GMD, SMPS/TSI3776
- Black Carbon EI, MAAP
- Measurements on left and right inboard engines
- JP-8, FT1, FT2 + Blends

AAFEX-2, March/April 2009 (Warm Weather)

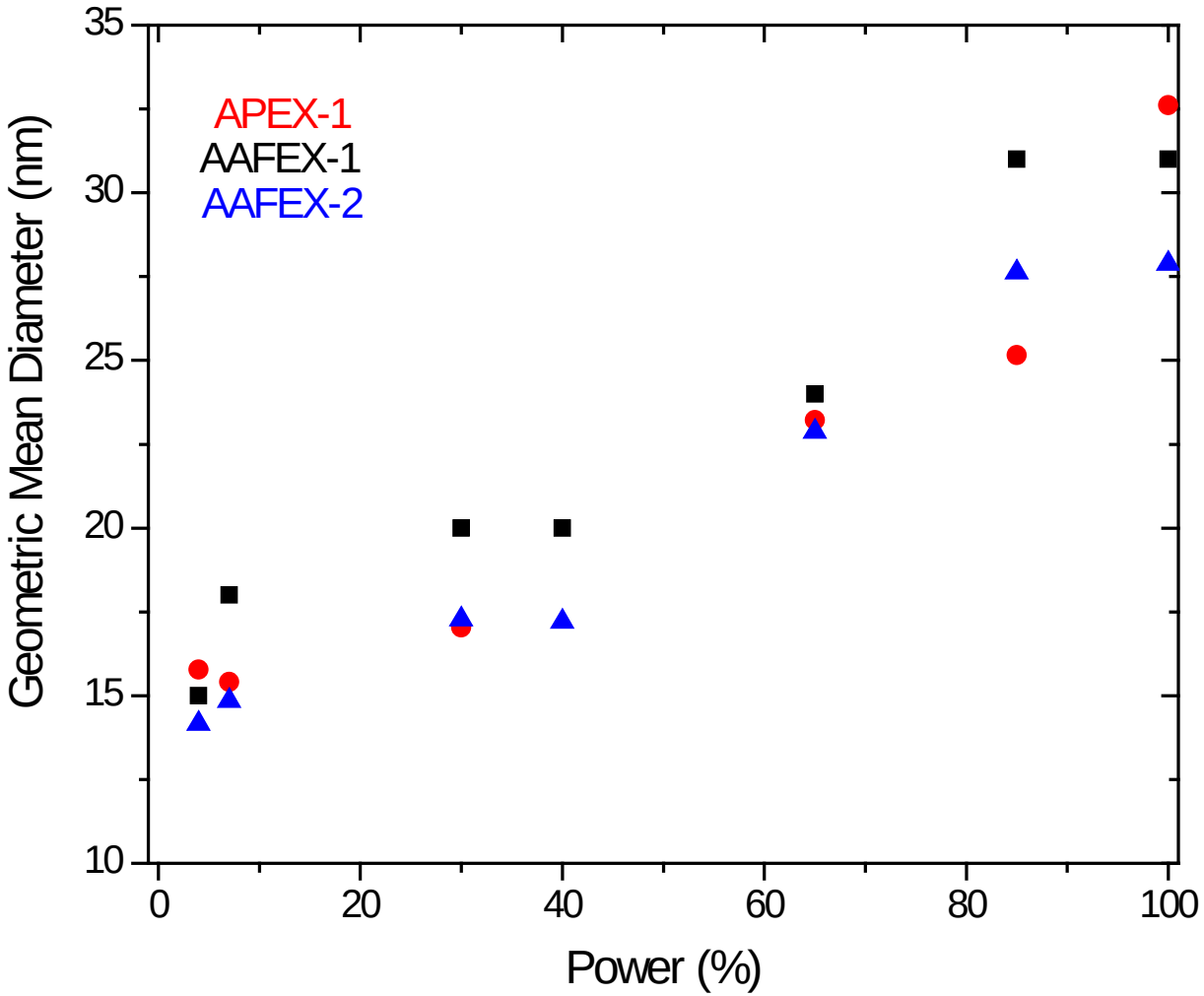
- Number EI, TSI 3775; Nonvolatile TSI3022
- Volume EI/GMD, SMPS/TSI3776
- Black Carbon EI, MAAP
- Measurements on left and right inboard engines
- JP-8, HRJ, FT2

Number EI Comparisons: JP-8, right engine

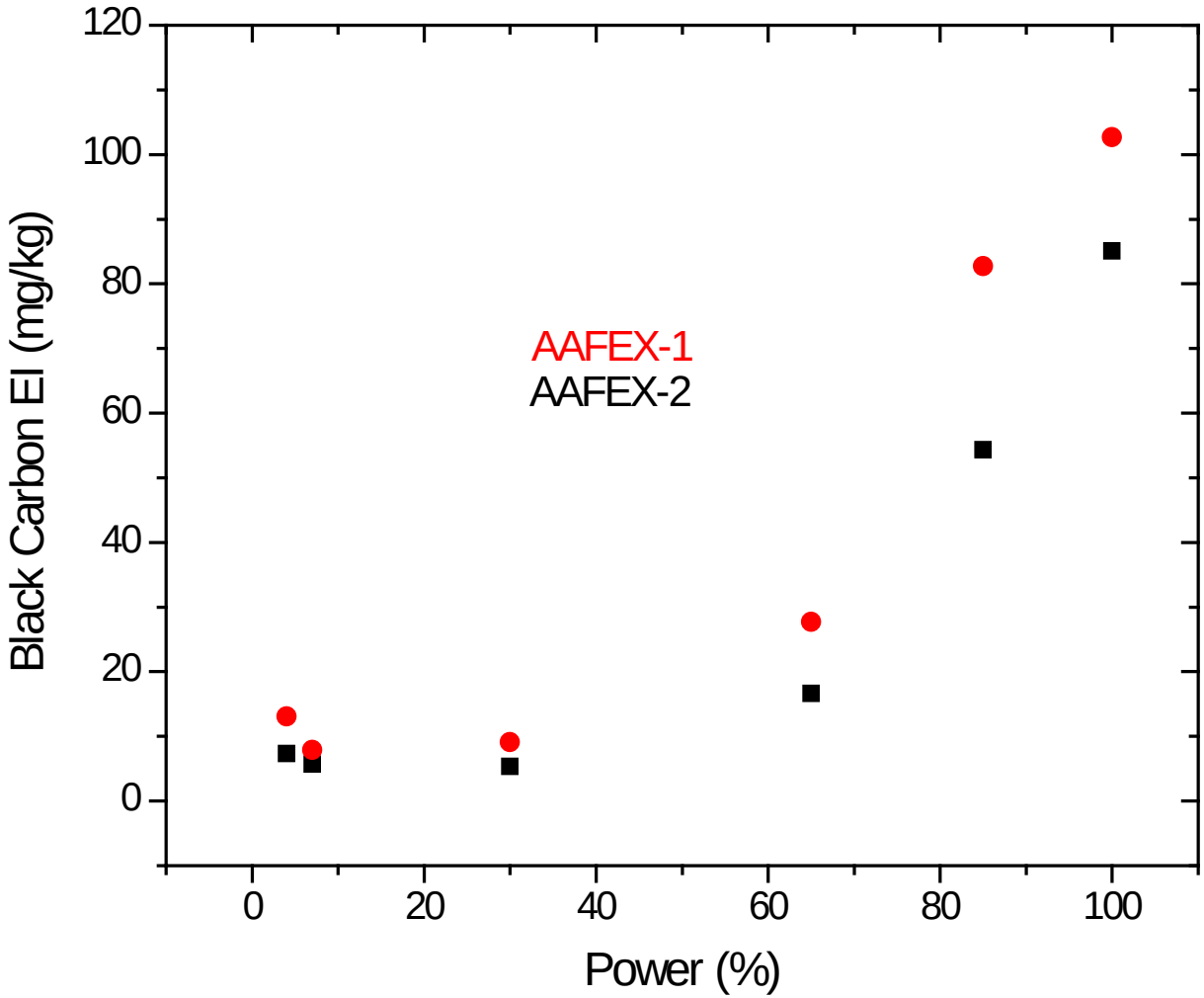


Colder conditions during AAFEX-1, more sensitive counters in AAFEX-1/2; more efficient thermal denuder used during AAFEX-1/2; error bars ~25 to 50% of mean values

Particle Size Comparison: JP-8, right engine

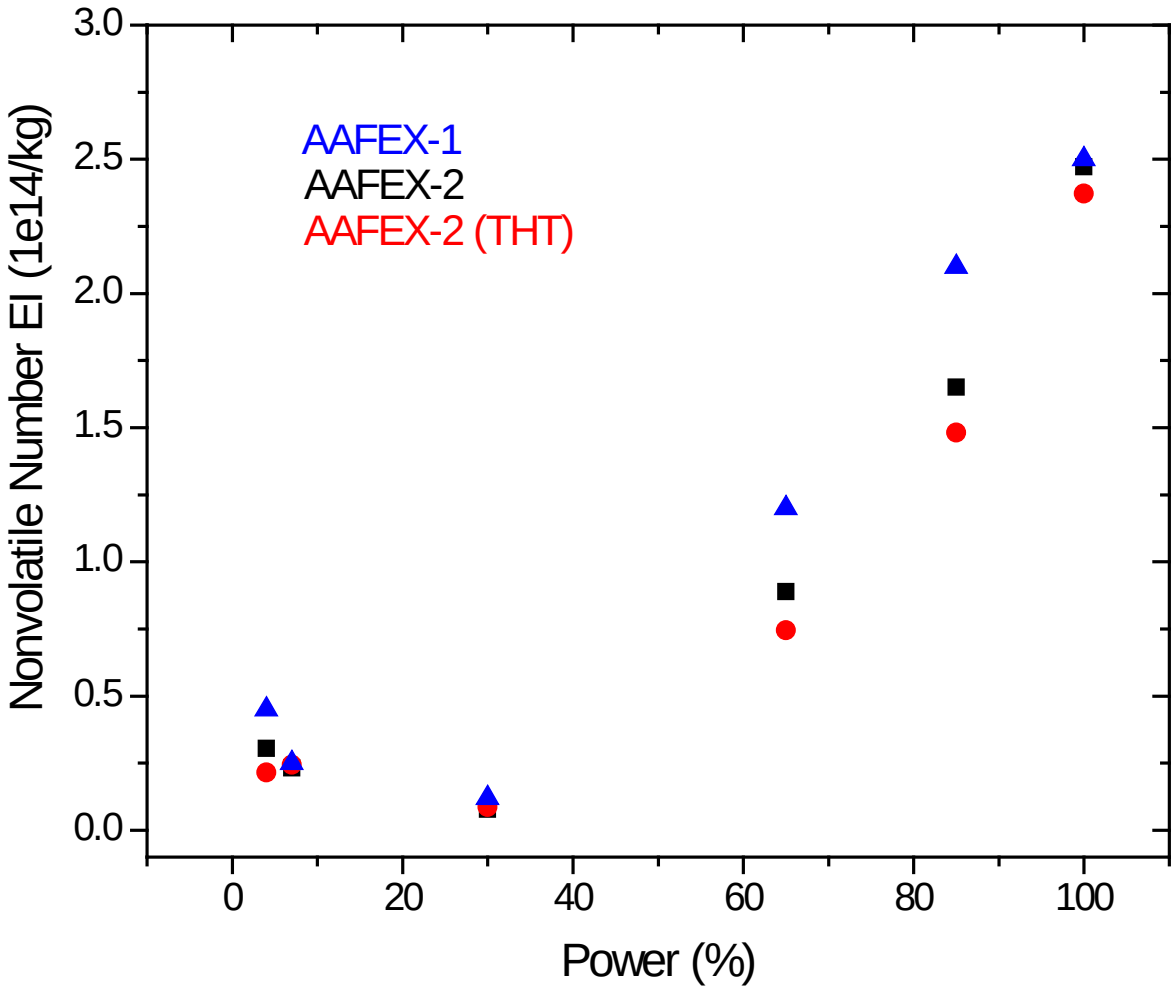


Black Carbon Mass Comparison: JP-8, right engine

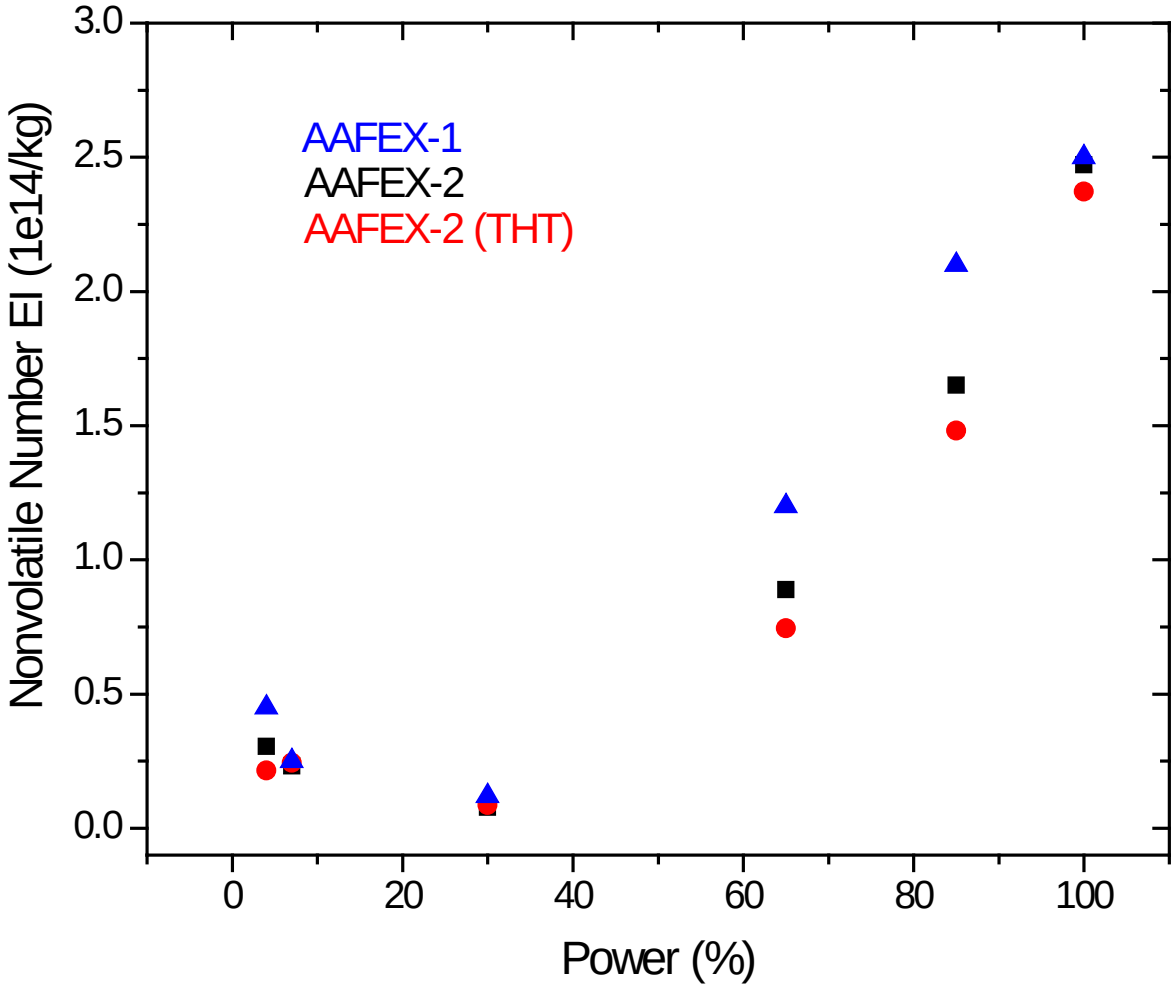


Colder conditions during AAFEX-1

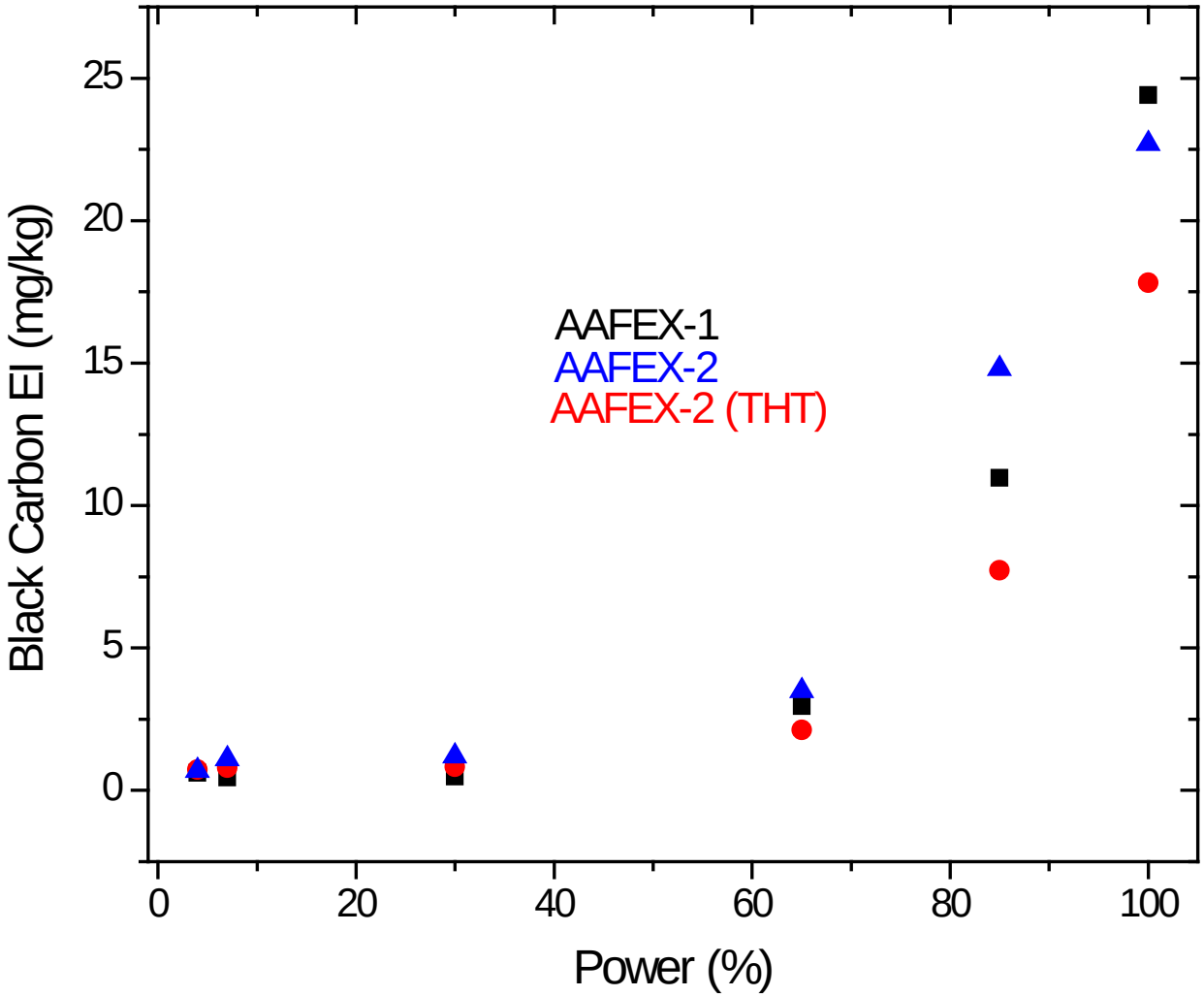
Nonvolatile Number Emissions: FT2, right engine



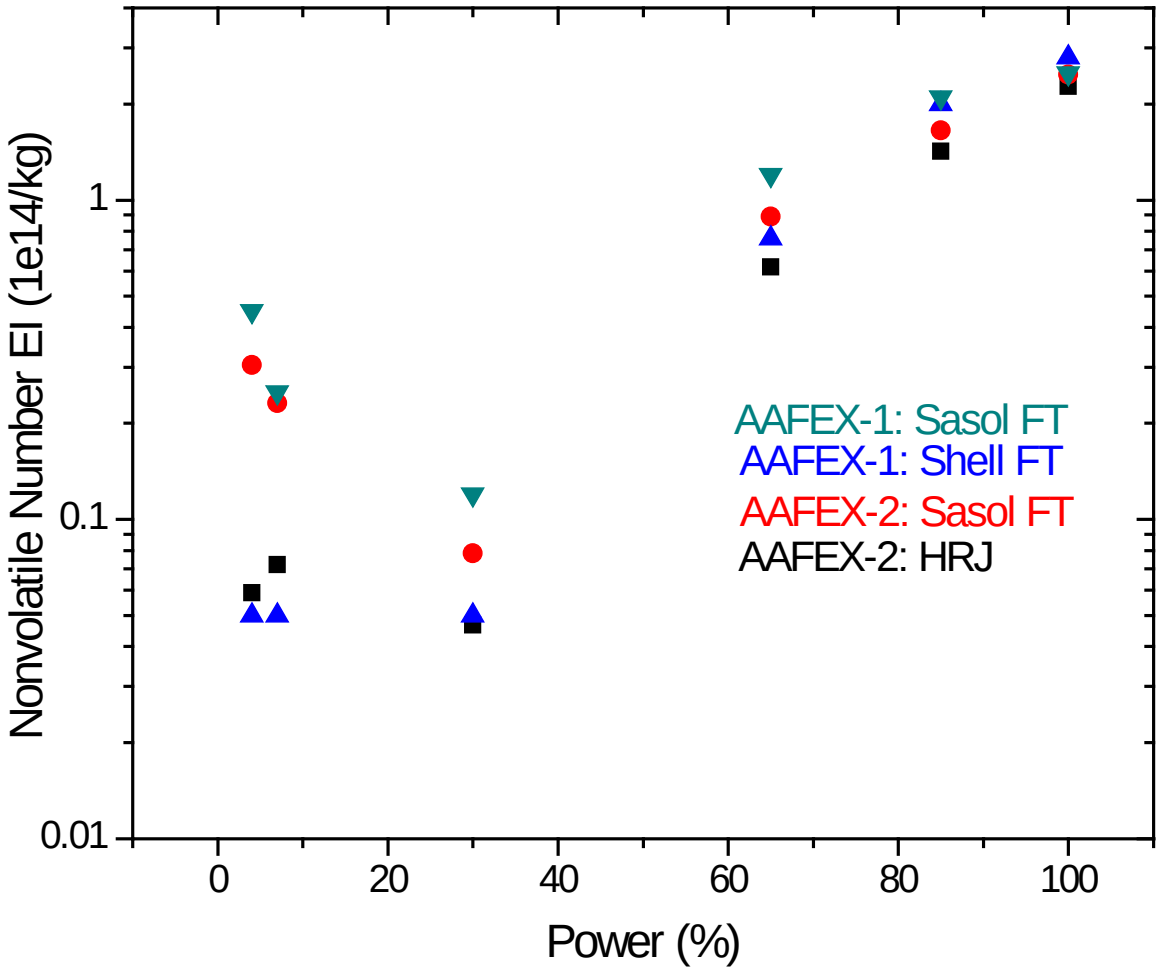
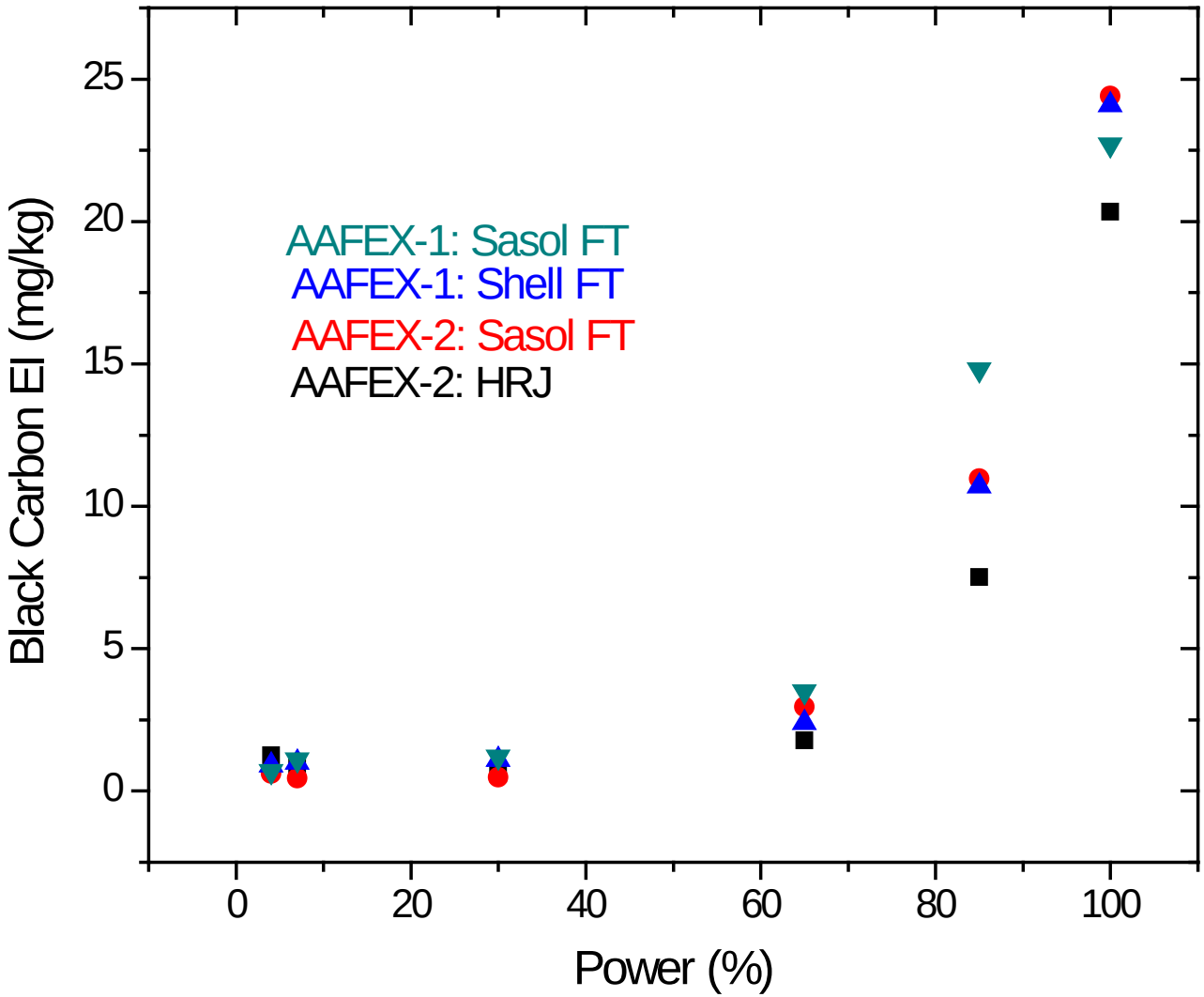
Nonvolatile Number Emissions: FT2, right engine



Black Carbon Emissions: FT2, right engine



Nonvolatile Number Emissions: Alt Fuels, right engine



Black Carbon Emissions: Alt Fuels, right engine