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Aerosol Tests Conducted at Aberdeen Proving Grounds in MD

Daniel Lucero, John Brockman (retired), Brandon Servantes, and Matthew Hankins

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Daniel Lucero, John Brockmann (retired),
and Brandon Servantes
Fire and Aerosol Sciences, 1532

Matthew Hankins
Chemical & Biological Systems, 6632

Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185-1135

Abstract

Test data are reported that demonstrate the deposition from a spray dispersion system (Illinois Tool Works inductively charging rotary atomization nozzle) for application of decontamination solution to various surfaces in the passenger cabin of a Boeing 737 aircraft. The decontamination solution (EnviroTru) was tagged with a known concentration of fluorescein permitting determination of both airborne decontaminant concentration and surface deposited decontaminant solution so that the effective deposition rates and surface coverage could be determined and correlated with the amount of material sprayed. Six aerosol dispersion tests were conducted. In each test, aluminum foil deposition coupons were set out throughout the passenger area and the aerosol was dispersed. The aerosol concentration was measured with filter samplers as well as with optical techniques Average aerosol deposition ranged from 3 to 15 grams of decontamination solution per square meter. Some disagreement was observed between various instruments utilizing different measurement principles. These results demonstrate a potentially effective method to disperse decontaminant to interior surfaces of a passenger aircraft.

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INTRODUCTION

This is a data report covering the measurements made by Sandia National Laboratories (SNL). On October 13 and 14, 2010, Boeing, ITW, and Sandia conducted a series of aerosol tests at Aberdeen Proving Grounds in MD. The primary purpose of these tests was to investigate the current capability of the ITW aerosol system for uniform dispersion of an aerosol within the geometry of a Boeing 737 aircraft. A variety of techniques were used to evaluate performance, but the primary method was the use of a fluorescence tag in the aerosolized liquid (EnviroTru). One 30-mL bottle of fluorescein liquid (coolant leak detector for autos) was added to 1.00 Liter of EnviroTru and dispersed into the aircraft using ITW's mobile aerosol system. A similar solution was prepared at SNL for calibration.

Six aerosol dispersion tests were conducted. In each test, aluminum foil deposition coupons were set out throughout the passenger area, aerosol was dispersed, and aerosol concentration measured. After the aerosol had been dispersed and had settled, the coupons were recovered and the fluorescent tag extracted and measured to indicate the amount of deposition at each location.

INSTRUMENTATION

Six tests were conducted during which measurements of spray airborne concentration and deposition on coupons were made. The deposition coupon placed at a specific location consisted of a group of four 1 by 2 inch swatches of aluminum foil placed on an eight by eleven inch sheet of paper. The paper prevented cross contamination of the filter swatches from prior releases by providing a barrier between the swatches and surfaces. Each swatch was analyzed separately and the results averaged for that location.

Aerosol concentrations were measured by filter sample collection and fluorometric analysis as well as with 2 DustTraks (TSI, Inc., Shoreview, MN), a MetOne (Met One Instruments, Grants Pass, OR), and an Aerodynamic Particle sizer (TSI, Inc., Shoreview, MN). The Measured concentrations varied considerably most likely as a result of each instrument’s differing ability to efficiently sample larger drops.

FILTER AND COUPON MEASUREMENTS

The sprayed liquid was prepared by adding a 30 ml bottle of commercially prepared fluorescein solution to 1 liter of liquid. SNL measurements post test gave the average fluorescein concentration in the sprayed solution as 422 mg/liter. This concentration was used to back out the amount of sprayed liquid that deposited on each filter swatch in the test and on the aerosol collection filters used to determine the airborne concentration.

Fluorometer Calibration Curve

A pre-weighed standard of sodium fluorescein with mass 0.1416 g was prepared from sodium fluorescein powder purchased from Fisher Scientific. The sodium fluorescein was weighted on a 5-place Mettler balance, quantitatively transferred to a 100 mL volumetric flask, and diluted with buffer to make a 1415 ppm solution. A 10.00 mL aliquot of the 1416 ppm standard was diluted ten-fold in a volumetric flask to achieve a 141.6 ppm standard. This solution was diluted further to make individual standards in the range of 1-4 ppm for preparation of the calibration curve. Dilutions in excess of 4 ppm exceeded the response limit of the fluorometer. The following fluorometer calibration curve was measured.

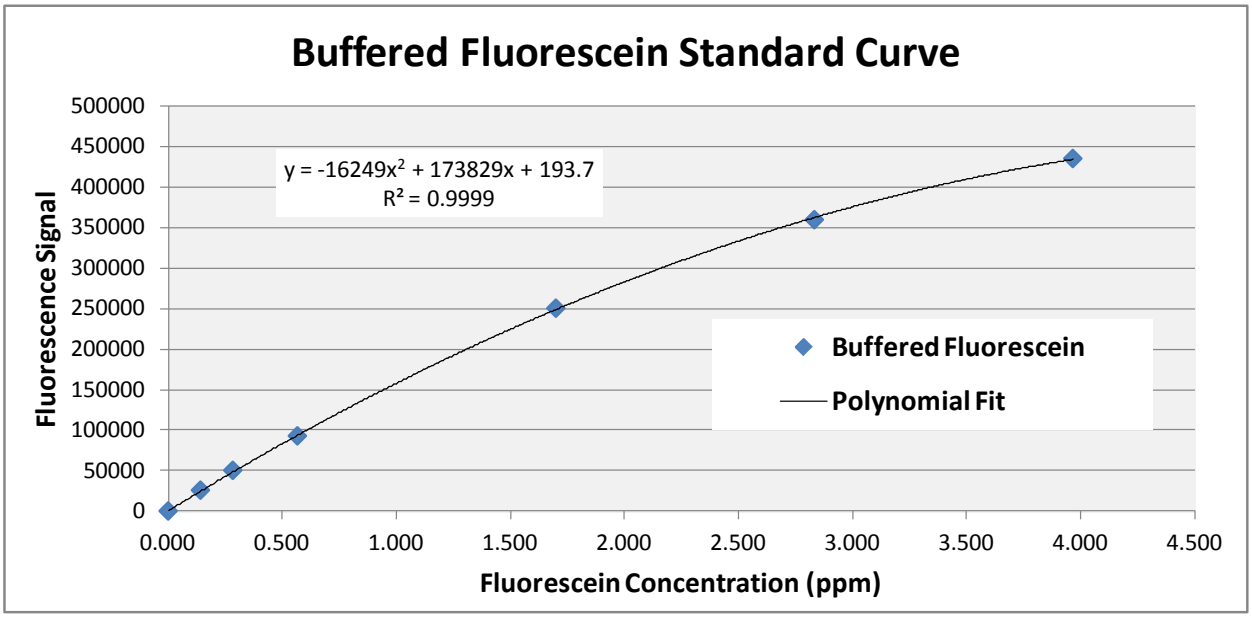


Figure 1. Buffered Fluorescein Standard Curve

Deposition Coupons

Aluminum foil coupons measuring 1"x2" were taped to a piece of office paper, then located on surfaces in the aircraft , near the aerosol head before each test was performed. The position of these coupons was identified by seat number and other descriptive terms. The liquid was dispersed for a specified time and then the aerosol was permitted to settle for 20 minutes. The coupons were retrieved from the aircraft, removed from the paper backing, and extracted with phosphate buffer solution (pH=11). The fluorescein concentration in the extract from each coupon was calculated from the fluorescence intensity in the buffered extract. The mass of fluorescein on each coupon was calculated from the concentration and volume of buffer used for the extraction. The florescence intensity and the calculations are recorded in sheets T1 through T6 of this spreadsheet for the six tests that were conducted. There were nine tests planned, six of which were actually completed. The coupons were grouped in sets of four and taped to a piece of office paper. For a specific group, the coupons were numbered 1-4 based on the relative position of coupons on the office paper (shown in Figure 2).

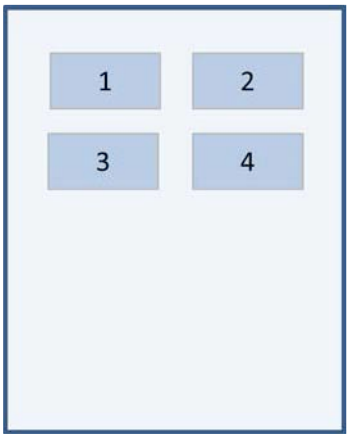


Figure 2. Position of Aluminum Foil Swatches on Paper

In tests 5 and 6, fabric deposition coupons were also co-located with aluminum coupons for comparison. No statistical difference was noted in the deposition.

Filter Samples

Two Sandia Sampling Unit (SSU) were placed in selected locations to provide time resolved filter samples of the spray. Each SSU contains a pump, a valved manifold, 5 filter holders, and a programmable timer. Sample flow was at 50 liters per minute (Tests 1, 2, 5, and 6) and 100 liters per minute (Test 3) with two minute samples taken at 5 minute intervals. The filters

were collected and bagged at the end of each test for later fluorometric analysis. The filters samples were kept in a dark container away from light.

The air flow was checked with a TSI flow meter at the start and end of each test and logged. The timing of the sampling was logged along with the filter ID denoting time and SSU and the ID placed on the bag.

The fluorometric analysis was performed at SNL and the airborne mass concentrations determined. These samplers sampled the larger drops with higher efficiency than the other methods employed and consequently, indicated considerably higher concentrations. Integral concentration was also calculated from these measurements. Three blanks were also run giving a threshold of 0.007 +/- 55% micrograms fluorescein per filter while measured concentrations were on the order of 1 to 10 micrograms fluorescein per filter with none measured below 0.21 micrograms fluorescein per filter.

DustTrak

Two DustTraks were placed in selected areas to provide real-time aerosol mass concentration. The upper limit in measured concentration is 100 mg/m^3. Note that particles larger than 10 micrometers will not be efficiently sampled by the DustTraks. Each DustTrak logged the concentration data and time. The DustTraks were bagged to protect them from excess liquid. Concentration was logged at 1 second intervals over the course of the tests and integral concentrations were calculated from these measurements.

MetOne

The MetOne is an optical particle counter that gives aerosol number concentration in 5 size bins. Aerosol mass concentration was calculated using an average size for each bin to give an average particle volume which was multiplied by the measured number of particles in the volume and the particle density of 1 gm/ml to give the mass concentration in each bin and these concentrations summed to give the aerosol mass concentration measured by the MetOne. 1 minute average data was used in the calculations and integral aerosol concentrations were calculated from these measurements.

Aerodynamic Particle Sizer (APS)

The APS was used to obtain an indication of the drop size from the nozzles. However since it was placed at some distance from the source and deposition region due to its sensitivity to high concentrations of airborne liquid, the results were quantitative and sizes much above 5 micrometers were not efficiently sampled. It was bagged to protect it from excess liquid.

The APS measures the particle number concentration as a function of particle aerodynamic diameter (which is the physical diameter for material with a density of 1 gm/ml) for a large number of closely spaced size bins. The mass concentration is calculated in the same way as with the MetOne.

TESTS

The six tests are summarized in the figure and table below.

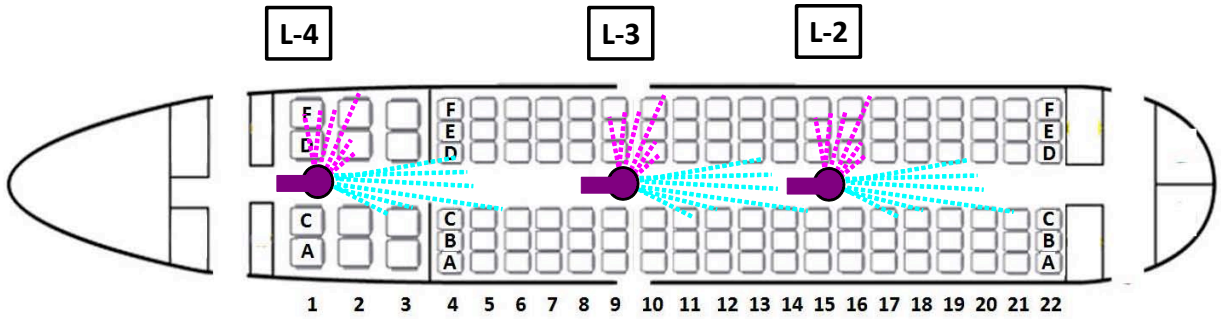


Figure 3. Layout of Boeing 737 used in tests with locations of spray.

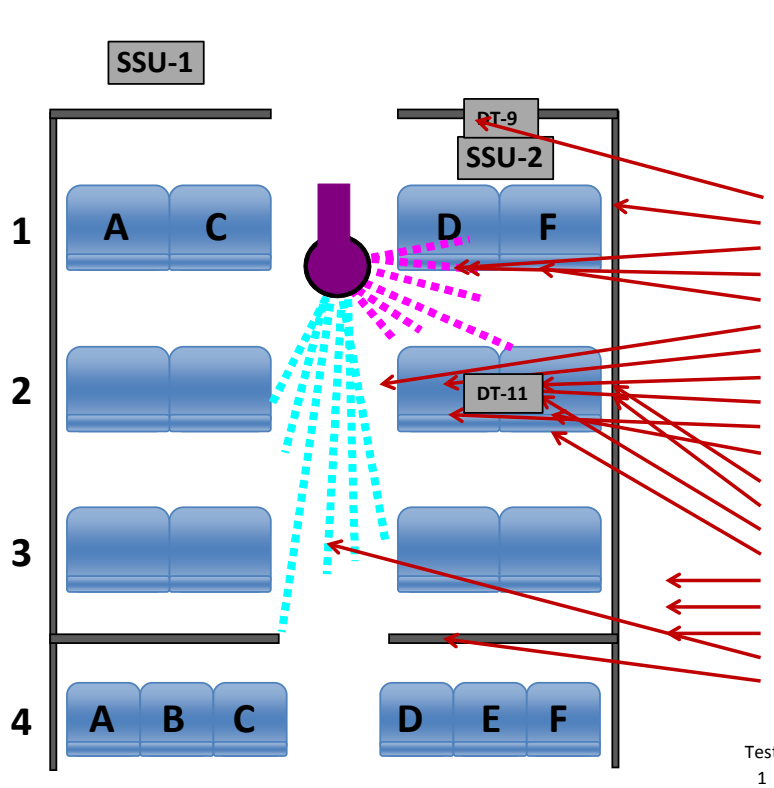
Table 1. Test Matrix

Test	Location	Spray Type	Upper Spray Nozzle (#1)	Lower Spray Nozzle (#2)	Spray Duration
1	L-4, Seats 2C/D	Mist	0 degree	0 degree	15 min
2	L-4, Seats 2C/D	Jet	0 degree	0 degree	5 min
3	L-4, Seats 2C/D	Jet	20 degree	12 degree	5 min
4	L-3 Seats 9C/D	Jet	20 degree	12 degree	5 min
5	L-3 Seats 9C/D	Jet	0 degree	0 degree	5 min
6	L-2 Seats 16C/D	Jet	0 degree	0 degree	5 min

The first three tests took place at location L-4, the second two at location L-3, and the sixth test at location L-2. There was a power interruption during Test 4 and no concentration data taken although deposition coupon data was measured. The coupon positioning was not duplicated among tests but there are similarities in placement among the tests to allow comparison and identification of general trends in deposition behavior.

Test 1

Figure 4 below shows the sprayer, instrument, and coupon locations as well as the measured surface mass concentration from the coupons. The standard deviation for the four swatches on each coupon is also given. The integral airborne mass concentration calculated from each of the measurement devices is also given in the figure. This test sprayed for 30 minutes and achieved higher concentrations than the other tests which sprayed for only 5 minutes although at a higher flow. Deposition varied with upward facing surfaces and surfaces in line of sight of the spray generally receiving higher deposition. Oddly, the coupon on the floor directly in front of the sprayer received a relatively small level of deposition. Also given are the integral aerosol concentrations calculated from each instrument. The filter samples give concentrations 1 to 2 order of magnitude higher than the DustTraks. This is likely the result of the filter sampler's higher sampling efficiency for larger particles. A deposition rate can be estimated from the ratio of integral concentration to the surface concentration.



T1-L4

T1 Location	Deposit gm/m^2	STDEV %
forward partition (1-20)	1.16	10%
1F Window shade (1-18)	2.45	16%
1D back of seat (1-6)	0.92	17%
1D behind tray top (1-10)	1.00	87%
1F behind tray top (1-11)	16.33	16%
2D bin latch (1-14)	0.89	3%
2D seat cushion (1-1)	2.08	23%
2F seat cushion (1-2)	3.53	10%
2 D/F between seat (1-9)	0.27	29%
2D seat back (1-3)	6.46	8%
2F seat back (1-4)	2.00	200%
2F window shade (1-16)	1.79	14%
2F side wall/below seat (1-17)	2.54	25%
2F Under seat/carpet (1-5)	5.93	16%
2F back of seat (1-7)	0.68	12%
2F PSU (1-8)	15.47	13%
2F PSU (1-12	1.96	10%
2F PSU (1-13)	0.15	11%
3D aisle (1-15)	0.11	11%
2D Aft partition (1-19)	2.51	3%

Integral Concentration (mg-min/m3)

Test	SSU-1	SSU-2	DT-9	DT-11	MetOne
1	10115	28027	468	465	-

Figure 4. Layout and Results for Test 1

Figure 5 shows the measured airborne concentrations from the SNL instruments and filters over time for Test 1. There was no Met one data reported on Test 1. SSU-1 measured concentrations are lower since this instrument was located behind the sprayer indicating spatial variation in the aerosol concentration. Toward the end of the test, the concentration had fallen a little over an order of magnitude from the peak; this trend is seen for all the instruments in spite of their large variation.

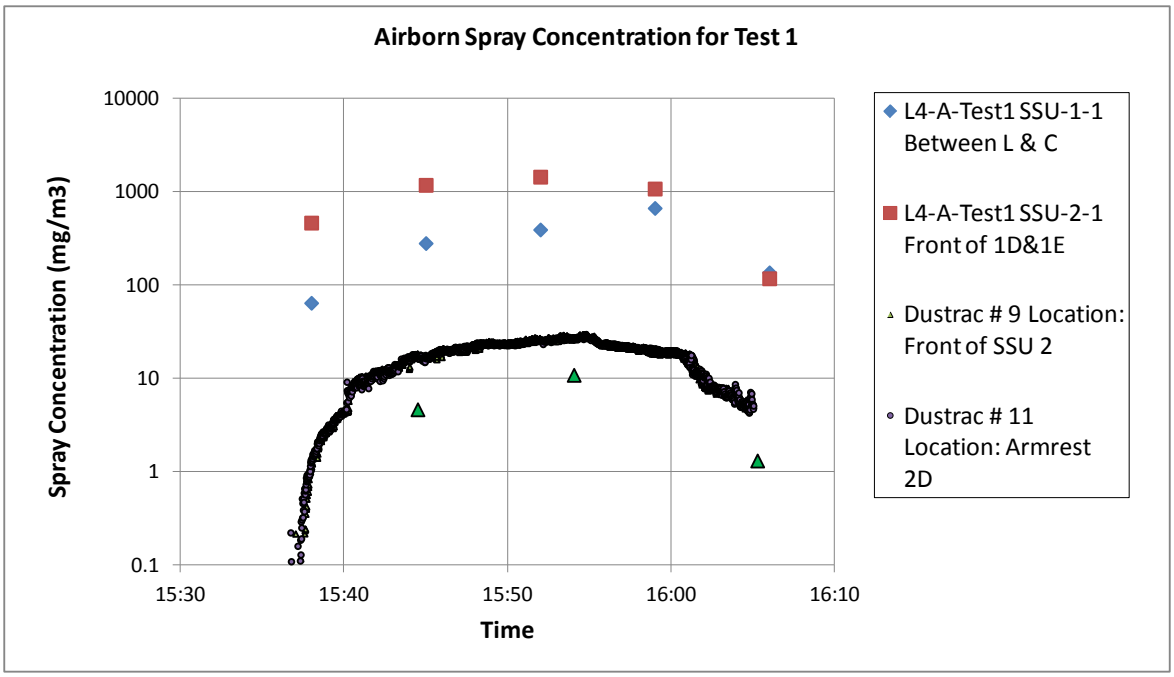


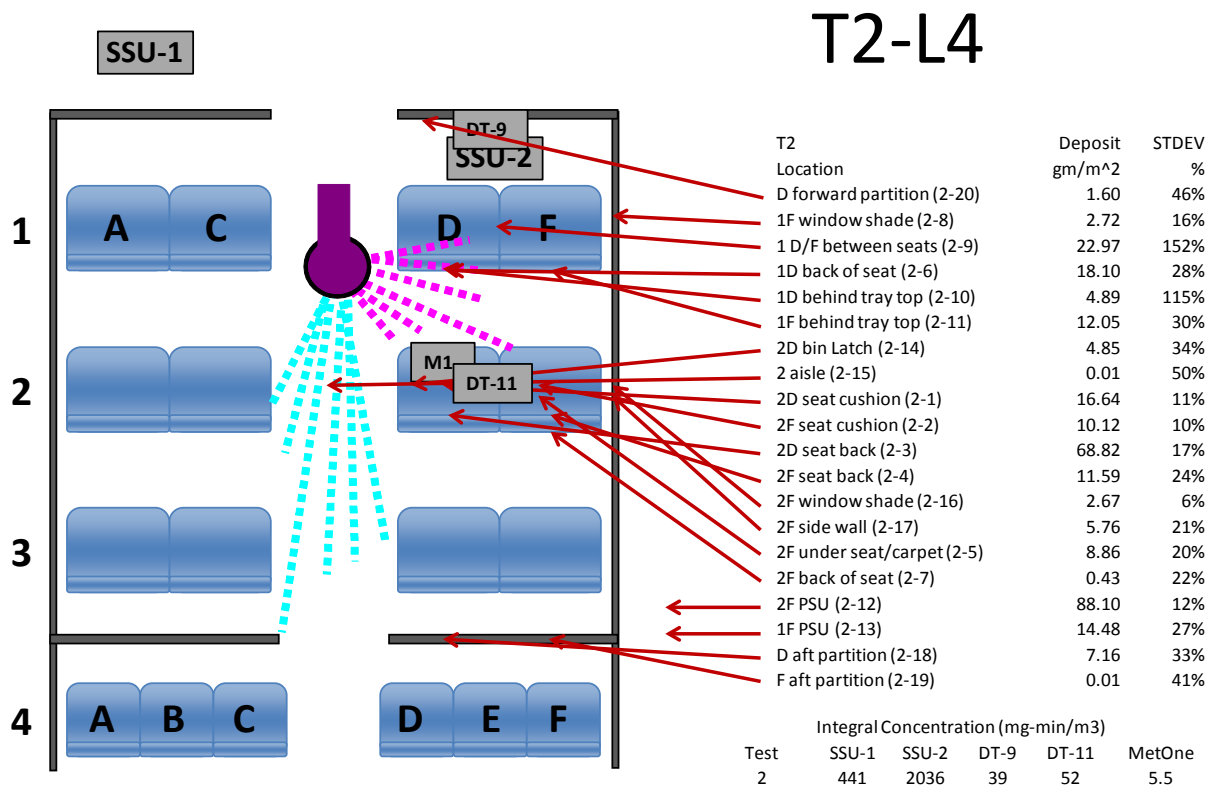
Figure 5. Airborne Concentration for Test 1

Test 2

Test 2 was similar to Test 1 in the location of the sprayer and instruments, however the dissemination of aerosol was for only five minutes and measured concentrations were lower than in Test 1. Figure 6 below shows the sprayer, instrument, and coupon locations as well as the measured surface mass concentration from the coupons. The standard deviation for the four swatches on each coupon is also given. The integral airborne mass concentration calculated from each of the measurement devices is also given in the figure. Deposition varied with upward facing surfaces and surfaces in line of sight of the spray generally receiving higher deposition. Again as seen in Test 1, the coupon on the floor directly in front of the sprayer received a relatively small level of deposition. Also given are the integral aerosol concentrations calculated from each instrument. The filter samples give concentrations 1 to 2 orders of magnitude higher than the DustTraks and the MetOne is an order of magnitude lower still. This is likely the result

of the filter sampler's higher sampling efficiency for larger particles and is seen throughout all the tests.

Figure 7 shows the measured airborne concentrations from the SNL instruments and filters over time for Test 2. Again, the SSU-1 measured concentrations are lower since this instrument was located behind the sprayer indicating spatial variation in the aerosol concentration. Toward the end of the test, the concentration had fallen a little over an order of magnitude from the peak; this trend is seen for all the instruments in spite of their large variation. One sees a sharp drop in concentration reflected by the DustTraks, MetOne, and APS at about 10 minutes into the test indicating the cessation of aerosol generation and decay of concentration. This sharp drop was not seen in the filter sample data.



T2 Location	Deposit gm/m^2	STDEV %
D forward partition (2-20)	1.60	46%
1F window shade (2-8)	2.72	16%
1 D/F between seats (2-9)	22.97	152%
1D back of seat (2-6)	18.10	28%
1D behind tray top (2-10)	4.89	115%
1F behind tray top (2-11)	12.05	30%
2D bin Latch (2-14)	4.85	34%
2 aisle (2-15)	0.01	50%
2D seat cushion (2-1)	16.64	11%
2F seat cushion (2-2)	10.12	10%
2D seat back (2-3)	68.82	17%
2F seat back (2-4)	11.59	24%
2F window shade (2-16)	2.67	6%
2F side wall (2-17)	5.76	21%
2F under seat/carpet (2-5)	8.86	20%
2F back of seat (2-7)	0.43	22%
2F PSU (2-12)	88.10	12%
1F PSU (2-13)	14.48	27%
D aft partition (2-18)	7.16	33%
F aft partition (2-19)	0.01	41%

Integral Concentration (mg-min/m3)

Test	SSU-1	SSU-2	DT-9	DT-11	MetOne
2	441	2036	39	52	5.5

Figure 6. Layout and Results for Test 2

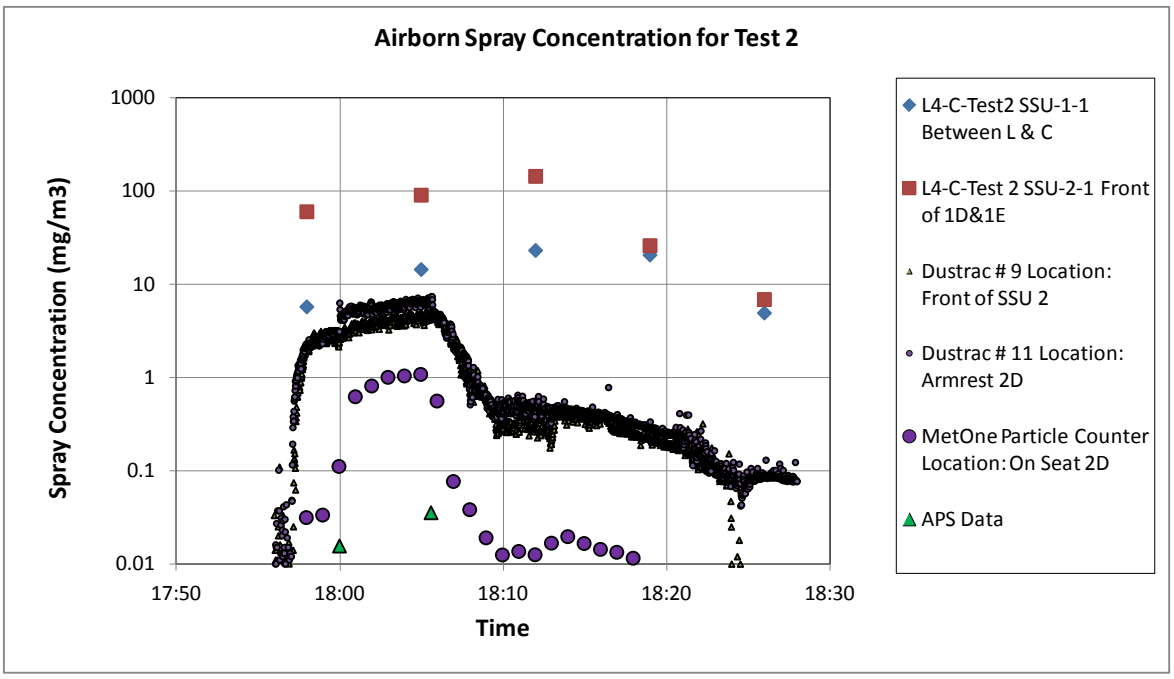
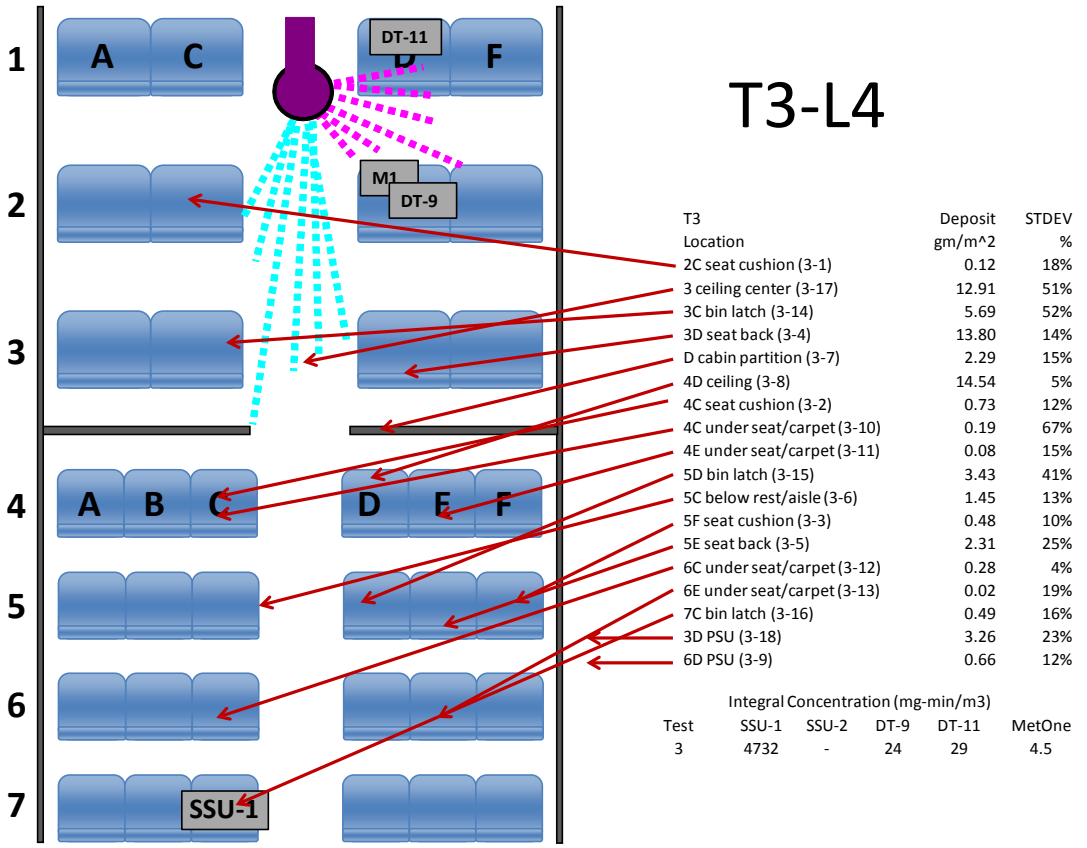


Figure 7. Airborne Concentration for Test 2

Test 3

In Test 3, the sprayer was in the same position as in Tests 1 and 2 and sprayed for 5 minutes as in Test 2 but with the spray heads directed differently. The instrumentation and filter sampler as well as the deposition coupons were located differently than in the previous two tests as can be seen from Figure 8. The SSU-2 filter sampler was not in operation for this test and the SSU-2 sampler was located in row seven quite a distance from the spray source although it measured a higher concentration than the higher of the two SSUs in the Test 2. Deposition coupons were also positioned farther from the spray source than in the previous two tests and reflected a general decline in surface deposition with distance from the spray source. The relative concentrations indicated by the filter sampler, the DustTraks, and the MetOne followed the same trend seen in earlier tests.

Figure 9 is the airborne concentration and the shows the same relative differences in concentration among the instruments as seen in the other tests. The DustTraks and MetOne show the rapid fall in concentration after cessation of dissemination. The SSU does not indicate such a rapid fall off but it is further away from the spray source and may have seen more averaging of the concentration.



T3 Location	Deposit gm/m^2	STDEV %
2C seat cushion (3-1)	0.12	18%
3 ceiling center (3-17)	12.91	51%
3C bin latch (3-14)	5.69	52%
3D seat back (3-4)	13.80	14%
D cabin partition (3-7)	2.29	15%
4D ceiling (3-8)	14.54	5%
4C seat cushion (3-2)	0.73	12%
4C under seat/carpet (3-10)	0.19	67%
4E under seat/carpet (3-11)	0.08	15%
5D bin latch (3-15)	3.43	41%
5C below rest/aisle (3-6)	1.45	13%
5F seat cushion (3-3)	0.48	10%
5E seat back (3-5)	2.31	25%
6C under seat/carpet (3-12)	0.28	4%
6E under seat/carpet (3-13)	0.02	19%
7C bin latch (3-16)	0.49	16%
3D PSU (3-18)	3.26	23%
6D PSU (3-9)	0.66	12%

Integral Concentration (mg-min/m3)

Test	SSU-1	SSU-2	DT-9	DT-11	MetOne
3	4732	-	24	29	4.5

Figure 8. Layout and Results for Test 3

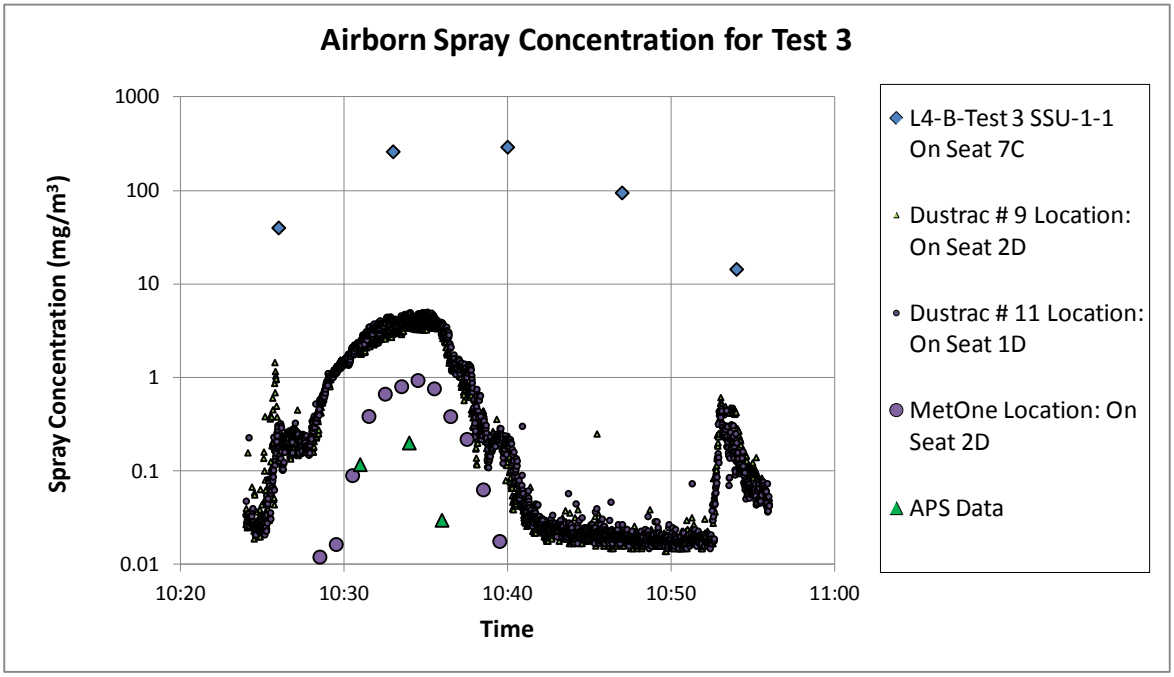
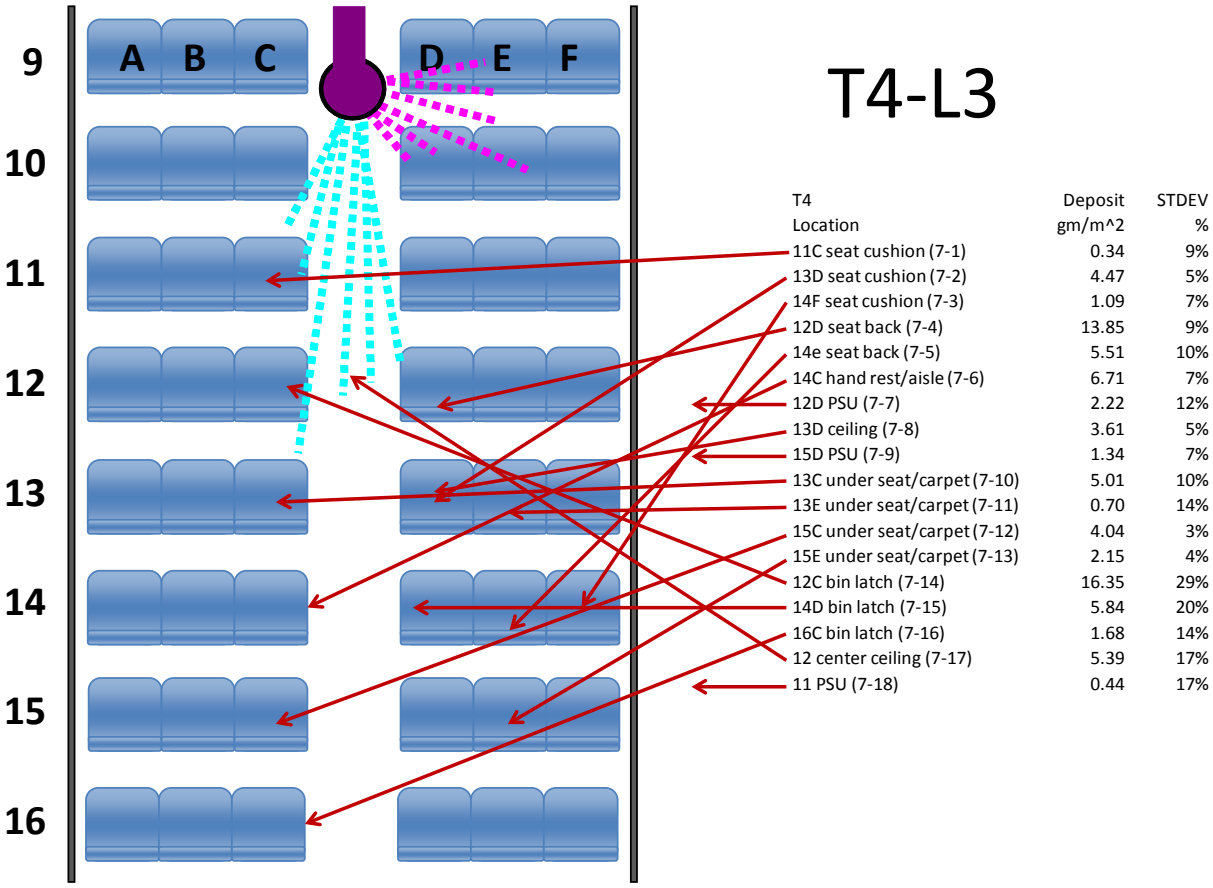


Figure 9. Airborne Concentration for Test 3

Test 4

There was a power interruption affecting all of SNL's measurement instrumentation and subsequently, no aerosol data. However, coupons were places and successfully recovered and that information is given in Figure 10.



T4 Location	Deposit gm/m^2	STDEV %
11C seat cushion (7-1)	0.34	9%
13D seat cushion (7-2)	4.47	5%
14F seat cushion (7-3)	1.09	7%
12D seat back (7-4)	13.85	9%
14e seat back (7-5)	5.51	10%
14C hand rest/aisle (7-6)	6.71	7%
12D PSU (7-7)	2.22	12%
13D ceiling (7-8)	3.61	5%
15D PSU (7-9)	1.34	7%
13C under seat/carpet (7-10)	5.01	10%
13E under seat/carpet (7-11)	0.70	14%
15C under seat/carpet (7-12)	4.04	3%
15E under seat/carpet (7-13)	2.15	4%
12C bin latch (7-14)	16.35	29%
14D bin latch (7-15)	5.84	20%
16C bin latch (7-16)	1.68	14%
12 center ceiling (7-17)	5.39	17%
11 PSU (7-18)	0.44	17%

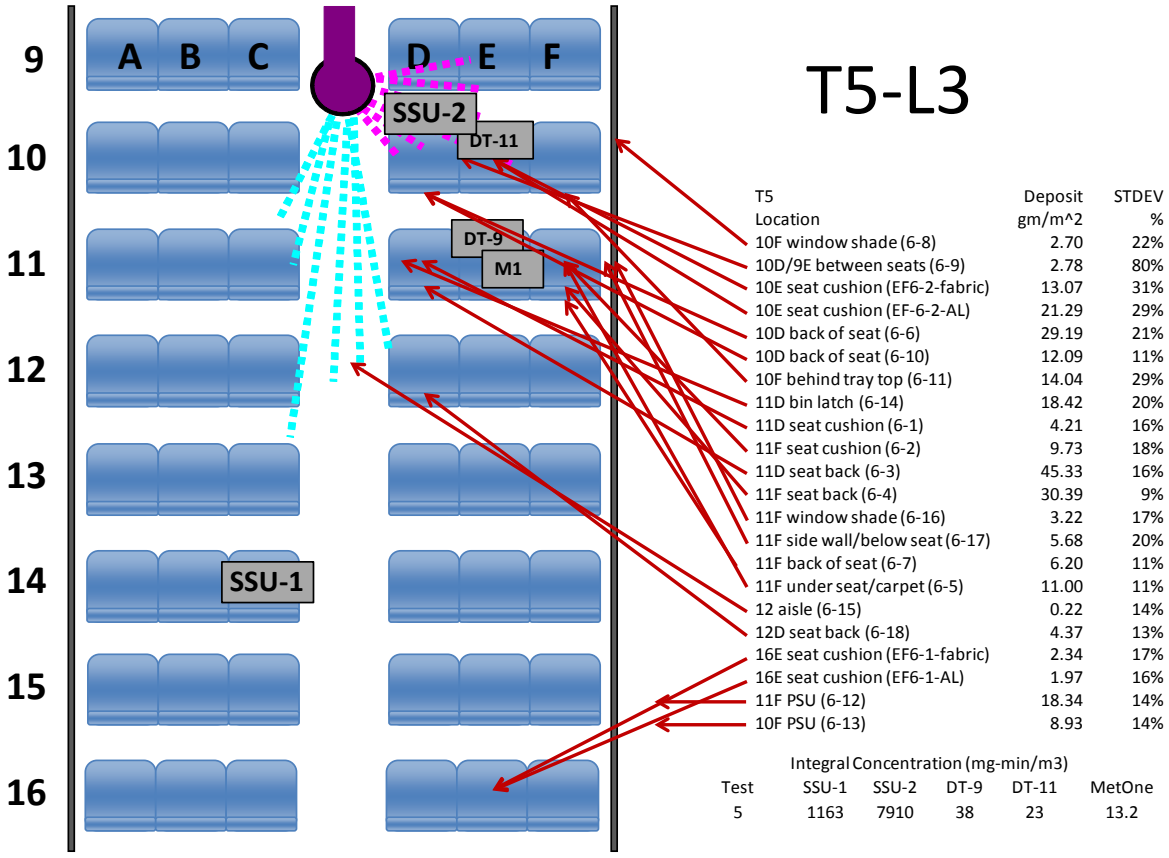
Figure 10. Layout and Results for Test 4

In this test, the sprayer was moved to a location between rows 9 and 10 and deposition coupons placed predominantly a few rows further downstream from the spray direction. Deposition was typically on the order of a few grams per square meter with some outliers. The spray heads had the same configuration as in Test 3 and sprayed for 5 minutes.

Test 5

The sprayer location in Test 5 was the same as in Test 4 but with the spray head orientation returned to that of Tests 1 and 2. Spray duration was also for 5 minutes. Figure 11 shows the instrument and coupon placement and gives the surface deposition results and the integrated concentration. SSU-2 was placed close to the point of dissemination with SSU-1 five rows farther downstream and the concentrations for SSU-2 were significantly higher than those for SSU-1. The DustTraks and MetOne were placed close to spray source and followed the same trend as in previous tests with regard to their relative concentrations. Deposition coupons were concentrated more closely to the spray source with a few further downstream. The deposition on the seat cushions in row 16 showed deposition on the same order as that seen on coupons closer to the spray source. Once more, the deposition on the floor in front of the spray source showed significantly lower concentration as was seen in Tests 1 and 2.

Generally, the deposition is fairly high, on the order of 10 mg/m^2, higher and more uniform than seen in the previous tests.



T5 Location	Deposit gm/m^2	STDEV %
10F window shade (6-8)	2.70	22%
10D/9E between seats (6-9)	2.78	80%
10E seat cushion (EF6-2-fabric)	13.07	31%
10E seat cushion (EF-6-2-AL)	21.29	29%
10D back of seat (6-6)	29.19	21%
10D back of seat (6-10)	12.09	11%
10F behind tray top (6-11)	14.04	29%
11D bin latch (6-14)	18.42	20%
11D seat cushion (6-1)	4.21	16%
11F seat cushion (6-2)	9.73	18%
11D seat back (6-3)	45.33	16%
11F seat back (6-4)	30.39	9%
11F window shade (6-16)	3.22	17%
11F side wall/below seat (6-17)	5.68	20%
11F back of seat (6-7)	6.20	11%
11F under seat/carpet (6-5)	11.00	11%
12 aisle (6-15)	0.22	14%
12D seat back (6-18)	4.37	13%
16E seat cushion (EF6-1-fabric)	2.34	17%
16E seat cushion (EF6-1-AL)	1.97	16%
11F PSU (6-12)	18.34	14%
10F PSU (6-13)	8.93	14%

Integral Concentration (mg-min/m3)

Test	SSU-1	SSU-2	DT-9	DT-11	MetOne
5	1163	7910	38	23	13.2

Figure 11. Layout and results for Test 5

Figure 12 shows the airborne concentration over time measured by the SNL instrumentation and shows the same trends seen in the previous tests. The cessation of spray delivery is seen in DustTrak and MetOne data but not in the filter data for either of the SSUs.

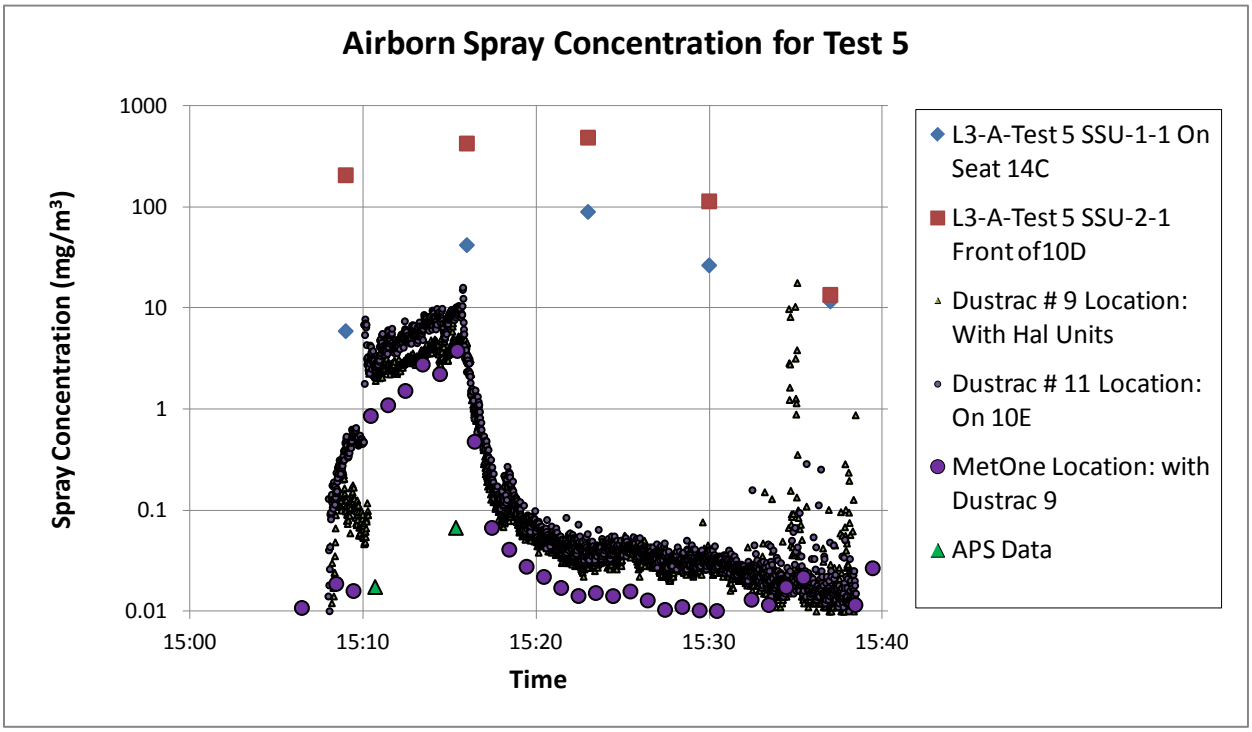
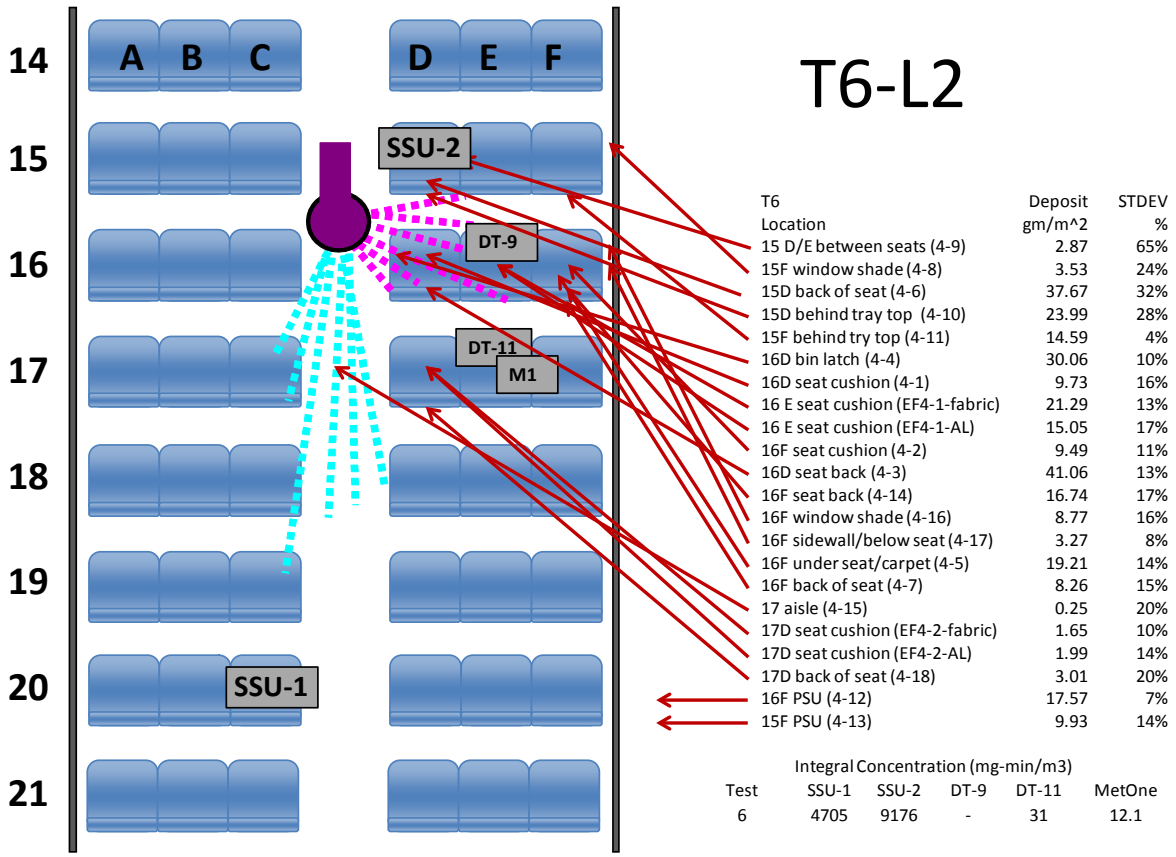


Figure 12. Airborne Concentration for Test 5

Test 6

Test 6 has the sprayer at a location between rows 15 and 16 with the spray head orientation the same as in Tests 1, 2, and 5. The instrumentation layout relative to the spray source is similar to that of Test 5 with the DustTraks switching position. The layout of the deposition coupons relative to the spray source is also similar to that of Test 5 as can be seen in Figure 13. Deposition levels are similar to those of test 5 making Tests 5 and 6 the ones with the highest and more uniform overall deposition with test 4 somewhat lower with more relative variation.

Figure 14 shows the airborne concentration over time measured by the SNL instrumentation and shows the same trends seen in the previous tests. The cessation of spray delivery is seen in DustTrak and MetOne data but not in the filter data for either of the SSUs.



T6 Location	Deposit gm/m^2	STDEV %
15 D/E between seats (4-9)	2.87	65%
15F window shade (4-8)	3.53	24%
15D back of seat (4-6)	37.67	32%
15D behind tray top (4-10)	23.99	28%
15F behind try top (4-11)	14.59	4%
16D bin latch (4-4)	30.06	10%
16D seat cushion (4-1)	9.73	16%
16 E seat cushion (EF4-1-fabric)	21.29	13%
16 E seat cushion (EF4-1-AL)	15.05	17%
16F seat cushion (4-2)	9.49	11%
16D seat back (4-3)	41.06	13%
16F seat back (4-14)	16.74	17%
16F window shade (4-16)	8.77	16%
16F sidewall/below seat (4-17)	3.27	8%
16F under seat/carpet (4-5)	19.21	14%
16F back of seat (4-7)	8.26	15%
17 aisle (4-15)	0.25	20%
17D seat cushion (EF4-2-fabric)	1.65	10%
17D seat cushion (EF4-2-AL)	1.99	14%
17D back of seat (4-18)	3.01	20%
16F PSU (4-12)	17.57	7%
15F PSU (4-13)	9.93	14%

Integral Concentration (mg-min/m3)

Test	SSU-1	SSU-2	DT-9	DT-11	MetOne
6	4705	9176	-	31	12.1

Figure 13. Layout and Results for Test 6

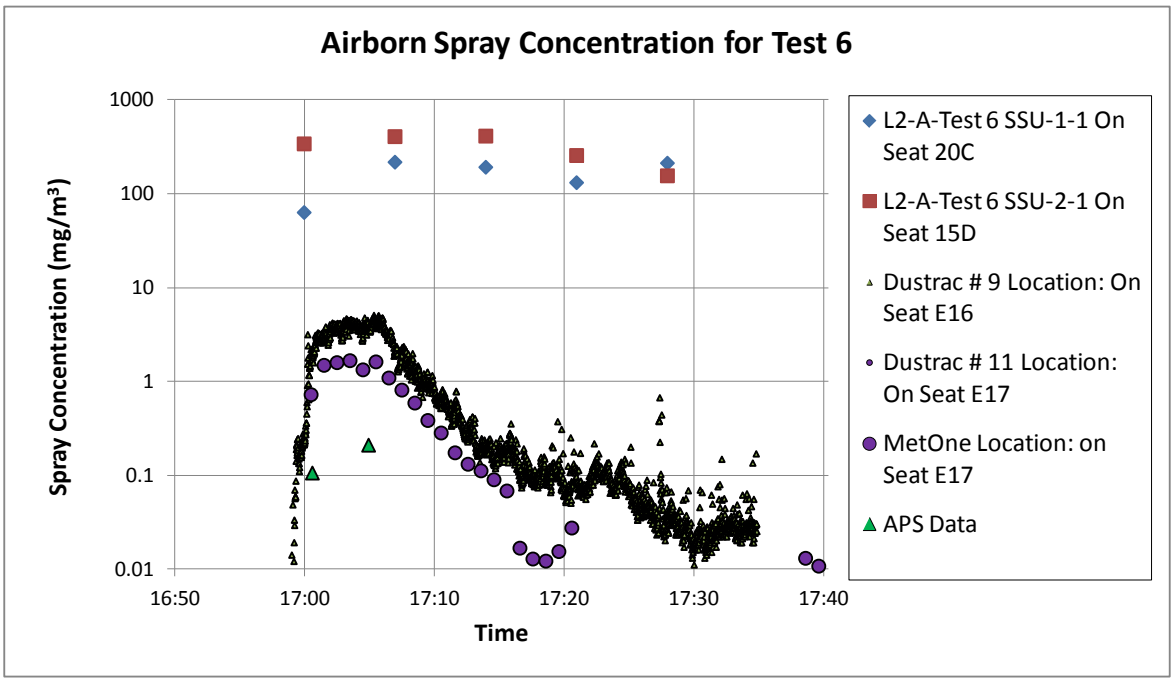


Figure 14. Airborne Concentration for Test 6

DISCUSSION AND CONCLUSIONS

One of the most noticeable trends is the much higher concentration measured by the Filter samples when compared to the DustTraks and MetOnes. This could be explained by the filter samplers' higher sampling efficiency for larger particles but the fact that the SSU data does not show the cessation of dispersion as seen by the DustTraks, the MetOne, and the APS is disturbing as the larger particles would fall off more quickly than the smaller ones and if the SSUs' higher concentration is the result of more efficiently sampling these larger particles, the fall off should be very noticeable.

Table 2 gives the integral concentrations measured in the tests from all the SNL instrumentation. One sees the definite trend discussed above. The MetOne is not designed for mass concentration measurement and the calculated values given are really more qualitative. The DustTraks are designed for aerosol mass measurement below 10 micrometers and show good agreement between themselves for the tests. One sees higher concentrations for the first test in which aerosol was generated continuously over the course of the test. The concentrations in tests 2 through 5 are lower but not greatly different form test to test.

Table 2. Integral Concentration from Sandia Instruments

Test	Integral Concentration (mg-min/m^3)				MetOne
	SSU-1	SSU-2	DT-9	DT-11	
1	10115	28027	468	465	-
2	441	2036	39	52	5.5
3	4732	-	24	29	4.5
4	-	-	-	-	-
5	1163	7910	38	23	13.2
6	4705	9176	-	31	12.1

One has difficulty in comparing the deposition from the various tests since the coupon locations were not entirely duplicated from test to test and a large range of deposition was seen from test to test. A gross metric for deposition level can be determined by taking the average of all deposition measurements in each test. The spread can be estimated by the standard deviation of these measurements. Table 3 gives these metrics for each of the tests. As we pointed out, tests 5 and 6 seem to have the higher concentration and least variation while test 2 has a comparable concentration but with considerably higher variation. Tests 1 and 3 have the lowest deposition with the higher variation. Test 4 has lower deposition but variation on the order of tests 5 and 6. Further analysis with more focus on the individual measurements is required to determine any trends among the tests and to correlate the results with the test parameters. This analysis can be done should follow on work be conducted.

Table 3. Average Deposition Measured on all Coupons in Each Test

Average Deposition (gm/m^2)		
Test	**Average**	**Std Dev**
1	3.41	135%
2	15.09	151%
3	3.48	142%
4	4.49	98%
5	12.07	94%
6	13.64	85%

We can use the data in the above two tables to estimate at least the order of magnitude of deposition velocity seen in the tests. The deposition velocity or deposition rate is the ratio of surface deposition to the integral concentration immediately adjacent to that surface. Given that our concentration measurements are not adjacent to any surfaces and our surface deposition levels vary widely we can only make a gross estimate. Such an estimate is given in Table 4.

Table 4. Average Deposition Velocity from Average Deposition and Integral Concentration from Each SNL Instrument

Average Deposition Rate (cm/sec)					
Test	**SSU-1**	**SSU-2**	**DT-9**	**DT-11**	**MetOne**
1	0.56	0.20	12.1	12.2	-
2	57.1	12.4	640	483	4543
3	1.23	-	242	204	1296
4	-	-	-	-	-
5	17.3	2.5	528	887	1523
6	4.8	2.5	-	745	1872

Deposition velocities on the order of a cm/sec are relatively high for small particles. A 10 micrometer diameter water droplet falls with a terminal velocity of 0.3 cm/sec and a 100 micrometer diameter droplet has a terminal velocity of about 30 cm/sec. The velocities calculated from the SSU concentration data in the above table would seem to be enhanced over gravity in some cases but not unreasonable if there were larger drops present or if the deposition was enhanced by either electrostatics, turbulence, or ballistic trajectories Those estimated from the DustTrak and MetOne concentrations are unrealistically high indicating that these instruments are grossly underestimating the concentration.

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