AAFEX Status Report #13 – 2 February 2009

Primary Activities: Cold-phase plume chemistry; aerosol vs. gas probe tests; sample dilution study; JP-8 and FT2 APU tests

Weather: 32 F at 7 am; dry with clear skies; winds were calm or < 3 mph from the NW all day. Temperatures reached 70 F in the afternoon. Almost perfect conditions for addressing the planned experimental objectives.

Summary: Participants were given a 1 hour reprieve today, post-Superbowl Monday, as work started at 5 am instead of 4. The idea was to have a 6:30 am engine start to sample exhaust emissions from downstream locations just before and after sunup, during the coldest part of the day as well as the time when photochemistry starts turning on, influencing NOy partitioning. Here's a recap of how things went.

- To support an upcoming engine test, AFRL had to pack up their equipment (Figure 1) and depart Camp AAFEX (Figure 2) on Saturday afternoon. Removal of their gear required re-plumbing some of the common gas sampling lines. Just before engine start Monday, a leak was discovered in the #3 engine gas valve box; as usual, Gary and Brad (without the help of their spiritual leader, Roy, who had rushed home to witness the arrival of his first granddaughter, Figure 3) quickly ferreted out the problem, but this caused a 40 min delay in schedule.

- The cold phase plume chemistry experiment started at 0712, with ignition in the #2 engine; #3 was lit-off around 0715; both engines burned the baseline JP-8 fuel, which contains ~1200 ppm S. After engine power was stabilized at 4%, Aerodyne performed extensive spatial profiling of the plume from 50 to 350 m downstream. After about 10 min, the ARI van was parked at the 200 m mark on the southern edge of the ramp and 1/30 m sampling group recorded emission parameters from each of the 30 m inlets at 4, 7, 30, 45, 65, 85, and 100% thrust settings. 30-m particle number and mass concentrations at 4% power decreased about 30% from start to finish of the 80-min-long test. This may be due to engine warm-up or the increase in ambient temperature (~10 F) or some combination of the two—analysis of data from engine runs conducted under relatively constant temperatures should help resolve the question.

- At the conclusion of the plume chase, the engines were shut down and ARI's van was re-connected to the 1/30 m sample distribution box. Meanwhile, an aerosol probe on the #3 engine rake was re-plumbed to introduce dilution flow about 1 meter downstream of the inlet tip; samples from this probe would subsequently be compared with those an adjacent standard "aerosol" probe in which dilution flow is introduced concentrically, about 2 cm inside the inlet tip. The objective of the comparison was to determine whether standard gas sampling probes could be easily modified to yield representative measurements of particle

number density and size distribution; use of gas probes would greatly simplify the cost and effort required to obtain an extensive engine particle-emission data base.

- Test #2 began at ~0945 and involved burning JP-8 in the #3 engine and sampling emission at the 1 m rake using tips 3 (standard aerosol probe) and 4 ("gas" probe") at 4, 7, 30, 45, 65, and 85% of maximum thrust. The rake was displaced 8" left of engine center; tip 4 was vertically aligned with engine center while tip 3 was 1.5" above it. At ground idle, total particle EI values were 12 x higher on tip 4 than 3, while nonvolatile EIs were about the same (Figure 4). Total EI ratios decreased to about 2 at higher thrust levels, whereas nonvolatile EI ratios were 1 ± 0.1 (i.e., indistinguishable) throughout the engine power envelop. ARI reported seeing engine oil in the tip 4 in most samples, which would explain the higher relative volatile aerosol number EIs. To investigate whether tip 4 was seeing oil vented from the center tube, emissions were measured with the rake offset -10" and -12" from center. At these points, tip 4 total particle EIs were about the same as tip 3 at 7% power and about 3 times higher at ground idle.

- An aerosol sample dilution study was also conducted during test #2. This involved recording particle number and mass EIs at varying dilution ratios—4, 8, 16, and 32 were targeted—at relatively high engine powers to investigate whether large particle concentrations were inertially enhanced at low sample flows and to evaluate the impact of dilution on volatile aerosol condensation. Data were collected from the aerosol probe 3 behind engine #3 at 65% and 85% power; we were only able to achieve dilution ratios of about 10, 20, and 40. Very little difference was seen in particle number EIs—further analysis will be required to evaluate effects on mass EIs.

- Test #2, the final AAFEX engine run, was completed around noon. Afterward, participants reconfigured their sampling systems to draw air from the DC-8 APU exhaust (Figure 5). Because we unable to access mid-range APU EGT settings in the earlier JP-8 tests , we repeated that experiment, then asked the ground crew to drain JP-8 from the #3 main (Figure 6) the tank which supplies fuel to the APU) and replace it with FT2 so that we could evaluate the difference in emissions between the two fuels. APU EGT values of about 360, 475, 550, and 610 were attained in the two tests; these corresponded to the generator, minimum pack, medium pack, and engine motoring modes of APU operation. Particle number and mass emissions varied inversely with EGT and, consistent with our engine findings, particle emissions dropped drastically when FT2 fuel was supplied to the combustor (Figure 7).

Figure 1. Aerial photograph of Camp AAFEX taken Jan 30 by NASA pilots on training mission.

Figure 2. AFRL begins packing up after 6 days of successful engine testing. First order of business: taking down the proudly displayed “TERTEL” banner.

Figure 3. Roy holds little Zoey, who arrived a couple of hours before he returned from Palmdale, where he provided many hours of excellent technical support to AEDC and AAFEX.

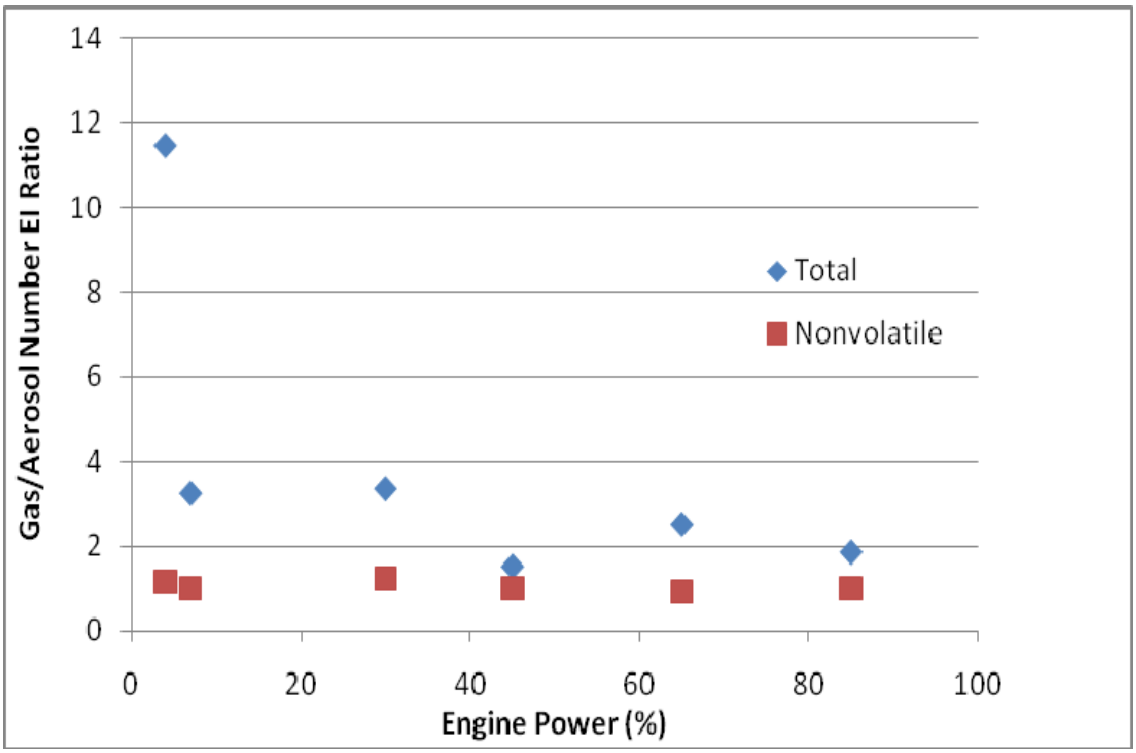
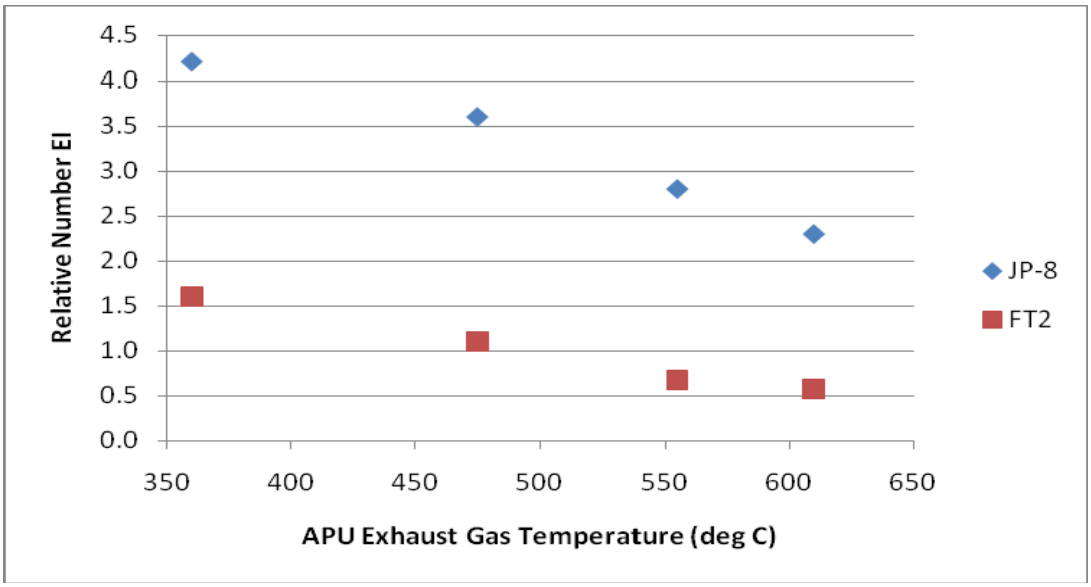


Figure 4. Ratio of number EIs for total (volatile+nonvolatile) and nonvolatile particle EIs for the "gas" and aerosol probe. **PRELIMINARY DATA—NOT FOR PUBLIC DISTRIBUTION**

Figure 5. APU exhaust port (upper right) and make-shift gas and aerosol sampling probes.

Figure 6. Cheerful and alert after spending Superbowl Sunday in quiet reflection, Donnie drains remaining JP-8 from the sump on the #2 main fuel tank in preparation for the FT2 APU test.



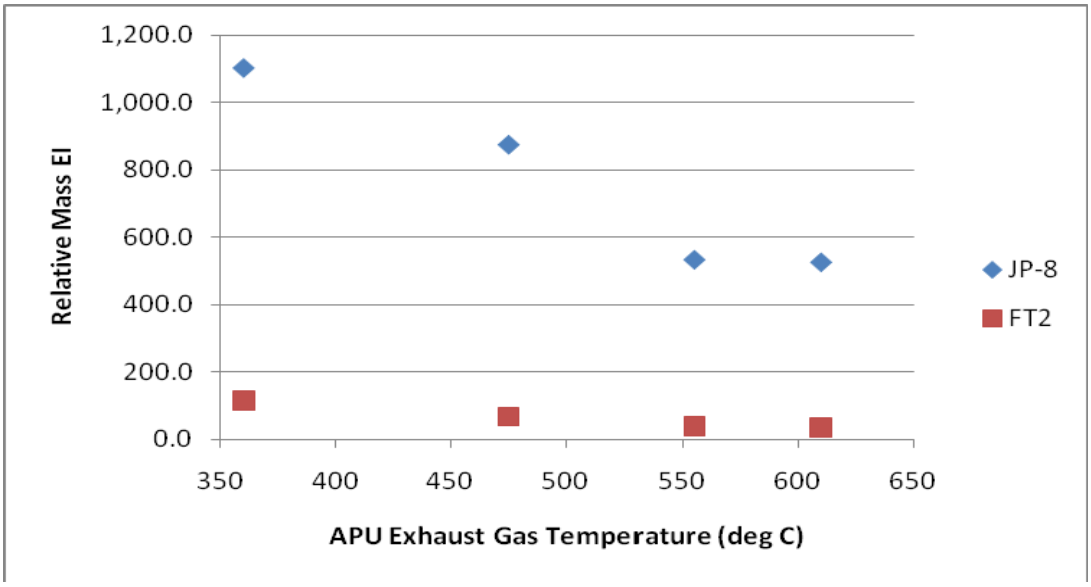


Figure 7. Comparison number (top) and mass emission indices from DC-8 APU burning JP-8 and FT2 (Sasol) fuel. **PRELIMINARY DATA—NOT FOR PUBLIC DISTRIBUTION**