Correlating Accelerated Tests and Outdoor Exposure Tests for Exterior Coating Gloss

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Within the generic categories of rail car exterior coatings, there are significant variations in performance. Therefore, testing is required to select coatings that will give the best performance. Outdoor exposure tests produce meaningful results but require months to years to obtain results. Therefore, four common accelerated test methods were evaluated to determine how their results would correlate with the results of outdoor exposures with respect to gloss retention.

In selecting a suitable rail car exterior coating, one must first select the most appropriate generic coating category, such as alkyd, epoxy, or epoxy/urethane. Generally, this selection will be based on such performance requirements as gloss, gloss retention, and chemical spill resistance. Other considerations include cost, environmental emissions of solvent, ease of application, and pot life of two-component coatings.[1,2]

If all coating materials within a generic class performed similarly, one could simply select a coating based on cost. However, this is not the case. Likewise, the most expensive coating does not necessarily perform best. Therefore, to make the best possible selection, testing is required.

To determine the effects of outdoor exposure on a coating's appearance, coated panels are mounted on an outdoor rack. The disadvantage of this type of testing is the length of time required to obtain results—six months to several years. With today's rapid development of new coatings and improvement of existing ones, by the time a set of coatings are evaluated, new and possibly better materials have already become available.

To alleviate this problem, a number of accelerated tests can produce results in a much shorter time. The question is whether these techniques produce results that will match those obtained in outdoor exposure tests or how far astray the results might be.

This article compares the results of four common accelerated test methods to those obtained from outdoor exposure tests. The methods compared include:

- salt spray to ASTM B 117,[3]
- carbon arc light/water exposure to ASTM G 23,[4]
- fluorescent ultraviolet (UV) light/water exposure to ASTM G 53[5] using a type "A" bulb, and
- fluorescent UV light water exposure to ASTM G 53 using a type "B" bulb.

Methods and Results

Outdoor Exposure

Coated panels are affected by a multitude of factors, such as UV light from the sun, heat, cold, rain, snow, sleet, humidity, dirt, airborne chemicals. Of these, UV radiation has the greatest effect.

In this study, an outdoor exposure rack was located in East Chicago, Indiana. The panels were exposed to temperatures from –23°C (–10°F) to 38°C (100°C), the elements, and airborne particulate matter and pollution. A duplicate set of coated panels was mounted on an exposure rack in Colton, California. This location is characterized by higher summertime temperatures than those in East Chicago, more intense sunlight, and blowing sand.

Included in the comparison were solvent-based alkyds, water-based alkyds, epoxies, and urethanes. Each type of coating was sprayed on pan-

TABLE 1
Effect of Outdoor Exposure Tests

Product	Exposure Location	Length of Exposure (years)	60° Gloss (%)		
			Original	Dirty	Washed
Water-based alkyd	E. Chicago	2	71.4	26.0	31.2
Water-based alkyd	Colton	2	73.0	38.7	68.6
DTM[A] urethane	E. Chicago	2	83.1	41.2	51.8
DTM urethane	Colton	2	71.4	16.5	49.4
Epoxy	E. Chicago	2	52.9	0.2	1.1
Epoxy	Colton	2	52.8	0.4	0.9
Acrylic alkyd	E. Chicago	2	76.6	15.0	24.6
Acrylic alkyd	Colton	2	76.2	4.4	17.3
Epoxy-urethane	E. Chicago	1-1/3	84.9	57.9	82.2
Epoxy-urethane	Colton	1-1/3	82.3	24.2	87.1
Epoxy	E. Chicago	2	83.8	16.0	29.6
Epoxy	Colton	2	79.2	4.8	13.1

[A]DTM = Direct to metal

els at the same time, from the same batch of paint. The results of the tests are shown in Table 1.

Table 1 shows how complicated the effects of location are upon appearance. In some cases, coatings performed better at the East Chicago site, and others performed better at Colton. Whether panels were washed or unwashed also affected the gloss by location and coating type.

To eliminate the factor of dirt accumulation in this study, panels were washed with water and detergent using a sponge and were rinsed with clean water. Otherwise, gloss measurements might have been affected by such factors as time since the most recent rainstorm or amount of airborne dirt carried by the wind. However, to see the effect of accumulated dirt on appearance, gloss measurements were taken on panels both before and after washing.

Figure 1 depicts gloss as a function of outdoor exposure time for both dirty and washed areas of panels for three types of paints: alkyd, epoxy, and epoxy primer with a urethane topcoat. The largest difference was seen in alkyd coatings, which indicates that washing rail cars painted with alkyd paint would significantly improve their appearance. Little improvement was seen in epoxies, which dull from chalking whether washed or not. Washing urethanes improves appearance, however, because of their hardness, they may accumulate less dirt than other coatings and their gloss remains visible through the dirt.

Note: The values plotted in Figure 1 are a composite of several coatings of the same generic type and are not the same as the values used in Table 1.

Salt Spray Testing

Salt spray testing per ASTM B117 is useful for evaluating materials exposed to a marine environment but was not useful for evaluating coatings for fading or loss of gloss due to weathering.

Carbon Arc Light/Water Exposure

Graphs showing change in gloss as a function of outdoor exposure time for four types of coatings are shown in Figures 2 through 5. Figure 2 shows results for solvent-based alkyd coatings; Figure 3 is for water-based coatings; Figure 4, epoxy coatings; Figure 5, epoxy primer/ urethane topcoat coatings.

Corresponding results for exposing the same coatings in an ASTM G 23 test unit are shown in Figures 6 through 9.

The data for exposed panels in East Chicago extend to 30 months with gloss measurements and observations noted every four to six months or less. The panels tested in the ASTM G 23 test unit were assessed after 250, 520, and 830 hours.

The ASTM G 23 test unit accurately predicted the coating with the best gloss retention in outdoor exposure (Figures 2 and 6, coating AL-1). Also, the ASTM test correctly predicted the order or rank of the four candidate coatings for the initial period of outdoor exposure. However, in the outdoor tests, the gloss value of coating AL-4 fell below that of coating AL-3, and coatings AL-1 and AL-2 showed several reversals. None of these phenomena occurred in the ASTM test unit during the 830-hour exposure period.

When comparing the results of water-based coatings in outdoor exposure (Figure 3) with the results from ASTM G 23 test unit exposure (Figure 7), some discrepancies again are noted. For example, the gloss of coating WB-1 decreased slowly in the ASTM test and then leveled off. In outdoor exposure, the same coating lost gloss at a faster rate than the other water-based coatings. Likewise, for coating WB-5, after a period of initial loss of gloss, gloss actually increased. This phenomenon was not seen in the ASTM G 23 test unit but rather gloss continually decreased.

For epoxy coatings, the results of outdoor exposure are shown in Figure 4; the results of ASTM G 23 test unit exposure are shown in Figure 8. The ASTM test unit accurately predicted that coating E-4 would maintain the best gloss retention and coating E-2 would have the worst. The ASTM test also showed the close performance of coatings E-1 and E-3 until after 500 hours of exposure, at which time the epoxies E-3 and E-1 began to separate. This was not seen in the outdoor exposure tests.

Epoxy coatings exposed in a carbon arc ASTM G 23 test unit became hard, brittle, and in some cases, wrinkled. This did not happen to the coatings exposed outdoors or tested by other methods.

Some of the epoxy coatings on the outdoor exposure rack changed color from black to a milky gray, which also did not occur in the ASTM

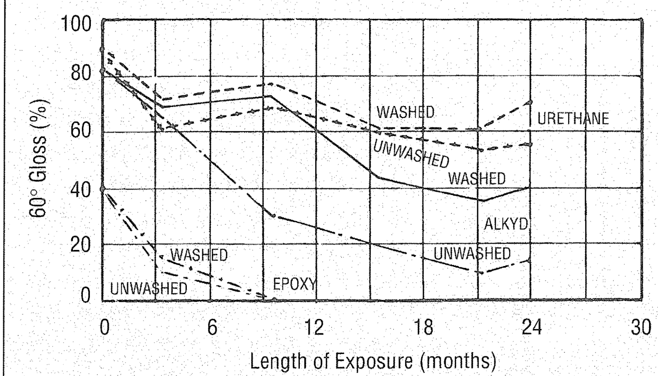

FIGURE 1
Effect of washing on gloss retention.

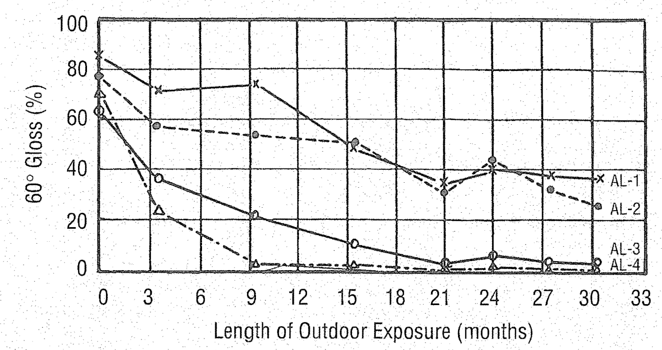

FIGURE 2
Gloss retention of DTM alkyd coatings on outdoor exposure rack.

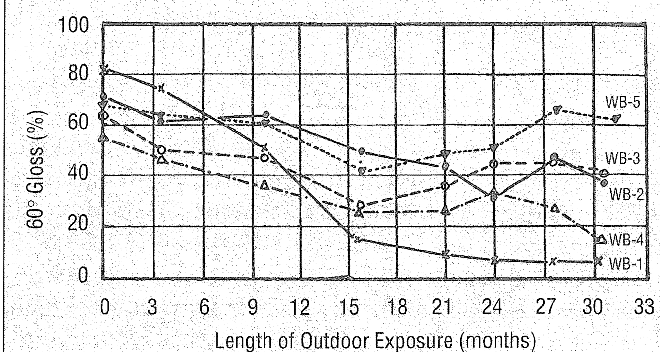

FIGURE 3
Gloss retention of water-based coatings on outdoor exposure rack.

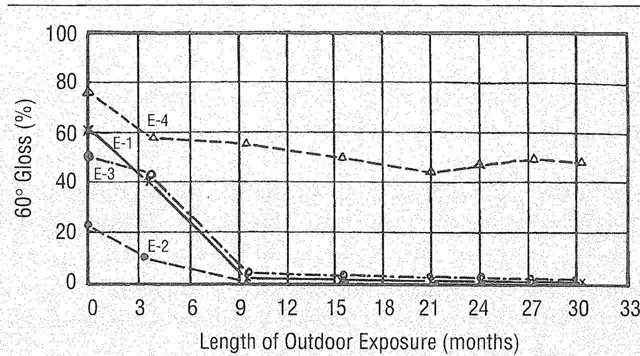

FIGURE 4
Gloss retention of epoxy coatings on outdoor exposure rack.

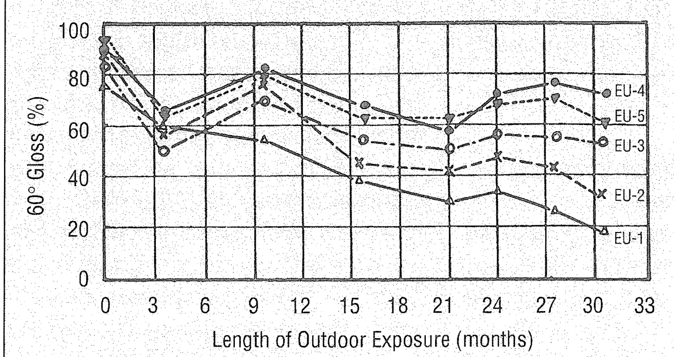

FIGURE 5
Gloss retention of epoxy-urethane coatings on outdoor exposure rack.

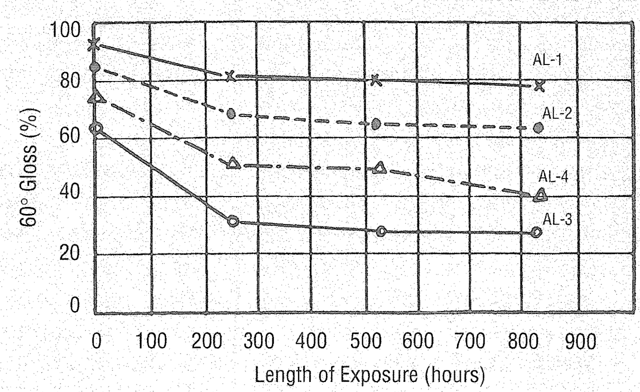

FIGURE 6
Gloss retention of alkyd coatings in an ASTM G 23 test apparatus.

G 23 test unit.

For epoxy-urethane coatings, the results of outdoor exposure are shown in Figure 5 and the results of ASTM G 23 testing are shown in Figure 9. The results did not correlate well. The best performing coating, EU-4, was predicted, but the order of the others differed. For example, in the ASTM G 23 test unit, coating EU-2 produced the worst results and EU-1 was in the middle of the group. In outdoor exposure, EU-1 gave the poorest test results and EU-2 was in the middle group during the first year of exposure.

Fluorescent UV Light/Water Exposure, Type "A" Bulb

The ASTM G 53 cabinet used in this set of UV light tests was equipped with type UVA-340 bulbs. The operating cycle consisted of 8 hours of UV light followed by 4 hours of humidity. The same type of comparisons

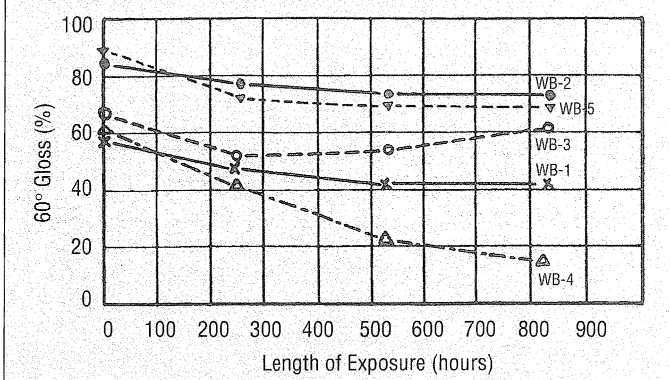

FIGURE 7
Gloss retention of water-based coatings in an ASTM G 23 test apparatus.

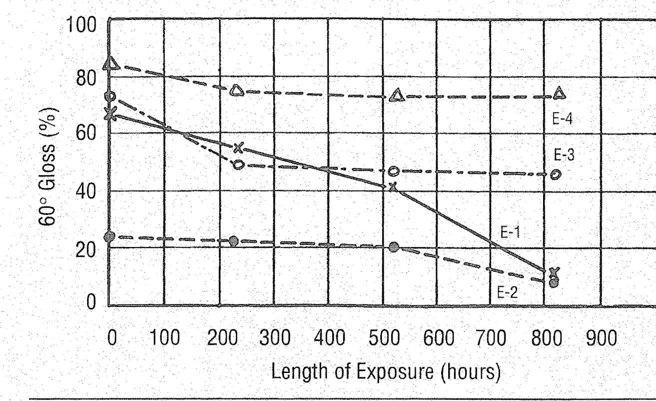

FIGURE 8
Gloss retention of epoxy coatings in an ASTM G 23 test apparatus.

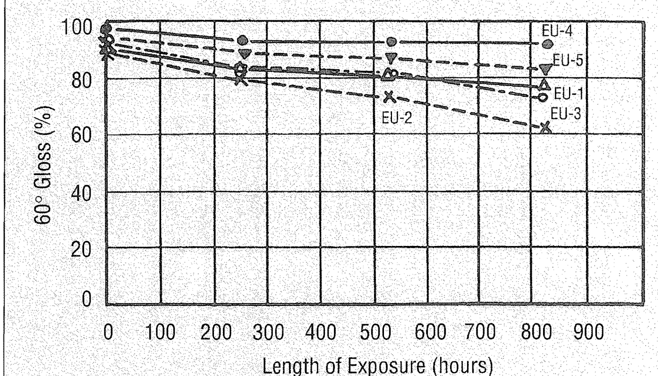

FIGURE 9
Gloss retention of epoxy-urethane coatings in an ASTM G 23 test apparatus.

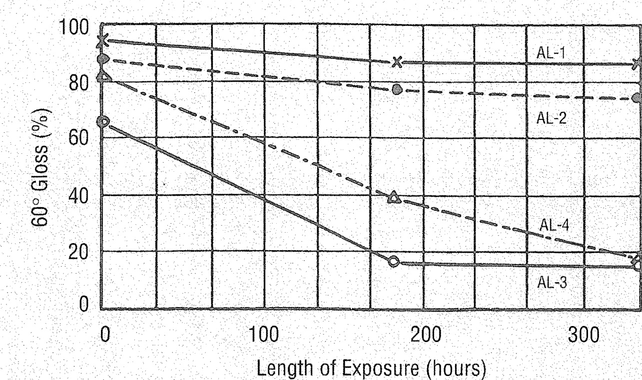

FIGURE 10
Gloss retention of alkyd coatings exposed in an ASTM G 53 cabinet, type A bulb.

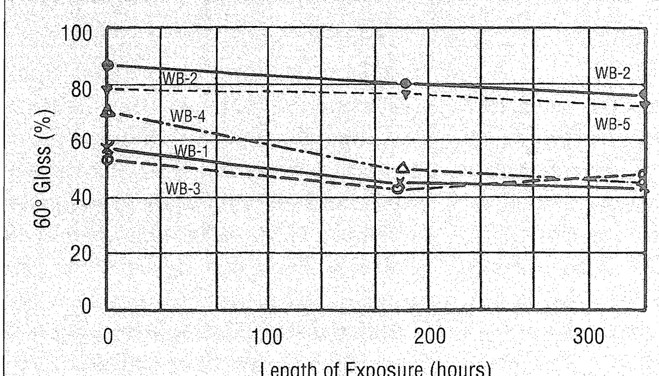

FIGURE 11
Gloss retention for water-based coatings exposed in an ASTM G 53 cabinet, type A bulb.

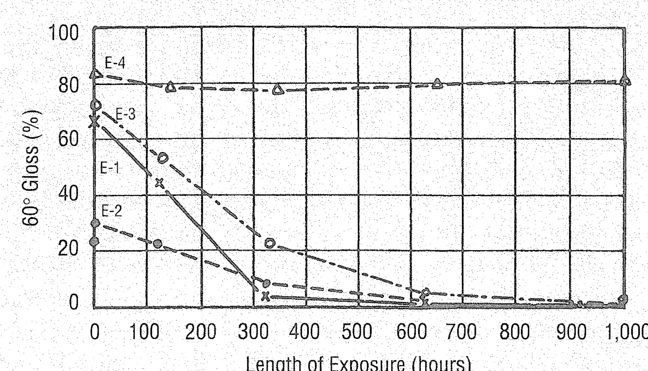

FIGURE 12
Gloss retention of epoxy coatings exposed in an ASTM G 53 cabinet, type A bulb.

can be made for coatings tested in a ASTM G 53 cabinet as were made for tests performed in an ASTM G 23 test unit. The gloss retention results for alkyd coatings tested in a ASTM G 53 cabinet with type A bulbs are shown in Figure 10 (compare with outdoor exposure results in Figure 2).

The ASTM cabinet test accurately predicted the best-performing alkyd coating, AL-1. It also predicted the performance rank of the remaining three alkyd coatings: AL-2, AL-4, and finally, AL-3. Figure 2 shows that the performance of coating AL-4 dropped below that of AL-3 after about 1-1/2 months of exposure. In Figure 10, it appears that the same happened

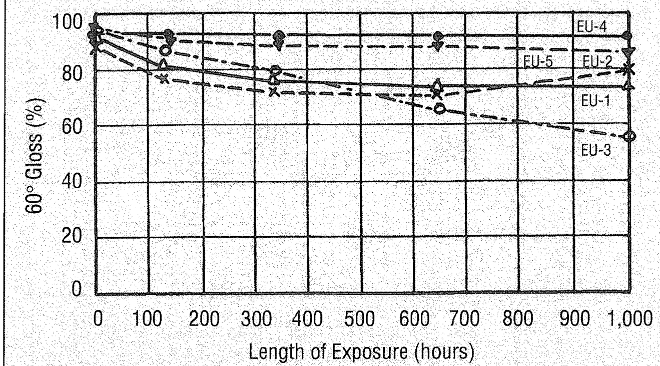

FIGURE 13
Gloss retention of epoxy-urethane coatings exposed in an ASTM G 53 cabinet, type A bulb.

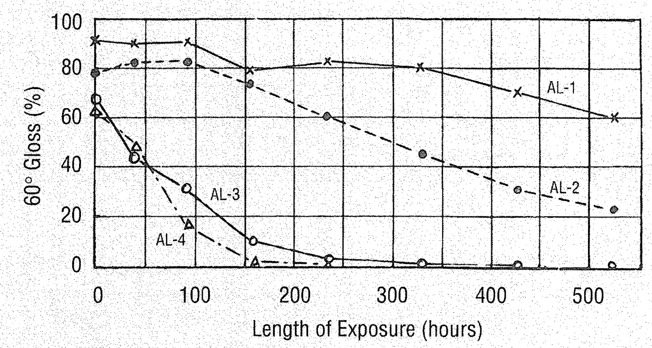

FIGURE 14
Gloss retention of alkyd coatings in an ASTM G 53 cabinet, type B bulb.

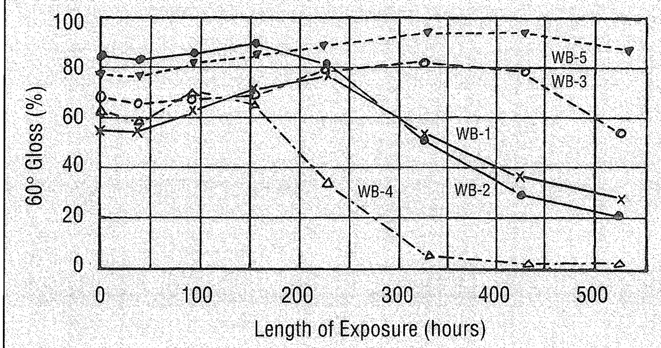

FIGURE 15
Gloss retention of water-based coatings in an ASTM G 53 cabinet, type B bulb.

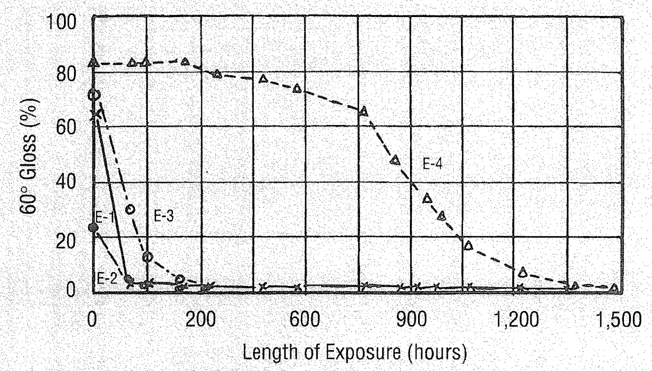

FIGURE 16
Gloss retention of epoxy coatings exposed in an ASTM G 53 cabinet, type B bulb.

after 330 hours.

For water-based coatings, the gloss retention of panels exposed outdoors demonstrated a number of changes in order of ranking over the time of the test (Figure 3). A good example is coating WB-1, which started out with the highest gloss and at some time between 12 and 15 months ranked as having the lowest gloss of the five candidates.

In the ASTM G 53 cabinet, coatings WB-2 and WB-5 were nearly equal and superior to WB-1, WB-3, and WB-4, which also were nearly equal but poorer. This "pattern" was not seen in the coated panels exposed outdoors. Also, the coatings tested in the ASTM G 53 cabinet exhibited very little change from their initial gloss, while the coatings tested outdoors showed both significant decreases and increases in gloss.

For epoxies, the gloss retention of coatings exposed outdoors is shown in Figure 4. Gloss retention for comparable coatings exposed in an ASTM G 53 cabinet is shown in Figure 12. The ASTM G 53 cabinet accurately predicted that coating E-4 would have a minimum loss of gloss and would retain gloss better than the other epoxy coatings tested. It also demonstrated a total loss of gloss for the other three epoxies, which occurred after about 9 months outdoors and after about 300 hours in the ASTM cabinet.

For the epoxies tested, the results of ASTM G 53 cabinet tests (with "A" bulbs) correlated very well with outdoor exposure tests. The ASTM G 53 tests also accurately predicted which coatings would lose gloss but would maintain their original black color and which would fade to gray.

Epoxy primer/urethane topcoat systems test results of outdoor exposure are shown in Figure 5, and gloss retention values after exposure in an ASTM G 53 cabinet are shown in Figure 13. ASTM G 53 testing correctly predicted that coating systems EU-4 and EU-5 would have the best gloss retention in outdoor exposure and that the two would be close in performance, with EU-4 being the best. Of the coatings showing poor performance, the ASTM G 53 test did not predict the results in the proper order. Also, the gloss measured on coatings exposed outdoors showed some increases as well as decreases over time. These characteristics were not detected in the ASTM G 53 cabinet with "A" bulbs.

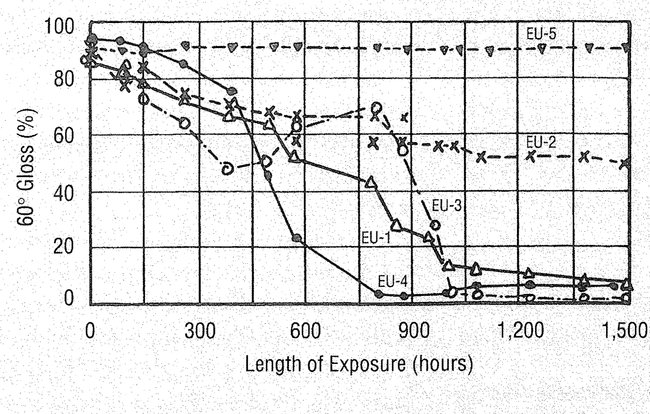

FIGURE 17
Gloss retention of epoxy-urethane coatings exposed in an ASTM G 53 cabinet, type B bulb.

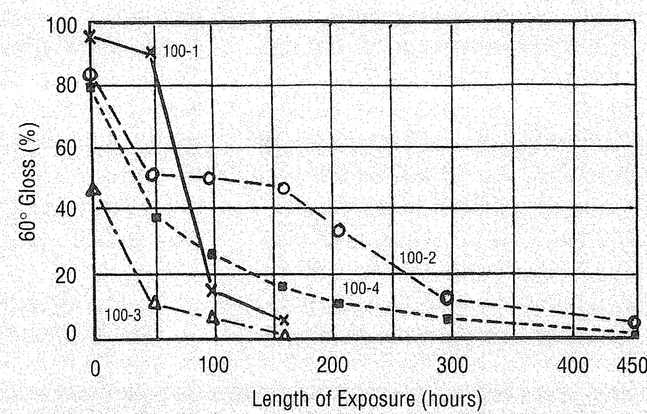

FIGURE 18
Gloss retention of 100% solids epoxy coatings in an ASTM G 53 cabinet, type B bulb.

Fluorescent UV Light/Water Exposure, Type "B" Bulb

For the second UV-light test, the ASTM G 53 cabinet was equipped with type UV B-313 bulbs. The operating cycle consisted of 16 hours of UV-light exposure followed by 8 hours of condensation. The results of ASTM G 53-B tests are shown in Figure 14 for alkyd coatings, Figure 15 for water-based, Figure 16 for epoxies, Figure 17 for epoxy-urethane systems, and Figure 18 for 100% solids epoxy. The results for 100% solids epoxy coatings exposed outdoors at East Chicago are shown in Figure 19.

ASTM G 53 exposure with "B" bulbs (Figure 14) correlates well with outdoor exposure for alkyd coatings (Figure 2). Coating AL-l was the best in both cases. In addition, the order of performance of the other three coatings was identical in both tests. Also, the ASTM G 53 test correctly showed that the gloss value of coating AL-4 was initially above that of AL-3 but then fell below it.

For water-based coatings, there was a certain lack of correlation; however, testing in the ASTM G 53-B cabinet correctly predicted that coating WB-5 would surpass the other water-based materials in gloss in the outdoor exposure test. The correlation between ASTM G 53-B and outdoor exposure test results was not as good for the other water-based coatings; however, the correlation was better than that obtained from ASTM G 23 and ASTM G 53-A tests.

For the epoxy coatings, the results of ASTM G 53-B tests are shown in Figure 16. The results correlate well with the gloss retention obtained in outdoor exposure (Figure 4). Both figures show that coating E-4 not only had the best gloss retention, but gloss retention significantly better than that of the other epoxies evaluated.

Likewise, coating E-2 had the poorest results and coatings E-1 and E-3 suffered nearly total loss of gloss in both ASTM G 53-B tests and outdoor exposure. The ASTM G 53-B test showed a rapid loss of gloss in coating E-4 after 750 hours. This was not seen in the outdoor exposure, however, it may happen after additional hours. The ASTM G 53-B test, like the ASTM G 53-A test, correctly predicted color fade from black to gray on those coatings that faded during outdoor exposure.

Comparing results from ASTM G 53 -B (Figure 17) and outdoor exposure (Figure 5) for epoxy-urethane coatings revealed interesting features. At first, there seemed little correlation, but then a comparison of ASTM G 53 results for the period from 0 to 150 hours correlated fairly well with the 31-month outdoor exposure. Thus, the rapid decrease in gloss of

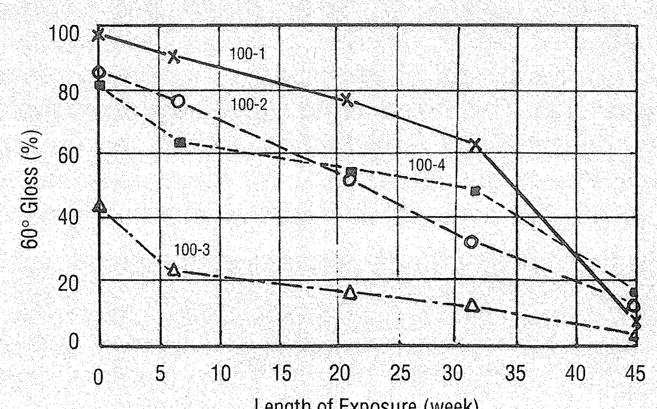

FIGURE 19
Gloss retention of 100% solids epoxy coatings on outdoor exposure rack (East Chicago).

the coating EU-4 may still occur sometime later in outdoor exposure.

For 100% solids epoxy coatings, the ASTM G 53-B test (Figure 18) predicted that coating 100-1 would have the best initial gloss retention but its performance would fail rapidly; the test also predicted coating 100-3 would yield the poorest results. Outdoor exposure tests (Figure 19) showed that indeed coating 100-1 would start out with the best gloss and coating 100-3 would perform poorest of the four candidates. The rapid loss of gloss shown in Figure 18 for coating 100-1 was not confirmed in actual outdoor testing. Likewise, the eventual superiority of coating 100-2 predicted in the ASTM test (Figure 18) was not seen in outdoor tests (Figure 19).

Conclusions

Results from the ASTM G 23 test apparatus correlated with the gloss retention in the outdoors test. It did not give any indication of color shift or fading, especially with epoxy coatings. Results were somewhat slow in that 830 hours of exposure seemed to correlate to only 6 to 8 months of outdoor exposure.

Testing in an ASTM G 53-A cabinet produced results that correlated well with outdoor exposure and results were obtained more quickly than those obtained using the ASTM G 23 unit. Also, color shift or fading was correctly predicted in the ASTM G 53-A tests.

Testing in an ASTM G 53-B cabinet produced results more quickly than any of the other methods. Testing for 150 to 200 hours seemed to approximate more than a year of outdoor exposure. Also, the fading and shifting in color of some coatings from black to gray correlated well with outdoor exposure using this test.

Accelerated tests were useful tools for selecting coatings that maintain their appearance outdoors. These test methods are best used in conjunction with outdoor exposure tests rather than as a substitute for them, because as seen in the collected data, anomalies do occur.

References

1. J.F. Montle, Y. Korobov, "Coating Manufacturers' Use of Accelerated and Field Tests to Evaluate Coatings," CORROSION/92, paper no. 327 (Houston, TX: NACE, 1992).
2. D. Helfand, K. Barrett, "A Resin Manufacturer's Use of Accelerated and Field Tests: Methods and Data Utilization."
3. ASTM B 117-94, "Test Method of Salt Spray (Fog) Testing," Vol. 03.03, Annual Book of Standards (Philadelphia, PA: ASTM, 1995).
4. ASTM G 23-93, "Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials," Vol. 06.01, Annual Book of Standards (Philadelphia, PA: ASTM, 1994).
5. ASTM G 53-93, "Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials," Vol. 03.03, Annual Book of Standards (Philadelphia, PA: ASTM, 1994).

More information may be available in paper no. 596, presented at CORROSION/94 in Baltimore, Maryland.