AAFEX Status Report #12 – 31 January 2009

Primary Activities: F2 cold-phase; FT2/JP-8 blend; JP-8 warm-phase plume experiment; sample line cleaning.

Weather: 34 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. ABSOLUTELY PERFECT CONDITIONS FOR A PLUME CHEMISTRY EXPERIMENT!

Summary: Participants were absolutely sharp at the 4:30 am brief and greeted the project scientist with a barrage of ideas: plume chasing, exhaust profiling, instrument inter-comparisons, sampling system changes and early teardown were all thrown on the table. We decided to conduct three test runs during the day, including the planned FT2 and blended runs and an additional experiment to sample the downwind exhaust under warm conditions. Participants were truly engaged and ready as we were, for the first time, able to start the first run slightly ahead of schedule. Thereafter, Camp AAFEX was a whirlwind of activity until the last participants departed around 6 pm. Here's a re-cap of the day's events.

- Engine Test #1 was a repeat of the previous afternoon's FT2 test matrix, only at 30 F colder temperatures. Shortly after 7 am and just before the midpoint intermission, Mike's crew noticed a fuel leak beneath the right wing and asked to power down engines to address the problem. AAFEX investigators looked on anxiously as DC-8 mechanics (Figure 1) removed an inspection plate and traced the source of the leak to a fuel valve located on the #3 main tank. Participants quickly assessed that seal shrinkage due to a lack of aromatics in the FT fuel were the cause. Matt (AFRL), a fuels expert, noted this was a common problem with synthetic fuels and that the seals should expand and the leak stop shortly after introducing a standard petroleum fuel. Though Mike and crew offered to continue the FT2 test in spite of the leak, because we had completed a full set of measurements across the engine thrust envelope, we decided to terminate the test and move on to the blended fuel experiment.

- 50/50 blended JP8/FT2 was loaded in #3 main and testing resumed at about 8:30 am. After initial startup, investigators monitored engine #3 emissions as it was run at 30% power to flush the fuel lines of remaining FT2 and replace it with blend. Particle EIs increased in tandem with SO2 as the proportion of FT2 in the fuel lines decreased (Figure 2). Once SO2 emissions stabilized, power was reduced to ground idle and standard emission test cycle commenced. Emission results were similar to those measured during the FT1/JP8 (see Jan 30 report): particle mass and number EIs were considerably higher than seen with pure FT2, but not as high as produced with pure JP-8---no surprise.

- Prior to test #3, the warm temperature plume experiment, Aerodyne hooked up their external generator, decoupled their van from the 1/30 m sampling lines, augmented their instrument suite with Dave's EEPS (Figure 3), and parked on the south-side of the ramp (Figure 4), downstream of the aircrafts left wing to await engine startup. This time, JP-8 was burned in

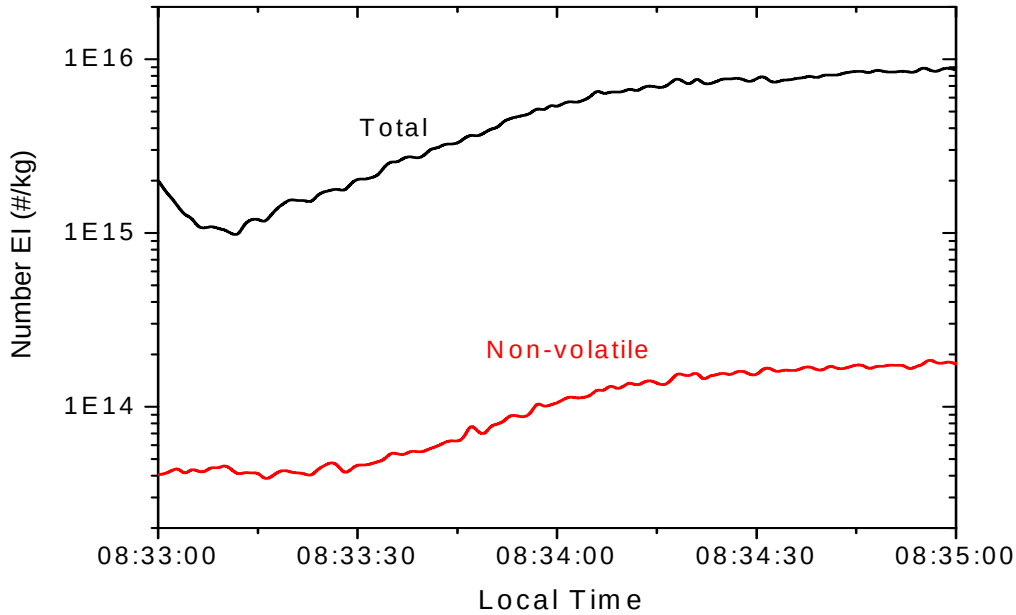
both engines, so once again, engine power was increased to 30% shortly after startup to burn residual blend out of the fuel system lines; increases in emission parameters similar to those shown in Figure 2 were observed. After engine power was reduced to ground idle (4%) the Aerodyne team drove their van in a serpentine pattern behind the plane, starting on the far edge of the ramp about 350 m downwind and closing to about 100 m. They repeated this pattern at the beginning and end of the test during the ground idle portions of the test matrix. At high engine powers, they parked far downwind or on the tarmac in front of the hanger where they encountered brief plume "hits" due to the slight northeasterly breeze. After the test, Scott was excited (his usual state) about the data set they had recorded and promised to provide graphs for a future daily report.

- During the exhaust chemistry experiment, the 1/30 m sampling team addressed other issues, including mapping emission parameters at three radial distances from the #3 engine centerline to assess concentration homogeneity across the exhaust plane as a function of power. This experiment was motivated by earlier observations of nucleation mode particles in samples collected 4" off the centerline at 30 and 45% engine power; subsequently, all measurements were recorded with the rake displaced 8" from dead center. Saturday's test involved drawing sample air from particle probe #3 at rake positions 0, 4, and 8" left of center while the engine was operated at 4, 7, 30, 45, 65, 85% of maximum thrust. In general, particle EIs were invariant with sampling location at each setting except 45%, where at rake position 0, total (volatile + nonvolatile) exceeded nonvolatile (assumed to be black carbon) particle concentrations by a ratio of 15 to 1; the ratio was 2:1 at the 8" position. The volatile particle enhancement along the centerline is apparently related to oil fumes emanating from the center vent tube (Figure 5). We speculate that these comprise only a small fraction of the overall particle emissions, but can lead to erroneous particle number and mass EI determinations in samples collected on engine center.

- Saturday's experiments also provided the opportunity to sample #3 engine particle emissions as it burned three different fuels in back-to-back tests. Figure 6 shows preliminary results that demonstrate the dramatic reduction in particle emissions seen when burning aromatic-free, synthetic fuels.

- Tests were also conducted to evaluate sampling line chemistry; results were ambiguous because the lines had become dirty and were continuously emitting low levels of organic acids and volatile particles. To clean the 30-m lines, the crew washed them out with high pressure water (Figure 7), blow dried them N2 gas, then attached a vacuum pump to one end to draw ambient air through them over the Superbowl-Sunday, down day.

Figure 1. Ace mechanic, Donnie Bailes (inset), removes under-wing inspection plate to trace source of fuel leak.



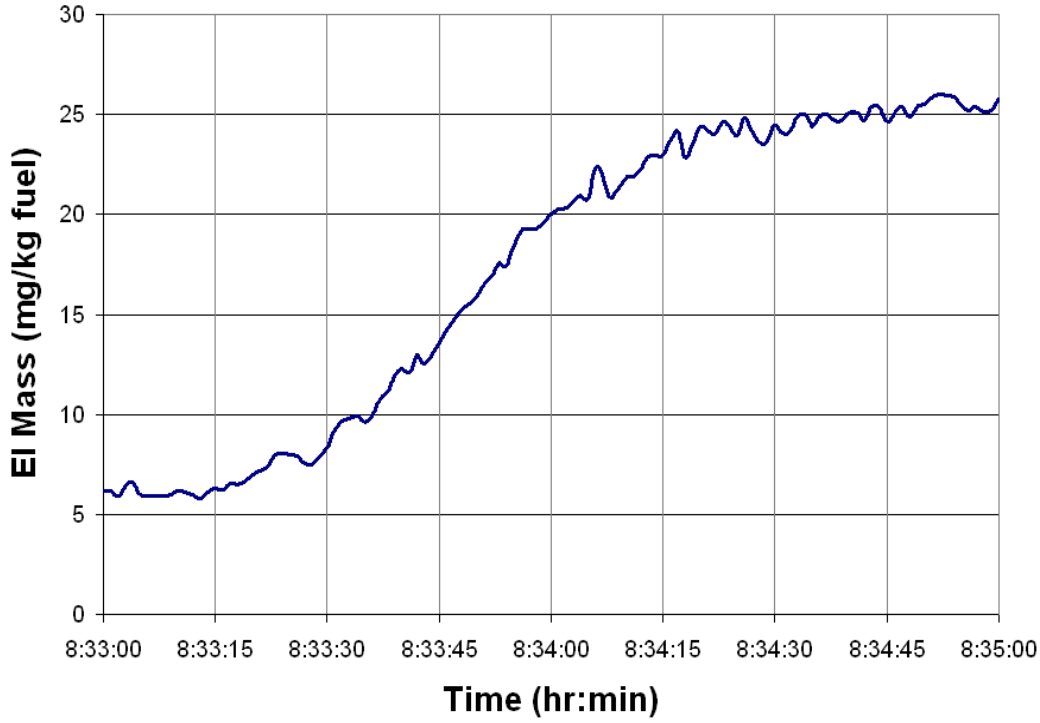
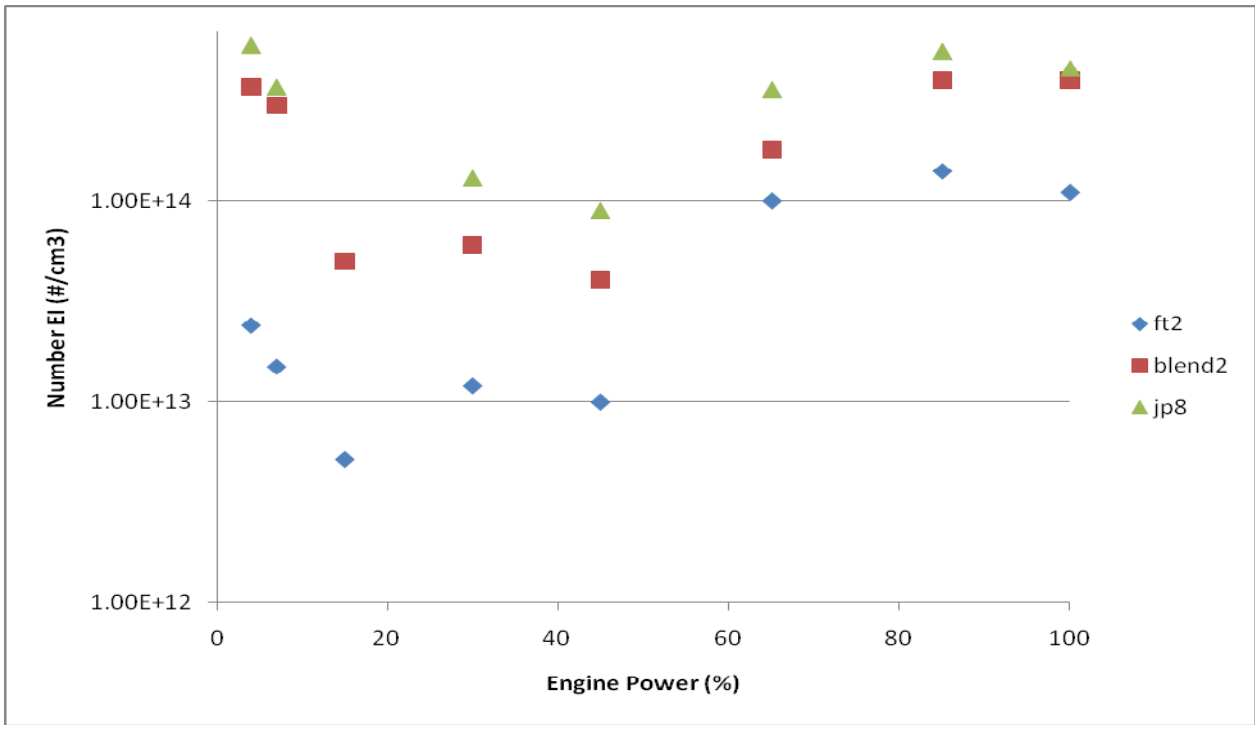


Figure 2. Time series of total and nonvolatile particle (top) and aerosol mass (bottom) EIs measured from the 30 m inlet as engine #3 burned out the remaining FT2 from the fuel system lines at the beginning of the FT2/JP8 blend test. **PRELIMINARY DATA, NOT FOR PUBLIC DISTRIBUTION**

Figure 3. As John looks on, Dave and Mike remove the miracle EEPS instrument from the 30-m UTRC death box for installation into the Aerodyne van for the plume chase.

Figure 4. Rick and his team prepare to sample the DC-8 exhaust plume at varying distances downwind in order to obtain a time history of NOx chemistry and particle nucleation and growth.

Figure 5. Brad works on sample rake with #3 engine in background. Note the vent tube protruding from the engine centerline.



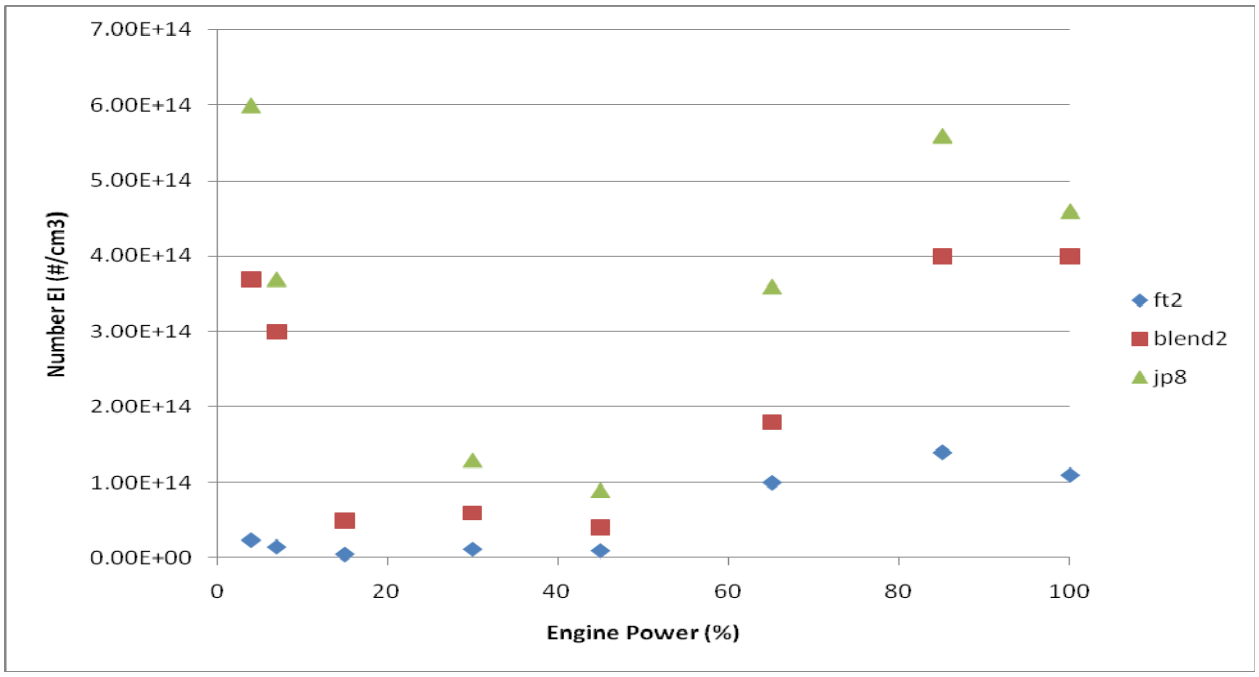


Figure 6. Comparison of nonvolatile particle emissions measured 1-m (probe tip 3, rake position -8) behind the #3 engine as it burned FT2 (blue), blended FT2/JP8 (red) and JP-8 (green) fuels during tests conducted between 5:30 am and 3 pm on Jan 31. Values will incease 5 to 30% after being corrected for sample density. Data are plotted in both log (top) and linear (bottom) format to better reveal diffences seen at the various power settings. **PRELIMINARY DATA, NOT FOR PUBLIC DISTRIBUTION**

Figure 7. Robert, finds relief after being confined in his trailer for a great part of the day; Bruce, tries to do the same, but can’t escape listening to the torrent of experiment ideas being articulated by Rick for the imaginative Aerodyne team. Photos illustrate the spirit of fun and comraderie that have prevailed throughout the AAFEX campaign.