Final AAFEX Status Report #14 – 3-4 February 2009

Primary Activities: Line-loss tests; Black carbon instrument inter-comparison; Tear-down and pack up.

Weather: 32 F at 7 am on both Tuesday and Wednesday; Clear with beautiful blue skies; Light winds, with highs near 70 F.

Summary: Participants arrived at Camp AAFEX around 7 am Tuesday morning and rushed about, some trying to accomplish last minute calibrations, others anxious to disassemble the sampling apparatus (Fiugure 1), pack everything up (Figure 2) and get out of town. ARI was able to load their belongings and head out by mid-morning Tuesday, while AEDC, LaRC and MST, the most equipment heavy of the groups, worked steadily until Wednesday afternoon before departing. Below are a few final highlights of the missions last days.

- One important mission objective was to compare measurements provided by the various black carbon instruments deployed at AAFEX. Using a Combustion Aerosol Standard (CAST) soot generator, a limited instrument inter-comparison experiment was performed Jan 25, before the first engine run. Analysis of these data suggested that a more extensive test using a broader range of soot particle concentrations and size distributions was needed to answer outstanding questions. Thus, with the participation of NASA, AEDC and MST, Dave (UTRC) led an 8-hour-long study to measure CAST emissions over a 3 order of magnitude concentration range with a variety of instruments including: a Laser-Induced Incandescence photometer (LII); a 3-wavelength Photo-Acoustic Spectrometer (PASS-3); a pair of Multi-Angle Aerosol Absorption Photometers (MAAP); a Differential Mobility Spectrometer (DMS-500); an Electrical Exhaust Particle Sizer (EEPS); a pair of photo-ionization PAH sensors (PAS-2000); an electrical aerosol detector (EAD); a pair of SMPS's, with and without thermal denuders on their inlets; and a smoke meter (SM). It was immediately apparent that the LII and SM lacked the sensitivity to measure low BC mass concentrations and that the MAAP, though highly sensitive, spent more time advancing its filter tape and re-zeroing than actually making measurements at high mass loadings. Other instruments gave readings that varied in proportion to black carbon loading throughout the tested concentration range. Interestingly, the ratio of BC mass (determined by the LII) to BC volume (SMPS) varied with CAST fuel to air ratio (FAR), suggesting that particles generated under rich flame conditions were fluffy, whereas those from a lean flame were more spherical and densely packed. Dave, Robert and Changlie were extremely pleased with the collected data set and thought that it would help inform deliberations of the SAE, E-31 committee, which is tasked with recommending engine emission measurement practices.

- Loss of particles to tubing walls can be a serious issue when using long lengths of sample lines as was done in AAFEX. Thus evaluating the transport efficiency of the lines connecting the inlet rakes/probes was an important, but tedious aspect of the mission.

Working with a nebulizer and DMA to create monodisperse particles and a single condensation nucleus counter to measure particle concentrations on the up- and downstream ends of the transport tube, Max and Elizabeth had earlier (before the engine runs started) determined size-dependent particle losses within the freshly-cleaned, 30 m and EPA sampling lines. On Tuesday, Max, Elizabeth, Eddie, and Bruce used a slightly different technique to characterize the transport of efficiency of the remaining lines. Instead of placing the CNC in a central location and drawing samples to it from each end of the test article through identical lengths of tubing, identical CNCs were used to simultaneously measure particle concentrations at the MST sample manifold and at the probe-ends of the various sample lines. A mini-eductor was used to draw poly-disperse sodium chloride particles produced by a tube furnace generator through a DMA and inject the selected size range of particles into the MST manifold; a scroll pump was hooked to the opposite end of the line to pull about 75 lpm of flow through each tested line. Losses through the 1 m lines were < 10% over the 75 to 200 nm size range, which was similar to results obtained for the 30 m lines in the earlier tests. However, a recheck of the 30 m lines yielded losses exceeding 30% for both the left and right inlets. Fearing that the apparent losses might be due to instrument problems, the team swapped the locations of the two CNCs and repeated the tests, obtaining the same results. Seamless stainless steel tubing was used throughout the 1 m sampling system, whereas the 30 m lines were composed of both ¾" stainless and ¾" carbon-impregnated PTFE. Low volumes (15 lpm) of exhaust air were drawn continuously through the 30 m sample lines during all engine runs to reduce the time needed to acquire stable species concentrations. We speculate that the transmission efficiency of PTFE tubing dropped as its surface became coated with soot and low volatility gases (e.g., Figure 3). Additional laboratory experiments will be conducted to better characterize this problem.

- All testing and calibration exercises were complete by 6 pm Tuesday, marking the official end of the mission. Teardown and packing continued until 3 pm on Wednesday.

Figure 1. Somewhat intimidated by the complexity of the setup, Brad tries to decide where to start in unraveling the 1-m exhaust sampling systems.

Figure 2. The most organized and spatially aware member of the science team, Changlie compresses his three racks of equipment + pumps and computers (top) into ruggedized boxes, which he and other members of the GRC team will take home as carry-on luggage.

Figure 3. The #3 engine rake before and after AAFEX engine runs. Note pattern left in soot coating by underlying cooling-coils in the rear cover.