



Waterborne CARC Forced-dry Time Evaluations - Preliminary Results/Conclusions

Iowa Waste Reduction Center
STAR for Defense (STAR4D)

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Background

Initial testing conducted by the Iowa Waste Reduction Center's Spray Technique Analysis and Research for Defense (STAR4D) Program staff in April and May of 2005 evaluated air dry time characteristics (i.e., unforced dry times) for waterborne polyurethane Chemical Agent Resistant Coatings (CARC) (MIL-DTL-64159 Type II) as compared to the solvent-based aliphatic polyurethane Hazardous Air Pollutants (HAPs) free (MIL-C-53039A) CARC alternative. Results of this work produced observations similar to what one would expect from review of vendor information, previous studies and conventional wisdom. Specific findings are listed below:

- Practical, unforced dry times (i.e., when newly painted parts can be handled, placed outside the booth and become scratch resistant) for waterborne CARC significantly exceed those observed for solvent-based product.
- Shortening of preliminary dry times using only air movement is negligible to marginally effective for waterborne CARC.
- Shortening of preliminary dry times using only a chemical accelerator is negligible to marginally effective for waterborne CARC.
- Solvent-based CARC appears resistant to inclement weather (rain) in as little as 0.5 hours of dry time.
- Waterborne CARC is not resistant to inclement weather (rain) after as much as 7 hours of dry time.

Given the apparent facts that waterborne CARC dries/cures slower than solvent-based CARC, and the related potential for decreased productivity for facilities that switch to waterborne CARC, investigation of forced-dry techniques to shorten waterborne CARC dry/cure times is warranted. That said, the purpose of this study is to evaluate the affect of infrared heating as a forced-dry technique.

Dry Time Measurements

For the purposes of this and previous STAR4D 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

Evaluation Results

Forced-dry time tests using Sherwin Williams MIL-P-53022B Type II solvent-based primer and MIL-DTL-64159 Type II - waterborne CARC topcoat were conducted by STAR4D staff on June 1, 2005. Primer and topcoat were prepared and applied in strict accordance with the product manufacturer's specifications. Testing was conducted using three sets of 3" by 6" steel test panels cleaned with a solvent wipe and further prepared as described below:

Alpha Panel Identification	Panel Preparation
B	Bare metal panel with fresh applications of primer & CARC topcoat
P	Fully cured primed panel (>7 days) with fresh application of CARC topcoat
T	Fully cured primed and topcoated panel (>7 days) with re-application of fresh CARC topcoat

The three panel preparation scenarios were utilized to represent the variety of complete and touch-up painting conditions one would experience in the field.

Individual panels from each of the three sets were subjected to the following drying conditions:

Numeric Panel Identification	Drying Condition
1	Air dry only
2	Air dry (i.e., flash time) for 45 minutes & infrared heat
3	No air dry (i.e., no flash time) & infrared heat

Panels identified numerically with the number 1 serve as the test controls. Panels identified with the number 2 represent parts painted to manufacturer recommendations regarding 45 minutes of flash time prior to forced-dry heating. Panels identified with the number 3 were subjected to infrared forced-drying heat immediately after application of the topcoat (i.e., no flash time). While the third scenario deviates from manufacturer recommendations, it was included in the test to evaluate if a flash time is necessary to maintain acceptable surface finish quality (i.e., no blistering).

Infrared heating was conducted using an InfraTech, high intensity medium wavelength portable element operating at 1500 watts/120 volts. Panels subjected to infrared treatment were suspended approximately 20 inches from the lamp. This distance resulted in a near immediate and sustained panel temperature of approximately 130⁰F.

To simplify discussion, no differences in dry time characteristics or finish quality were observed among the differently prepared panel sets (i.e., panels B, P and T) when treated to the same drying procedure. For example, Panels B-2, P-2 and T-2 all dried at the same rate and with the same observable finish quality using the 45 minute air dry followed by infrared heating.

The control panels (number 1 panels - air dry only) experienced similar drying characteristics as those subjected to similar air drying conditions in previous STAR4D studies. Specifically, the panels remained tacky after more than 1 hour of dry time. They, as previously observed, also exhibited significant softening of the newly applied finish when subjected to a simulated rain, in this case, after approximately 1.5 hours of dry time.

All panels numerically identified as 2 (i.e., those allowed to air dry/flash for 45 minutes before the forced-dry step) were subjected to infrared heat at a sustained temperature of approximately 130⁰F. As expected, these panels dried significantly faster and more thoroughly with time than the control panels. For example, the surfaces were no longer tacky after 20 minutes of heated dry time and a “dry moderate” condition was reached in approximately 40 minutes. After 45 minutes of heated dry time, panel surfaces were resistant to softening when subjected to 30 minutes of simulated rain exposure.

All panels numerically identified as 3 (i.e., those subjected to forced-drying with no prior air dry/flash time) were subjected to the same forced-dry conditions as those receiving a 45-minute flash time (i.e., number 2 panels) with identical results. Most noteworthy, no blistering or other finish failures were observed.

While no surface damage (blistering) was observed for panels prepared and force-dried under the conditions discussed above (i.e., medium wavelength infrared exposure at a 20-inch distance from panel to element yielding a sustained temperature of approximately 130⁰F), concerns for surface damage exist for more aggressive infrared exposure/increased temperatures. To evaluate this possibility, three 3" by 6" steel test panels were cleaned with a solvent wipe and then coated with MIL-P-53022B Type II primer according to manufacturer specifications. The primer was allowed to air dry for approximately 40 minutes. The panels were then finished with MIL-DTL-64159 Type II - waterborne CARC topcoat and immediately subjected to the infrared exposure at distances from the element of 5, 13 and 21 inches. These distances resulted in sustained panel temperatures of 230⁰F, 165⁰F and 120⁰F respectively. The panels at 5-inch and 13-inch positioning were considered Dry Moderate after 20 minutes of forced-dry time. The panel positioned 21 inches from the lamp reached the Dry Moderate criterion at 55 minutes. None of the panels exhibited any observable surface finish damage (blistering).

Additional testing of the effect of infrared forced-drying on surface finish quality was conducted on automotive fenders under the conditions described in the following table:

Substrate	Under coating	Coating Applied	Heat source	Temp (when removed)	Time	Result
Fender	E-coat, Primer, Waterborne CARC topcoat	Primer (no flash time)	Combination IR / Convection	325 ⁰ F	< 1 minute	Hard and brittle. Broke away and exposed bare metal
Fender	E-coat, Primer, Waterborne CARC topcoat	Primer and Waterborne CARC topcoat (wet on wet- no flash)	Combination IR / Convection	350 ⁰ F	< 1 minute	Extreme blistering
Fender	E-coat, Primer, Waterborne CARC topcoat	Primer (10 minute flash) and Waterborne CARC topcoat (no flash)	Combination IR / Convection	220 ⁰ F	30 min	No visible defects
Fender	E-coat, Primer, Waterborne CARC topcoat	Primer and Waterborne CARC topcoat (wet on wet- no flash)	Combination IR / Convection	220 ⁰ F	30 min	slight blistering

All test fenders had previously been E-coated for routine corrosion protection by the manufacturer and then coated with MIL-P-53022B Type II primer and MIL-DTL-64159 Type II - Waterborne CARC topcoat by STAR4D staff according to manufacturer specifications more than 7 days prior to conducting this evaluation. These types of parts represent previously painted military equipment for subsequent repaint or touch up. The fully cured fenders were subjected to reapplication of primer/topcoat, short flash/no flash and forced-dry temperatures as specified above. The “Combination IR/Convection” designation in the heat source column refers to a commercial PED Technologies long wavelength infrared/convection cure oven. While infrared elements provide the drying/curing action, convective heat is also generated within the oven enclosure.

One would expect exposure to aggressive infrared and resulting high part temperatures to, at some point, cause finish surface damage. Such damage was observed on fenders which reached part temperatures of 325⁰F to 350⁰F in a relatively short contact time in the oven. Photographs 1 and 2 show the extent of this damage.



Photograph 1 – Primer over previously finished fender, infrared force-dried at 325⁰F for 1 minute



Photograph 2 – Primer and topcoat over previously finished fender, infrared force-dried at 350⁰F for 1 minute

Similarly prepared fenders, subjected to reduced infrared exposure in the cure oven, reached a sustained part temperature of 220⁰F. These fenders exhibited minimal to no surface damage. Photographs 3 and 4 show an example of these primed and topcoated fenders.



Photograph 3 – Primer and topcoat over previously finished fender, infrared force-dried at 220⁰F for 30 minutes



Photograph 4 – Detail of Photograph 3

Conclusions

- Dry Moderate (i.e., no major finish impressions or visual damage when subjected to moderate finger pressure and a 90° twist) conditions can be obtained within 20 to 40 minutes on properly primed parts finished with waterborne CARC topcoat when subjected to infrared heating (medium wavelength) at part surface temperatures of 160°F to 130°F.
- A rain resistant waterborne CARC finish can be obtained after approximately 45 minutes of infrared (medium wavelength) exposure with parts reaching a surface temperature of 130°F.
- Surface finish damage (i.e., blistering) was not observed when infrared exposure was controlled to limit part surface temperature to less than 220°F.
- Flash time does not appear necessary to obtain acceptable finish quality for infrared forced-dry heating at part surface temperatures up to 220°F.

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