Failure Analysis Associates

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Paint Application Report for DUX Area, Inc. at Fort Hood Army Base, Killeen, TX

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Background

On June 11, 2007, Ron Joseph went to Fort Hood Army Base in Killeen, TX to conduct paint usage tests using a manual DUX spray gun and the high-volume low-pressure (HVLP) spray gun currently being used at the Building 9576 404th paint booth (Figure 1).

During recent months, DUX received anecdotal feedback from their customers that their spray gun was capable of achieving 15-40% reductions in paint usage. The purpose of the test program at Fort Hood was to compare the DUX Pressure Feed spray gun (Figure 2) with an HVLP spray gun under comparable and controlled conditions. For these tests, a Graco Pressure Feed HVLP, XT Series spray gun was used for comparisons (Figure 3). The paint shop normally uses this spray gun.

The results of both tests demonstrated significant paint savings; 44.1% when the DUX spray gun applied Hentzen Coatings MIL-C-53039, "Coating, Aliphatic Polyurethane, Single Component, Chemical Agent, Resistant," and 25.47% when the same spray guns applied Sherwin-Williams MIL-DTL-64159, "Coating, Water Dispersible Aliphatic Polyurethane, Chemical Agent Resistant." The results of the first series of tests with the Hentzen Coatings MIL-C-53039 are considered reliable. However, due to several unforeseen circumstances, results achieved in the second series; namely, the application of Sherwin-Williams MIL-DTL-64159 are questionable.

Specifically, this was the first time the painters had applied the Sherwin Williams coating and they were unfamiliar with its application characteristics. This was most unfortunate. Had Mr. Joseph and DUX Area, Inc. known that the painters were not familiar with the Sherwin-Williams MIL-DTL-64159 product they would have arranged for the painters to be adequately trained during the previous week. Once the test program started, the personnel at Foot Hood were under pressure to complete the painting; hence, inadequate time was allowed for the painters to familiarize themselves with the coating and application techniques using both spray guns. This was reflected in significantly different film thicknesses between the Graco HVLP, XT Series spray gun and the DUX spray gun. The total time required to coat each vehicle in the second test also varied due to unfamiliarity with the coating and the operators' inability to properly judge when adequate coating thickness was achieved. Despite these issues, the data was normalized to account for coating thickness and are providing the results of the second test as another point of reference.

Test Program

The test program consisted of two test series of identical military vehicles (two each), two different types of spray guns, and two different coatings. Table 1 provides an overview of the test program selection. Table 2 identifies the equipment, used during the tests.

When both spray guns were used to apply coatings to military vehicles, the critical parameters for the test series were:

1. The same paint would be used on each of the two vehicles.

2. Identical vehicles were to be used.

3. The same painter would apply the coating to each vehicle.

4. Each coating was to be mixed per the paint manufacturer's specification, and the mixing ratio and viscosity were to be the same. Environmental parameters, such as ambient temperature and humidity would be as similar as practical.

The variables were:

1. Each painter would be trained in the use of the DUX spray gun.

2. Each painter would set up the spray gun according to his preference. In other words, he would adjust his fan pattern, fluid flow rate, and apply the paint at a speed comfortable to him.

3. Technical representatives from DUX would select the fluid orifice for their spray gun, while for the HVLP spray gun the painter would use the same fluid orifice used in his current production painting.

4. The painter would apply a coating thickness typical of his customary practice. In comparing paint usage, Mr. Joseph would normalize the results for dry film thickness (DFT).

It was anticipated the drying time of the coating could be monitored to determine if one spray gun contributed to faster drying than the other spray gun. However, this did not materialize because of the shop setup.

Mr. Vince Craig of Global Finishing Systems brought an AdvancedCure® tower to Fort Hood with the anticipation of being able to speed up drying. Unfortunately, the spray booth was not wide enough to accommodate the tower.

Figure 1. Overview of Building 9576 404th paint booth.

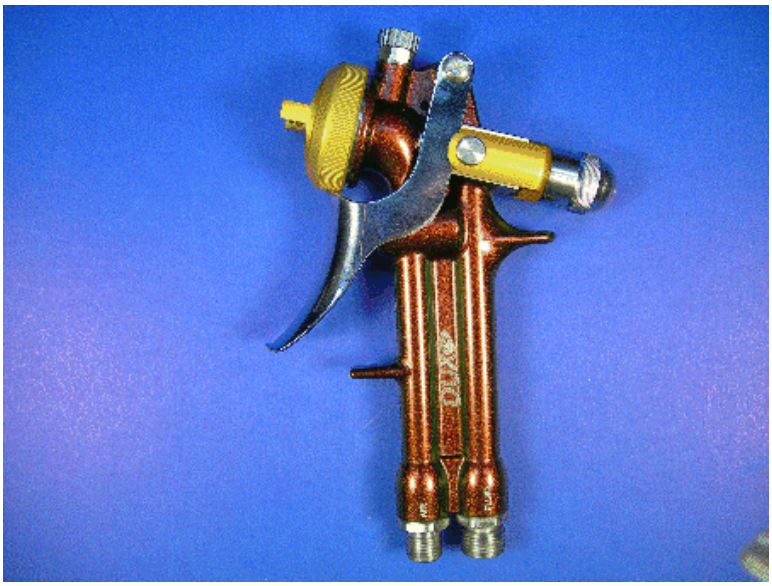

Figure 2. DUX spray gun.

Figure 3. Graco HVLP, XT Series spray gun.

Table 1. Test program overview

Component	Test 1	Test 2	Test 3	Test 4
Vehicle	M1068A3	M1068A3	LMTV M1083A1	LMTV M1083A1
Spray Gun	Graco HVLP, XT Series	DUX Pressure Feed	DUX Pressure Feed	Graco HVLP, XT Series
Coating	Hentzen Coatings MIL-C-53039	Hentzen Coatings MIL-C-53039	Sherwin-Williams MIL-DTL-64159	Sherwin-Williams MIL-DTL-64159

Table 2. Equipment for paint usage tests at Fort Hood

DUX spray gun	Spray gun
	Range of tips
	Calibrated pressure gauges for handle of both spray guns
	Pressure gauges for cap of DUX spray gun
	Pressure gauges for cap of Graco HVLP, XT Series spray gun
	Air hose, 50 ft, 3/8 inch
	Fluid hose (light flex), 50 ft
	QD fittings for DUX spray gun
	QD fittings for Graco HVLP, XT Series spray gun
HVLP spray gun	Graco HVLP, XT Series spray gun
Mixing paint	Sherwin-Williams MIL-DTL-64159
	Hentzen Coatings MIL-C-53039
	Squirrel mixer
	Water for mixing
Pressure pot	Pressure pot, 2-gallon for water-dispersible paint
	Pressure pot, 2-gallon for solvent-based paint
	Air regulator, 100 psig
	Pressure gauge (0-100 psig, large diameter)
	Fluid shut-off valve
	Agitator on pressure pot
Mixing ratio (by weight)	Tech data sheets
	MSDS
	Density cups
	Syringes
	Scale, 3 decimals
Viscosity of paint	Zahn Cups Nos. 2 and 3
Temperature of paint	Thermometer 0-120°F
Temperature of spray booth	Thermometer 0-120°F
Humidity of spray booth	Humidity meter
Wet film thickness (WFT)	WFT gauge
Dry film thickness (DFT)	DFT gauge
Weight of paint used	Scale (0-30 lbs)
Fluid flow rate	Plastic beakers
	Stop watch
Drying time (by measuring weight loss of solvent and/or water)	Scale, 3 decimals
	Steel or aluminum panels
	Stop watch
Air velocity in spray booth	Anemometer
Time to paint vehicle	Stop watch
Fan width	Contrast charts
	Ruler
Miscellaneous	Digital camera
	Video camera
	Batteries
	Q-panels
	Rags
	Tripod
	Extension cord (50 ft) with multi-plug outlets
Protective clothing	Coveralls
	Steel toed shoes
	Respirator
Data sheets	Data sheets
Vehicles	Two identical vehicles
	Vehicles prepped and primed
Drying of vehicles	Air dry

Amended Protocol

The original test protocol was written by Mr. Joseph prior to arrival at Fort Hood and is not included in this report. After seeing the paint booth, application equipment, and meeting with Mr. Jerry Eller, Operations Supervisor, Fort Hood, the protocol was slightly amended. The Amended Protocol is provided.

Preliminary Steps

1. Place an electronic scale on the paint booth concrete floor and adjust it so the bubble level is centered. The scale shall have a maximum capacity of 130 lbs and the precision shall be ± 0.02 lbs.

2. Place a calibrated weight on the scale and confirm the scale's calibration.

3. If the scale reading fluctuates, it might be necessary to surround it with a cardboard shield to protect the scale from drafts.

4. Place a 2-gallon pressure pot on the scale and drape the hoses and spray gun onto the lid. Ensure that the hoses are completely free of the floor or anything else that is close to the pressure pot.

5. Remove the pressure pot from the scale and repeat the procedure to confirm the reading accuracy of the scale.

6. Once it has been shown that the pressure pot together with the hoses and spray gun can be accurately weighed, leave the pressure pot on the scale for the duration of the test.

7. Place an electronic scale with a capacity of 200 g ± 0.01 g immediately outside the paint booth on the concrete floor and adjust it so that the bubble level is centered.

8. Place a calibrated weight on the scale and confirm the scale's calibration.

9. Place a cardboard shield around the scale to prevent drafts from affecting the scale readings.

Commence Test

1. Drive military vehicle into the spray booth. The vehicle must have already been prepped for painting by sanding and masking according to normal shop procedures.

2. Record the vehicle identification.

3. Using a felt marking pen identify eight (8) aluminum panels: 6 in × 3 in. Weigh the panels on the smaller of the two scales and record the weights to two decimals.

4. Place four sets of two panels each in different locations on the vehicle. One set is to be placed somewhere on the front, back, left, and right sides of the vehicle, respectively.

For each vehicle included in the test, the panels shall be placed in the same locations. Figure 4 through Figure 6 show examples of panel locations.

5. Select the coating to be used.

6. Place the coating on a paint shaker for 10 minutes.

7. Mix the coating per manufacturer's instructions and agitate for 5-10 minutes to ensure homogeneity.

8. Remove the lid of a 2-gallon pressure pot.

9. Place cheesecloth over the opening of the pressure pot and pour the required amount of coating (approximately two gallons) into the pressure pot.

10. If surplus paint remains in the first container, replace the lid or cover with aluminum foil to prevent solvent evaporation.

11. Measure the viscosity of the coating using a Zahn No. 3 Cup, and record the coating temperature.

12. Attach an air hose between the regulator on the spray booth wall and the regulator on the pressure pot. Similarly, attach a new air hose between the regulator on the pressure pot and the spray gun.

13. Attach a new fluid hose between the pressure pot and the spray gun.

14. Set-up the spray gun by adjusting the fluid and air pressures at the pressure pot. Allow the painter to adjust the fluid needle and fan control knob on the spray gun to enable achieving an acceptable fan width and atomization pattern while moving at a comfortable painting speed.

15. Label two Leneta® contrast cards with the date, name of the vehicle, coating, and spray gun used in the test.

16. Using masking tape, place the Leneta® contrast cards on the wall of the paint booth and allow the painter to apply one pass of coating to the center of each card. Remove the painted card and place it in a clean location where the coating can dry, and at that time measure and record the fan width.

17. Using a combined thermometer/humidity meter, record the ambient temperature, and relative humidity inside the paint booth.

18. When the painter is satisfied the spray gun settings are correct, weigh the pressure pot, hoses, and spray gun. Record the weight.

19. Record the atomizing air and the fluid pressures. Both pressure gauges are located on the lid of the pressure pot.

20. The painter shall now commence spraying.

21. Start recording the spray time by initiating a stopwatch.

22. If atomization is poor or if too much paint is being applied, allow the painter to readjust his spray gun and continue.

23. While the painter moves around the vehicle, ensure he coats the small aluminum panels as if they were part of the vehicle surface (Figure 7). He must not paint them any differently by applying more or less coating.

24. If the painter runs out of paint, reweigh the pressure pot together with the hoses and spray gun, and record the weight.

25. Immediately stop the stopwatch.

26. If the spraying is interrupted for any reason, stop the stopwatch, and restart only when spraying recommences.

27. Before pouring fresh paint into the pressure pot measure the viscosity using a Zahn No. 3 Cup, and coating temperature. If the viscosity has increased by more than 20% this might be an indication that the coating is approaching its pot life. In that case, mix fresh coating rather than using aged material. This comment refers especially to two-component coatings. It is unlikely that this problem will occur with single-component coatings.

28. Open the pressure pot, refill it, and reweigh.

29. As soon as the painter starts spraying, initiate the stopwatch again.

30. After the vehicle has been completely sprayed, immediately stop the stopwatch and record the time it took to spray the vehicle.

31. Once again, record the temperature and relative humidity in the paint booth.

32. If this is the last operation for the day, clean out the pressure pot, hoses, spray gun, and associated equipment by following normal cleanup techniques.

33. Remove the small aluminum panels and place them is a safe, clean location to allow the coating to dry.

34. When the coating has cured for at least one hour reweigh them and record their weights.

35. Inspect the vehicle finish for defects and record any comments.

36. The painter shall determine when it is appropriate to drive the vehicle out of the paint booth.

37. If this was the first vehicle in the series, drive the second vehicle into the paint booth and repeat the procedure from Step 10.

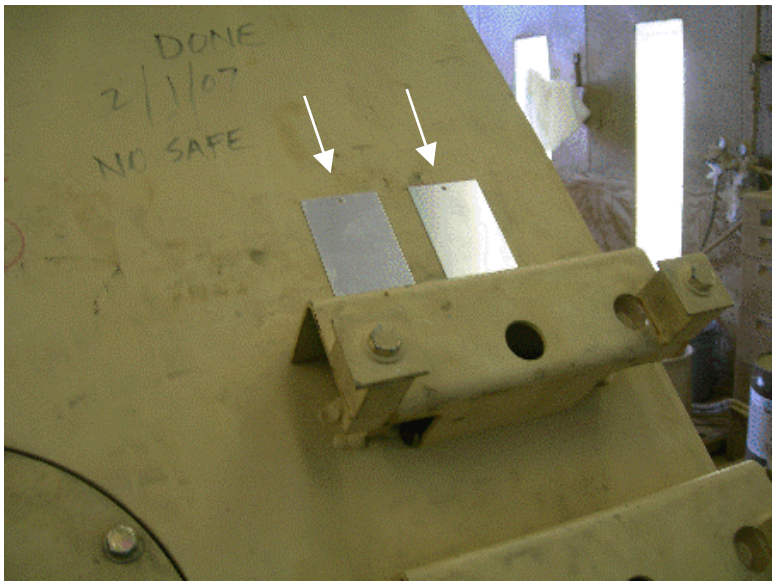

Figure 4. Small aluminum panels on the front of the M1068A3 vehicle used to measure dry film thickness.

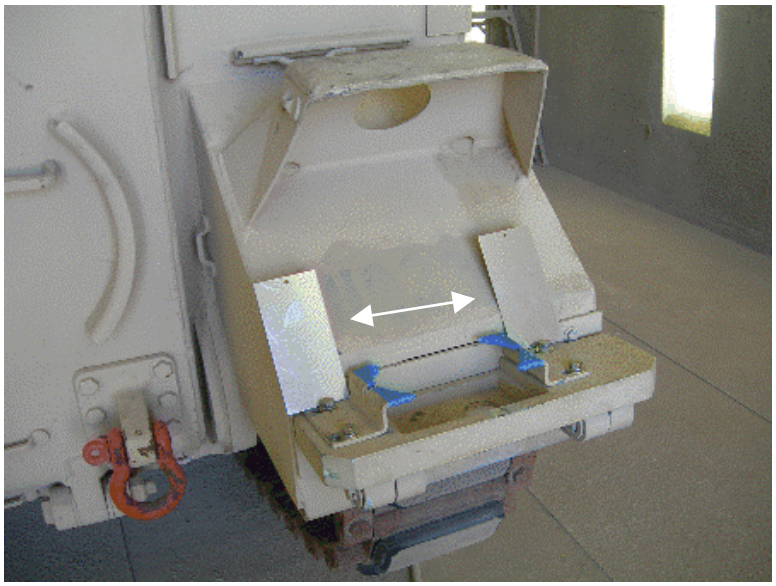

Figure 5. Small aluminum panels on the back of the M1068A3 vehicle used to measure dry film thickness.

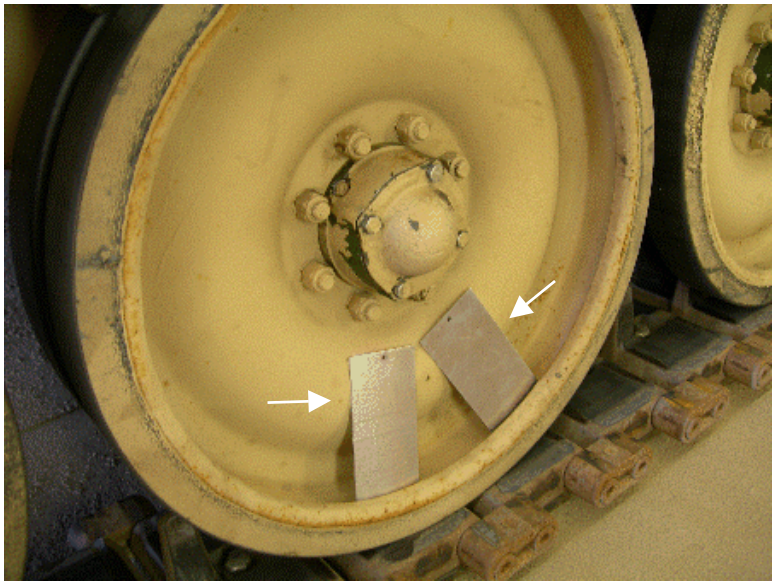

Figure 6. Small aluminum panels placed on wheel (side) of the M1068A3 vehicle used to measure dry film thickness.

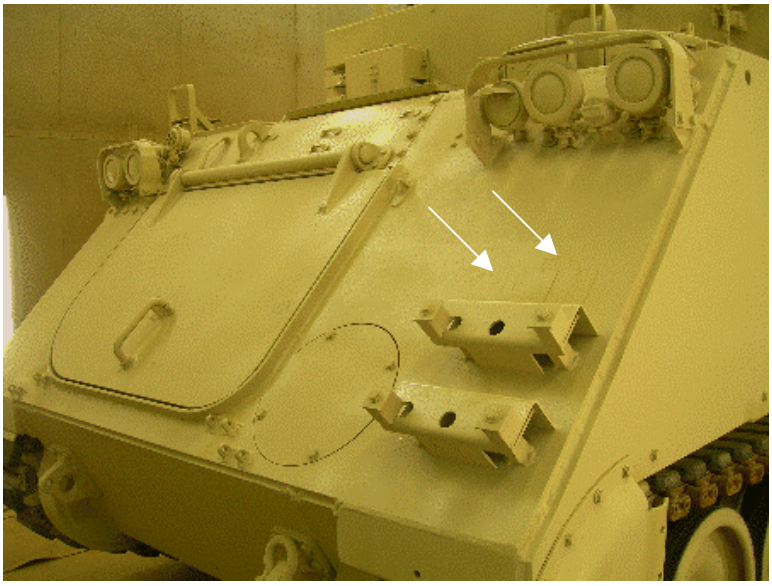

Figure 7. Small panels on the front of the M1068A3 vehicle used to measure dry film thickness (painted).

Experimental Testing

Several decisions were required before testing could commence.

- Based on discussions with the painters in this spray booth it was suspected that they exceeded an atomizing pressure of 10 psig measured at the cap of the Graco HVLP, XT Series spray gun. The compressed air line in Building 9576 does not have a readable air pressure regulator. Rather, the painters feed full line pressure of 120 psig to a single pressure pot fitted with a single regulator. The regulator on the pressure pot is usable but not readable; therefore, the painters do not know what atomizing pressure is being utilized.
- EPA regulations define HVLP spray guns as being spray devices that atomize paint at pressures less than 10 psig. Hence, if the painters in these tests were allowed to apply the coatings in excess of 10 psig, they would be violating the intent of HVLP. It was decided that during this set of tests, the painters would not operate above 10 psig at the cap. Mr. Eller provided a test cap/pressure gauge for the Graco HVLP, XT Series spray gun (Figure 8 and Figure 9).
- A 10-gallon pressure pot was made available for these tests by Mr. Eller; however, the lid was fitted with a single regulator, and this was not adequate for the purposes of these tests. Furthermore, the 10-gallon pressure pot filled with paint was too heavy for the electronic scale that had been brought to Fort Hood by the DUX representatives. The new pressure pot supplied by the DUX representative had a 2-gallon capacity and when filled with paint could easily be weighed accurately on the electronic scale. The lid was fitted with two regulators. This permitted for the fluid and atomizing air pressures to be separately controlled. A decision was made to use the 2-gallon pressure pot.
- Each painter would be allowed to set the fluid pressure and fluid flow rate to suit his style. Also, the painter could set each of the two spray guns at his preferred fan width. However, by limiting the maximum atomizing air pressure to 10 psig, the painter would probably need to use a lower fluid flow rate than usual.
- The DUX representatives assisted the painter in setting up the DUX spray gun, but the painter would have the freedom to request a higher fluid flow rate, and set the fan width to suit his painting style. The DUX representatives did not limit the painter's speed or the distance between the spray gun and the vehicle surface. The coating manufacturers (Hentzen Coatings and Sherwin-Williams) were also permitted to provide input on the spray gun settings when their respective coatings were being applied.

Steps 1 to 9 of the Amended Protocol were followed, and the painting equipment was setup. DUX representatives brought a new 2-gallon pressure pot with double regulators (fluid and atomizing air), and new fluid and air hoses.

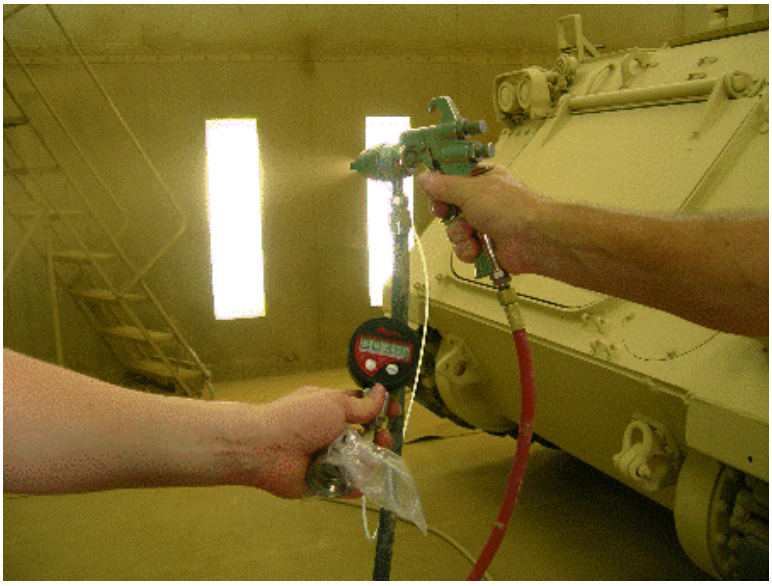

Figure 8. Accurate Dwyer pressure gauge used to measure atomizing air pressure at the cap of the Graco HVLP, XT Series spray gun.

Figure 9. Close up of Dwyer pressure gauge and kit to measure atomizing pressure.

Tuesday, June 12, 2007

Ron Joseph (Exponent) met with Robert Kennedy and Jerry Eller (Fort Hood), Jeff Hill, Brad Hainer, and Bill Sullivan (DUX), and John Pollina and Terry Tuttle (Hentzen Coatings). Mr. Joseph explained the purpose of the tests and Mr. Eller confirmed that six vehicles had already been prepped and the spray booth was ready to be used for the tests.

The spray booth was manufactured by Binks, and the dimensions are 40 ft (L) × 22 ft (W) × 16 ft (H). Air velocity measurements were conducted using a Kestrel Vane Anemometer and average readings of 100-120 ft/min were recorded.

The first vehicle, a M1068A3 "Standard Integrated Command Post System" was driven into the spray booth (Figure 10 and Figure 11).

Mr. Eller requested that the first two vehicles be coated with Hentzen Coatings MIL-C-53039 single-component, moisture-cured, chemical agent resistant coating (CARC), 1.5 lbs/gal volatile organic compounds (Figure 12). Hentzen Coatings MIL-C-53039 is a solvent-based coating.

The coating was placed on a paint shaker for 10 minutes and was then ready for use. There was no need to add any reducer. Mr. Eller asked that his painter be allowed to conduct the test with the shop's current Graco HVLP, XT Series spray gun, fitted with a 1.8 mm diameter orifice (tip). The Amended Protocol as outlined in Steps 10 through 46 was followed and all readings were carefully recorded.

The first vehicle was painted using the Graco HVLP, XT Series spray gun and the second vehicle was painted with the DUX spray gun (Figure 13). Mr. David Young was the designated painter. Within approximately 15 minutes after the vehicle had been sprayed, it was driven out of the paint booth and the second identical vehicle was driven into the paint booth.

Figure 10. Example of a M1068A3 vehicle.

Figure 11. M1068A3 vehicle inside spray booth.

Figure 12. Painter applying Hentzen Coatings MIL-C-53039 coating using the DUX spray gun.

Figure 13. Painter applying coating using the DUX spray gun.

Wednesday, June 13, 2007

A LMTV M107A1 “Light Medium Tactical Vehicle 4x4 Truck” was painted using the Graco HVLP, XT Series spray gun. The results for this test are not incorporated into this report, because a second vehicle of the same type was not available. Therefore, it was not possible to compare the paint usage between the DUX and Graco HVLP, XT Series spray guns.

Following removal of this vehicle from the paint booth, a LMTV M1083A1 “Light Medium Tactical Vehicle 4x4 Truck” was prepped and made ready for painting (Figure 14 through Figure 17). Mr. Kennedy requested this vehicle be coated with Sherwin-Williams MIL-DTL-64159 water-dispersible CARC. The DUX spray gun was used. Mr. Nelson Rodriquez was the painter.

Sherwin-Williams MIL-DTL-64159 is a three-component material mixed in the ratio: 2 parts (Component A), 1 part (Component B), and 0.5 part de-ionized water. The first two components were shaken for approximately 10 minutes each before mixing. Representatives from Sherwin-Williams mixed the coating in the presence of Mr. Joseph and used a squirrel mixer to ensure that a homogeneous coating was obtained. The Amended Protocol was followed to the letter.

It was intended that a second vehicle of exactly the same type be coated with the Graco HVLP, XT Series spray gun in the afternoon; however, so much time had elapsed since the coating was first mixed that the viscosity of the Sherwin-Williams MIL-DTL-64159 was approaching its pot life. It was decided to discard the mixed paint and commence again the following morning with freshly mixed paint.

Figure 14. Hood of LMTV M1083A1 vehicle.

Figure 15. Hood of LMTV M1083A1 vehicle moved forward for painting.

Figure 16. Painter applying coating to the underside of the LMTV M1083A1 vehicle hood.

Figure 17. LMTV M1083A1 vehicle showing flat bed.

Thursday, June 14 2007

A fresh batch of Sherwin-Williams MIL-DTL-64159 coating was mixed and the Graco HVLP, XT Series spray gun was used with Mr. Rodriquez as the designated painter.

For the first three tests, the 1/4-inch air hose supplied by DUX was used to connect the pressure pot to the spray gun. Mr. Rodriquez commented that he was not able to get sufficient air to the spray gun. Hence, for the last test, the air hose leading from the pressure pot to the spray gun was changed out for one of Fort Hood's 3/8-inch air hoses. This concluded the tests conducted at Fort Hood.

Discussion

Hentzen Coatings, MIL-C-53039

The results of the Hentzen Coatings MIL-C-53039 test series are provided in Table 3.

Table 3. Results using Hentzen Coatings MIL-C-53039 single-component, moisture-cured, CARC

Parameter	Test 1	Test 2
Date	6/12/2007	6/12/2007
Painter	David Young	David Young
Vehicle	M1068A3	M1068A3
Coating vendor	Hentzen Coatings	Hentzen Coatings
Coating	MIL-C-53039	MIL-C-53039
Zahn Cup	3	3
Viscosity (sec)	12	13
Temperature (°F)	82	89
Type of spray gun	HVLP	DUX
Name of spray gun	Graco HVLP, XT Series	DUX
Orifice diameter (mm)	1.8	1.4
Cap size	192-322-070-086	A1
Air pressure at pressure pot (psig)	34	32
Air pressure at cap (psig)	3.6	4.6
Fan width (in)	2.5	2
Total time to paint vehicle (min)	28.5	27
Fluid pressure (psig)		
Fluid flow rate (Fl oz/min)	24.4	11.8
Spray booth temperature (°F)	86	87
Humidity (%RH)	47	47
Coating weight on small panels (g)	0.96	1.37
Average dry film thickness on small panels (mils)	2.53	3.40
Weight of coating used (lbs)	17.0	12.75
Weight of coating used normalized for HVLP (lbs)	22.85	12.75
Savings for DUX spray gun (%)		44.19

The viscosity in Test 1 was 12 seconds on a Zahn No. 3 Cup while it was slightly higher at 13 seconds in Test 2. Coating temperature was reasonably close: 82°F and 89°F, respectively. Normally, higher afternoon temperatures require the painter to reduce his fluid flow rate to prevent runs and sags. Although, painters in the paint booth tend to turn up their fluid flow rates to enable them to work faster, this test showed that Mr. Young covered both vehicles in essentially the same amount of time: 28.5 minutes with the Graco HVLP, XT Series spray gun and 27.0 minutes with the DUX spray gun.

DUX representatives suggested a 1.4 mm fluid orifice be used on their spray gun, because a larger fluid orifice was not required for this job. Mr. Young preferred to use a 1.8 mm fluid orifice for the Graco HVLP, XT Series spray gun since he is accustomed to using this size. Despite the larger fluid orifice on the Graco HVLP, XT Series spray gun, the dry film thickness (DFT) of 2.53 mils was less than the 3.40 mils that resulted when the DUX spray gun was used.

The actual weight of the coating used was 17.0 lbs with the Graco HVLP, XT Series spray gun and 12.75 lbs with the DUX spray gun. To normalize the coating usage for the same DFT the following calculation was performed:

$$\text{Normalized coating weight for the Graco spray gun} = 17.0\,\text{lbs} \times \frac{3.40\,\text{mils}}{2.53\,\text{mils}} = 22.85\,\text{lbs}$$

In other words, if the painter applied the same DFT of 3.40 mils with the Graco HVLP, XT Series spray gun as for the DUX spray gun, the coating usage would have increased to 22.85 lbs.

For equal DFT values, the DUX spray gun resulted in a savings of:

$$\frac{(22.85\,\text{lbs} - 12.75\,\text{lbs})}{22.85\,\text{lbs}} = 44.19\%$$

Sherwin-Williams, MIL-DTL-64159

The results of the Sherwin-Williams MIL-DTL-64159 test series are provided in Table 4.

For application of Sherwin-Williams MIL-DTL-64159, the DUX representatives increased the fluid orifice from 1.4 mm to 1.6 mm. Mr. Rodriquez was comfortable using the 1.8 mm fluid orifice on the Graco HVLP, XT Series spray gun that had been used by Mr. Young the previous day.

The viscosity in Test 3 was 19 seconds on a Zahn No. 3 Cup, while it was slightly higher at 21 seconds in Test 4. Coating temperature was also close: 83°F and 81°F, respectively. Bear in mind, both tests were conducted in the morning before the paint booth could heat up.

The fluid flow rate was 9.7 Fl oz/min for the DUX spray gun and 15.3 Fl oz/min for the Graco HVLP spray gun. Once again, when using the Graco HVLP, XT Series spray gun the painter, this time Mr. Rodriquez, chose to use a higher fluid flow rate than for the DUX spray gun. The selection of fluid flow rates for this test was again subjective, since the operators had no experience with this coating and therefore had little frame of reference.

The DFT for the DUX spray gun was 1.49 mils, and for the Graco HVLP, XT Series spray gun was 1.08 mils. This was lower than he had intended.

Because of the lower fluid flow rate (9.7 Fl oz/min) with the DUX spray gun, the painter took almost twice as long to paint the vehicle than when he used the Graco HVLP, XT Series spray gun (15.3 Fl oz/min). Painting times were 96 minutes and 53 minutes, respectively.

Table 4. Results using Sherwin-Williams MIL-DTL-64159 two-component water-dispersible CARC

Parameter	Test 3	Test 4
Date	6/13/2007	6/13/2007
Painter	Nelson Rodriquez	Nelson Rodriquez
Vehicle	LMTV M1083A1	LMTV M1083A1
Coating vendor	Sherwin-Williams	Sherwin-Williams
Coating	MIL-DTL-64159	MIL-DTL-64159
Zahn cup	3	3
Viscosity (sec)	19	21
Temperature (°F)	83	81
Type of spray gun	DUX	HVLP
Name of spray gun	DUX	Graco HVLP, XT Series
Orifice diameter (mm)	1.6	1.8
Cap size	A1	192-322-070-086
Air pressure at pressure pot (psig)	32	40-45
Air pressure at cap (psig)	3.3	8
Fan width (in)	2.5	1.5-2.0
Total time to paint vehicle (min)	96	53
Fluid pressure (psig)	26-28	30-32
Fluid flow rate (Fl oz/min)	9.7	15.3
Spray booth temperature (°F)	89	78
Humidity (%RH)	63	65
Coating weight on small panels (g)	0.63	Not measured
Average dry film thickness on small panels (mils)	1.49	1.08
Weight of coating used (lbs)	25.45	24.75
Weight of coating used normalized for HVLP (lbs)	25.45	34.15
Savings for DUX spray gun (%)		25.47

The actual weight of coating used was 25.45 lbs with the DUX spray gun and 24.75 lbs with the Graco HVLP, XT Series spray gun. To normalize the coating usage for the same DFT the following calculation was performed:

$$\text{Normalized coating weight for the Graco spray gun} = \frac{24.75\,\text{lbs} \times 1.49\,\text{mils}}{1.08\,\text{mils}} = 34.15\,\text{lbs}$$

In other words, if the painter applied the same DFT of 1.49 mils with the Graco HVLP, XT Series spray gun as he did for the DUX spray gun, the coating usage would have increased to 34.15 lbs.

For equal DFT values, the DUX spray gun resulted in a savings of:

$$\frac{(34.15\,\text{lbs} \;\; 24.75\,\text{lbs})}{34.75\,\text{lbs}} = 25.47\%$$

Conclusions

Two sets of paint usage tests were conducted. In each test series, one Graco HVLP, XT Series spray gun and one DUX spray gun were used.

Painters in the Building 9576 404th paint booth use a 3/8-inch air hose but do not measure the atomizing air pressure either at the handle of the spray gun or at the cap. It is suspected that their atomizing pressure at the cap of their Graco HVLP, XT Series spray gun normally exceeds 10 psig. Due to the strict nature of HVLP regulations, it was decided to limit the atomizing pressure on the Graco HVLP, XT Series spray gun to 10 psig at the cap for these tests.

In the first series of tests (Tests 1 and 2), Hentzen Coatings MIL-C-53039 single-component, moisture-cured, CARC was used. When the paint usage results were normalized for equal film thickness, the DUX spray gun achieved a paint savings of 44.1 %.

In the second series of tests (Tests 3 and 4), Sherwin-Williams MIL-DTL-64159 two-component, water-dispersible, CARC was applied. When the paint usage results were normalized for equal film thickness, the DUX spray gun achieved a paint savings of 25.47%.

Appendix

Fort Hood Paint Usage Tests Data Sheets

Vehicle 1A

Date	6/12/2007		
Paint Booth #	Binks		
Paint Booth Name	Building 9576 404th Paint Booth		
Name of Painter	David Young		
Vehicle Type			
Vehicle reference number	M1068A3		
	Standard Integrated Command Post System		
MIL-C-53039	Hentzen Coatings		
MIL-C-53039 - color	Beige		
Code #	08609 TUZ LVOC, 1.5 lbs/gal		
Batch #	08931		
Type of water	N/A		
Name of person mixing	David Young		
Time mixed	~ 9:15 AM		
Viscosity - Zahn Cup	2	3	
Viscosity (sec)	39	12	
Coating temperature (°F)	82	82	
Calculating Coating Density	Component A	Component B	Reducer/Water
Weight per gallon (WPG) (lbs/gal)	11.003	0	0
Mixing ratio	1	0	0
WPG of mixed coating (lbs/gal)	11.00		
WPG of mixed coating (g/L)	1318.16		
Spray Gun Details			
Type of spray gun	HVLP		
Name of gun	Graco HVLP, XT Series		
Needle size			
Orifice diameter	1.8 mm		
Cap size	192-322-070-086		
Air pressure at pressure pot (psig)	34		
Air pressure at cap (psig)	3.6		
Fan width (in)	2.5		
Approximate gun-target distance (in)	Painter kept moving		
Total Time to Paint Vehicle	28.5 min		
Fluid Flow Rate (g/min)			
Wt. of fluid in beaker (g/30 secs)	519.4		
Wt. of empty beaker (g)	44.4		
Wt. of fluid only (g/30 sec)	475.1		
Fluid flow rate (g/min)	950.1		
Density of mixed paint (g/L)	1318.2		
Fluid flow rate (mL/min)	720.8		
Fluid flow rate (Fl oz/min)	24.4		
Paint Booth Details			
Type of paint booth	Semi-Downdraft		
Length (ft)	40		
Width (ft)	22		
Height (ft)	16		
Air velocity inside booth with vehicle (fpm)	100-120		
Temperature (°F)	86		
Humidity (%RH)	47		

Vehicle 1A (cont'd)

Coating Weight (lbs)	Start	End		
	65.75	48.75		
Weight of coating used (lbs)	17.00			
Drying Times on Panels (mins)	5-10			
		Start	End	Wt.
Coating Weight on Small Panels (g)	100	40.41	41.61	1.20
	101	40.42	41.89	1.47
	102	40.59	41.16	0.57
	103	40.59	41.26	0.67
	104	40.42	41.47	1.05
	105	40.59	41.67	1.08
	106	40.66	41.59	0.93
	107	40.52	41.22	0.70
			Average	0.96
			Std. Dev	0.30
			% COV	31.66
Average DFT on Small Panels (mils)	100	1.61	1.57	1.26
	101	2.58	2.55	3.28
	102	2.37	2.26	3.25
	103	3.51	4.31	2.99
	104	3.77	3.97	3.15
	105	1.61	2.20	2.30
	106	1.08	1.45	2.11
	107	2.09	1.28	1.13
			Average	2.53
			Std. Dev.	1.01
			% COV	39.85

Vehicle 1B

Date	6/12/2007		
Paint Booth #	Binks		
Paint Booth Name	Building 9576 404th Paint Booth		
Name of Painter	David Young		
Vehicle Type			
Vehicle reference number	CCPM 1068 A3		
MIL-C-53039	Hentzen Coatings		
MIL-C-53039 - color	Beige		
Code #	08609 TUZ LVOC, 1.5 lbs/gal		
Batch #	08931		
Type of water	N/A		
Mixing ratio (Base:Curing Agent:Water)	Used as supplied		
Name of person mixing	David Young		
Time mixed	~ 12:30 PM		
Viscosity - Zahn Cup	3		
Viscosity (sec)	13		
Coating temperature (°F)	89		
Calculating Coating Density	Component A	Component B	Reducer
Weight per gallon (WPG) (lbs/gal)	11.003	0	0
Mixing ratio	1	0	0
WPG of mixed coating (lbs/gal)	11.00		
WPG of mixed coating (g/L)	1318.16		
Spray Gun Details			
Type of spray gun	DUX		
Name of gun	DUX		
Needle size			
Orifice diameter	1.4		
Cap size	A1		
Air pressure at pressure pot (psig)	32		
Air pressure at cap (psig)	4.6		
Fan width (in)	2		
Approximate gun-target distance (in)	Painter kept moving		
Total Time to Paint Vehicle	27.0		
Fluid Flow Rate (g/min)			
Wt. of fluid in beaker (g/30 secs)	275.0		
Wt. of empty beaker (g)	44.4		
Wt. of fluid only (g/30 sec)	230.7		
Fluid flow rate (g/min)	461.3		
Density of mixed paint (g/L)	1318.2		
Fluid flow rate (mL/min)	350.0		
Fluid flow rate (Fl oz/min)	11.8		
Paint Booth Details			
Type of paint booth	Semi-Downdraft		
Length (ft)	40		
Width (ft)	22		
Height (ft)	16		
Air velocity inside booth with vehicle (fpm)	100-120		
	Start	End	
Temperature (°F)	87	90.5	
Humidity (%RH)	47	42	
Coating Weight (lbs)	Start	End	
	66.7	53.95	
Weight of coating used (lbs)	12.75		

Vehicle 1B (cont'd)

Drying Times on Panels (mins)	15			
		Start	End	Wt.
Coating Weight on Small Panels (g)	200	40.87	42.52	1.65
	201	40.41	41.9	1.49
	202	40.68	41.6	0.92
	203	40.33	42.05	1.72
	204	40.37	42.49	2.12
	205	40.6	41.61	1.01
	206	40.41	41.51	1.1
	207	40.04	40.97	0.93
			Average	1.37
			Std. Dev.	0.44
			% COV	32.43
Average DFT on Small Panels (mils)	200	2.96	2.64	3.89
	201	2.63	3.17	3.31
	202	3.22	3.40	2.79
	203	6.39	5.83	4.37
	204			
	205			
	206	2.26	3.17	3.16
	207	3.31	2.75	2.57
			Average	3.40
			Std. Dev.	1.11
			% COV	32.82

Vehicle 3A

Date	6/13/2007		
Paint Booth #	Binks		
Paint Booth Name	Building 9576 404th Paint Booth		
Name of Painter	Nelson Rodriquez		
Vehicle Type			
Vehicle reference number	LMTV M1083A1 Light Medium Tactical Vehicle 4x4 Truck		
MIL-DTL-64159 Type 2	Sherwin-Williams		
MIL-DTL-64159 Color - Component A	Beige		
Code #	F93H504		
Batch #	5012-48106		
MIL-DTL-64159 - Component B	Clear		
Code #	F93H504		
Batch #	5012-48108		
Type of water	Distilled		
Mixing ratio (Base:Curing Agent:Water)	2:1:0.5		
Name of person mixing	Bob Hebert		
Time mixed	10:45 AM		
Viscosity - Zahn Cup	3		
	Start	End	
Viscosity (sec)	19		
Coating temperature (°F)	83		
Calculating Coating Density	Component A	Component B	Reducer/Water
Weight per gallon (WPG) (lbs/gal)	10.22	8.88	8.34
Mixing ratio	2	1	0.5
WPG of mixed coating (lbs/gal)	9.57		
WPG of mixed coating (g/L)	1146.31		
Spray Gun Details			
Type of spray gun	DUX		
Name of gun	DUX		
Needle size			
Orifice diameter	1.6 mm		
Cap size	A1		
Air pressure at pressure pot (psig)	32		
Air pressure at cap (psig)	3.3		
Fluid pressure at pressure pot (psig)	26.28		
Fan width (in)	2.5		
Approximate gun-target distance (in)	4-20		
Total Time to Paint Vehicle	Start	Stop	Mins
	11:07 AM	12:21 PM	74.0
	12:23 PM	12:45 PM	22.0
			96.0
Fluid Flow Rate (g/min)			
Wt. of fluid in beaker (g/30 secs)	208.0		
Wt. of empty beaker (g)	44.4		
Wt. of fluid only (g/30 sec)	163.7		
Fluid flow rate (g/min)	327.4		
Density of mixed paint (g/L)	1146.3		
Fluid flow rate (mL/min)	285.6		
Fluid flow rate (Fl oz/min)	9.7		

Vehicle 3A (cont'd)

Paint Booth Details				
Type of Paint booth	Semi-Downdraft			
Length (ft)	40			
Width (ft)	22			
Height (ft)	16			
Air velocity inside booth with vehicle (fpm)	100-120			
	Start	End		
Temperature (°F)	89.2			
Humidity (%RH)	63			
Coating Weight (lbs)	Start	End		
	51.95	32.5		
	39.35	33.35		
Total coating used (lbs)		25.45		
Drying Times on Panels (mins)				
		Start	End	Wt.
Coating Weight on Small Panels (g)	400	42.52	43.06	0.54
	401	41.9	42.41	0.51
	402	41.6	42.42	0.82
	403	42.05	42.75	0.70
	404	42.49		
	405	41.61		
	406	41.51	42.08	0.57
	407	40.97	41.58	0.61
			Average	0.63
			Std. Dev.	0.12
			% COV	18.57
Average DFT on Small Panels (mils)	400	1.46	1.42	1.52
	401	1.52	1.72	1.20
	402	1.54	1.32	1.82
	403	1.20	1.32	1.53
	404			
	405			
	406	1.63	1.50	1.41
	407	1.35	1.40	1.46
			Average	1.49
			Std. Dev.	0.18
			% COV	11.88
Average Wet Film Thickness (mils)				
Front	7.0	5.0	6.0	4.0
	6.0	7.0	6.0	6.0
	8.0	4.0	4.0	8.0
	5.0	6.0	6.0	6.0
				5.9
Left	6.0	4.0	4.0	3.0
	8.0	4.0	5.0	6.0
	4.0	5.0	5.0	5.0
	6.0	8.0	5.0	4.0
				5.1
Right	4.0	5.0	6.0	4.0
	6.0	7.0	6.0	6.0
	8.0	4.0	4.0	8.0
	5.0	6.0	6.0	6.0
				5.7

Vehicle 3A (cont'd)

Back	6.0	5.0	8.0	6.0
	4.0	5.0	5.0	5.0
	4.0	4.0	5.0	4.0
	5.0	4.0	5.0	4.0
				4.9
			Ave WFT (mils)	5.4
			Std. Dev	1.3
			% COV	23.9

Vehicle 3B

Date	6/14/2006		
Paint Booth #	Binks		
Paint Booth Name	Building 9576 404th Paint Booth		
Name of Painter	Nelson Rodriquez		
Vehicle Type			
Vehicle reference number	LMTV M107A1		
	Light Medium Tactical Vehicle 4x4 Truck		
	AT6640ECKF		
MIL-DTL-64159 Type 2	Sherwin-Williams		
MIL-DTL-64159 Color - Component A	Beige		
Code #	F93H504		
Batch #	5012-48106		
MIL-DTL-64159 - Component B	Clear		
Code #	F93H504		
Batch #	5012-48108		
Type of water	Distilled		
Mixing ratio (Base:Curing Agent:Water)	2:1:0.5		
Name of person mixing	Bob Hebert		
Time mixed	8:10 AM		
Viscosity - Zahn Cup	3		
	Start	End	
Viscosity (sec)	21		
Coating temperature (°F)	81		
Calculating Coating Density	Component A	Component B	Reducer/Water
Weight per gallon (WPG) (lbs/gal)	10.22	8.88	8.34
Mixing ratio	2	1	0.5
WPG of mixed coating (lbs/gal)	9.57		
WPG of mixed coating (g/L)	1146.31		
Spray Gun Details			
Type of spray gun	HVLP		
Name of gun	Graco HVLP, XT Series		
Needle size			
Orifice diameter	1.8 mm		
Cap size	192-322-070-086		
Air pressure at pressure pot (psig)	40-45		
Air pressure at cap (psig)	8		
Fluid pressure at pressure pot (psig)	30-32		
Fan width (in)	1.5-2.0		
Approximate gun-target distance (in)	4-20		
Total Time to Paint Vehicle	Start	Stop	Mins
	8:44 AM	9:26 AM	42.0
	9:30 AM	9:41 AM	11.0
			53.0
Fluid Flow Rate (g/min)			
Wt. of fluid in beaker (g/30 secs)	304.1		
Wt. of empty beaker (g)	44.4		
Wt. of fluid only (g/30 sec)	259.7		
Fluid flow rate (g/min)	519.4		
Density of mixed paint (g/L)	1146.3		
Fluid flow rate (mL/min)	453.1		
Fluid flow rate (Fl oz/min)	15.3		

Vehicle 3B (cont'd)

Paint Booth Details				
Type of paint booth	Semi-Downdraft			
Length (ft)	40			
Width (ft)	22			
Height (ft)	16			
Air velocity inside booth with vehicle (fpm)	100-120			
	Start	End		
Temperature (°F)	77.9	78.8		
Humidity (%RH)	65	69		
Coating Weight (lbs)	Start	End		
	50.75	29.65		
	42.6	38.95		
Total coating used (lbs):		24.75		
Drying Times on Panels (mins)				
		Start	End	Wt.
Coating Weight on Small Panels (g)	500			0.00
	501			0.00
				0.00
				0.00
				0.00
				0.00
				0.00
				0.00
	Average			0.00
Average DFT on Small Panels (mils)	500	1.29	1.40	1.09
	501	0.88	0.56	1.26
			Average	1.08
			Std. Dev.	0.26
			% COV	24.49
Average Wet Film Thickness (mils)				
Front	4.0	2.5	4.0	3.0
	3.0	4.0	4.5	3.5
	3.5	4.0	4.0	4.0
	3.5	4.0	4.0	3.5
				3.7
Left	4.0	2.5	4.0	4.0
	3.0	3.0	3.5	4.0
	3.5	3.5	4.0	3.5
	3.5	4.0	4.0	4.0
				3.6
Right	5.0	4.5	3.5	2.5
	7.0	5.0	4.5	4.0
	3.5	3.5	4.0	4.4
	4.0	4.0		
				4.2
Back	4.5	5.0	4.0	5.0
	3.5	4.0	4.0	5.0
	3.5	4.0	3.4	2.5
	3.5	4.0	4.0	4.0
				4.0
			Ave WFT (mils)	3.9
			Std. Dev	0.7
			% COV	18.5