Waterborne CARC Dry Time Evaluations - Results/Conclusions

Iowa Waste Reduction Center
STAR4Defense

July 18, 2005

Background

The Department of Defense authorizes several types of Chemical Agent Resistant Coatings (CARC) for military equipment applications. Three of the most commonly used products include two formulations of a solvent-based aliphatic polyurethane (MIL-C-53039A) and a water-reducible polyurethane (MIL-DTL-64159 Type II - Waterborne). Volatile Organic Compounds (VOC) and dry time characteristics (as reported on Sherwin Williams Data Sheets) for each product type are summarized below:

Characteristic	MIL-C-53039A	MIL-C-53039A HAPs Free	MIL-DTL-64159 Type II - Waterborne
VOC (maximum)	3.5 lbs/gal	1.5 lbs/gal	1.45 lbs/gal
Set-to-Touch[1,2]	5 - 30 minutes	5 - 30 minutes	60 minutes
Dry-Hard[1,2]	3 hours	3 hours	6 hours
Dry-Through[1,2]	4 hours	4 hours	8 hours
Complete Cure[1]	7 days	7 days	7 days

[1] 2 mils dry-film thickness @ 77^0 F and 50% relative humidity
[2] ASTM D 1640 standard.

While the dry time information listed in the preceding table is of general interest and use, it likely results from ideal or laboratory conditions which may vary from those experienced in field application settings. Practical dry time characteristics for the MIL-C-53039A products are relatively well established through “real world” experience with the product over a relatively long period of time. This experience provides painters a close estimate of when recently painted equipment can be accessed for subsequent operations (i.e., masking removal, stenciling, camouflaging etc.) and/or when the equipment can be moved outside of the spray booth and into an outdoor environment. Furthermore, this experience allows for an accurate prediction of time required for drying and, thus, how the spray booth may be utilized to maximize production.

“Real world” dry time characteristics for the MIL-DTL-64159 Type II - Waterborne are less established and predictable since its history of use is limited. It is reported, and generally assumed, that the MIL-DTL-64159 Type II - Waterborne will require longer dry times. This gives rise to concerns that painting facility production will decrease using the MIL-DTL-64159 Type II - Waterborne product unless existing spray booths are modified (i.e., installation of heating, air movement and/or dehumidification equipment) to allow forced-dry capabilities.

Numerous field-type measures exist to determine when a painted item is dry to the point where it can be accessed for subsequent operations and/or when the equipment can be moved outside of the spray booth and into an outdoor environment. While these methods may be effective for the painter responsible for the job, they are subjective, making comparisons of “dry” among different painters, facilities, and products difficult to measure. Ideally, a practical “field” dry time test should be developed to provide painting facilities time measurements to determine at which point recently painted equipment can be considered acceptably dry.

Dry Time Measurements

For the purposes of the following CARC dry time evaluations, the following terminology and determination methods are used:

Terminology	**Determination Method**
Tacky	Finish remains sticky when lightly touched
Dry Moderate	No major finish impressions or visual damage when subjected to moderate finger pressure and a 90^0 twist
Scratch Resistant	No removal of finish when subjected to a heavy pressure fingernail scratch

Preliminary Evaluation Results

An initial laboratory dry time test using MIL-DTL-64159 Type II - Waterborne CARC was conducted by IWRC staff in April 2005. Testing was conducted using 1-foot square steel test panels. The panels were cleaned using a solvent wipe, allowed to dry and then primed with Sherwin Williams buff MIL-P-53022B Type II primer at a wet film thickness of 0.003 inches. The primed panels were allowed to dry for approximately 1 hour. The panels remained somewhat tacky at this 1 hour time interval.

Sherwin Williams green MIL-DTL-64159 Type II - Waterborne CARC topcoat was prepared according to manufacturer directions. The resulting viscosity was measured at 22 seconds in a Zahn 3 cup. The prepared CARC was separated into three equal aliquots. Aliquots #1 and #2 consisted of the originally prepared CARC plus 1% and 2% concentrations of a urethane accelerator (Sherwin Williams AM0022V66), respectively. Aliquot #3 consisted of the originally prepared CARC with no accelerator. Individual primed test panels were then coated with these three variations of topcoat at a wet film thickness of 0.005 inches. The three varieties of topcoated test panels were divided into two test groups. One group was allowed to dry in a paint booth with an exhaust air flow rate of 120 feet/minute. The second group was allowed to dry in the same booth, but was shielded from any appreciable air movement. The booth was maintained at a temperature of 75^0 F. The relative humidity in the booth was measured at 35%.

Results from this preliminary test are summarized in the following table:

Panel Type	Air Flow @ 0 feet/minute	Air Flow @ 120 feet/minute
CARC + 1% accelerator	Not Tacky @ 2 hours	Not Tacky @ 2 hours
CARC + 2% accelerator	Not Tacky @ 2 hours	Not Tacky @ 2 hours
CARC (no accelerator)	Somewhat Tacky @ 3.5 hours	Not Tacky @ 3 hours

While one might expect a shorter preliminary dry time for panels with higher accelerator concentrations and those subjected to the higher air flow rate, the difference is not remarkable. This may be due to the subjective nature of the measurement criterion. Also, a Sherwin Williams representative mentioned the benefits of the accelerator are more pronounced in the later dry/curing stages (i.e., ASTM Dry-Hard and Dry-Through dry times).

All panels failed the Dry Moderate criterion at 6.5 hours. At this point, the air flow in the booth was discontinued. Although a significantly harder finish was noted the following morning or after approximately 20 hours, the panels still failed the Scratch Resistant criterion. The Scratch Resistant criterion was met after an additional 24 hours of dry time.

A second set of evaluations were conducted on May 5, 2005 to simulate the effect of rain on newly applied CARC finishes. This is important to facilities that have limited paint booth space and are forced to move recently painted equipment outside of the booth prior to a desired dry time. These evaluations utilized MIL-DTL-64159 Type II - Waterborne CARC and MIL-C-53039A - HAPs Free CARC, both green in color. Automotive fenders were used as the test substrate. The test fenders had been previously coated with CARC and thoroughly cured.

Test fenders A, B and C were coated with MIL-C-53039A - HAPs Free CARC at a wet film thickness of 0.005 inches. Test fenders 1 through 7 were coated with MIL-DTL-64159 Type II waterborne CARC at a wet film thickness of 0.005 inches. The test fenders were allowed to dry in a paint booth with an exhaust air flow rate of 100 ft/min, a temperature of 70^0F and a relative humidity of 30% for the time periods identified in the table below:

Fender ID	CARC Type	Dry Time* (hours)	Water Spray Conditions
A	Solvent-based HAPs free	0.5	Brief
B	Solvent-based HAPs free	1	Brief
C	Solvent-based HAPs free	2	Brief

1	Waterborne	0.5	Brief
2	Waterborne	1	Brief
3	Waterborne	2	Brief
4	Waterborne	3	Continuous for 1 hour
5	Waterborne	4	Continuous for 1 hour
6	Waterborne	5	Continuous for 1 hour
7	Waterborne	7	Continuous for 1 hour

* Exhaust air flow rate of 100 ft/min, temperature of 70^{0}F and relative humidity 30%.

After their respective dry times, fenders were removed from the booth and subjected to a water spray to simulate a situation where newly painted equipment would require placement outdoors and into inclement weather (i.e., rain). Fenders A, B and C and 1, 2 and 3 were sprayed for just long enough to wet the entire surface of the fender. Fenders 4 through 7 were subjected to a 1-hour continuous spray. After the water spray, all fenders were returned indoors to dry and allow for inspection.

Fenders A and B (painted with the MIL-C-53039A - HAPs Free CARC) remained tacky at each of their respective dry times (i.e., 0.5 and 1 hour). Fender C was slightly tacky at a 2-hour dry time. A brief water spray on fenders A and B resulted in significant water beading, while a similar spray on fender C resulted in water sheeting. <u>None of the three MIL-C-53039A - HAPs Free CARC finished fenders showed visual damage as a result of the water spray</u>. At 3.5 hours after painting, all solvent-finished fenders were resistant to damage from heavy pressure finger nail scratch test indicating a Scratch Resistant condition. While it is certainly not recommended to place newly painted equipment in a damaging environment (i.e., rain) prior to adequate dry times, this demonstration suggests doing so may not cause significant damage to the paint finish.

Fenders 1 and 2 (painted with MIL-DTL-64159 Type II Waterborne CARC) were significantly tacky at their respective dry times. Their exposure to a brief water spray resulted in permanent spots and runs in the finished surface. Fender 3, which was slightly tacky at the end of its 2-hour dry time, did <u>not</u> show any spots or runs when subjected to a brief water spray.

Fenders 4, 5 and 6 were not tacky at the end of their respective dry times. However, when subjected to a 1-hour continuous water spray, the recently applied paint finish softened significantly. In this softened condition, the finish was easily damaged with moderate finger contact. One could remove the finish as a film which suggests the water spray penetrated the film and interfered with its adhesion to the substrate. Fender 7 was also affected by the water spray, similar to that experienced with fenders 4 through 6, but required more aggressive finger contact to damage the finish. This suggests that a more thorough cure occurs with time, as would be expected.

When fenders 4 through 7 were removed from the water spray and allowed to dry, the finish appeared to dry back to its pre-water spray condition in approximately 30 minutes. Whether a wetted and dried finish will maintain the same properties (i.e., adhesion, durability, ultraviolet resistance, etc.) as a finish that was allowed to cure as recommended by the manufacturer is undetermined but important to consider.

None of the MIL-DTL-64159 Type II Green water-reducible CARC painted fenders were considered Scratch Resistant after 8 hours, as all finishes could be scratched through to the substrate with heavy fingernail pressure.

Conclusions

The above evaluations tend to confirm many of the commonly held assumptions regarding CARC drying times and characteristics. Other issues that might warrant further consideration/investigation were also noted. For example:

- Dry times for Waterborne CARC to no longer be tacky (and thus acceptable for some degree of handling) appear to exceed 1 hour, the value reported in product data sheets.
- Shortening of preliminary dry times using only air movement is negligible to marginally effective.
- Shortening of preliminary dry times using only a chemical accelerator is negligible to marginally effective.
- Moderate Dry times for Waterborne CARC exceed 6.5 hours at reasonably favorable drying conditions (i.e., 120 feet/minute air flow, a temperature of 75^0 F and relative humidity of 35%).
- Scratch Resistant dry times for Waterborne CARC exceed 24 hours at reasonably favorable dry conditions.
- Solvent-based CARC appears resistant to inclement weather (rain) in as little as 0.5 hours of dry time.
- Waterborne CARC is <u>not</u> resistant to inclement weather (rain) after as much as 7 hours of dry time.
- Waterborne CARC appears to return to dry when removed from inclement weather (rain), however, concern regarding its ability to retain its original properties is warranted.

STAR4D is a program of the Iowa Waste Reduction Center at the University of Northern Iowa.