TECHNICAL ARTICLE LU-8027

Correlation of Accelerated and Natural Weathering of Sealants

By Gregory Fedor, R&D Engineer and Patrick Brennan, Vice President of Technical Services; The Q-Panel Co., Cleveland, OH 44145

Short wave UV light is responsible for much of the damage to sealants exposed outdoors. Moisture also causes damage, and there often is a synergistic effect between UV and moisture. Experience has shown that materials resistant to UV alone or to moisture alone often fail when exposed to UV and moisture in combination. A third consideration is temperature. Temperature accelerates the rate of any chemical reaction, and while most photochemical reactions are not temperature sensitive, any subsequent chain reactions usually are temperature dependent. Because outdoor exposures are time consuming and the weather is variable from year to year and place to place, accelerated laboratory weathering testers are widely used for research and development, quality control, and material certification.

The objective of this study was to determine if there was any correlation between natural and accelerated weathering of sealants and, if so, which accelerated device best correlated with the natural exposure.

Experimental

Samples for the test were prepared and submitted by volunteer companies from ASTM Committee C-24 on Building Seals and Sealants. An independent laboratory collected samples from the participants, chose which ones would be exposed and coded and forwarded them for exposure. Each test specimen was prepared by the sealant manufacturer in accordance with ASTM C-793 *(l)*. Specimen size was 5 x 1.5 x 0.125 in. All samples were adhered to a clean, bare 3 x 6 in aluminum substrate.

Sealant types tested included one- and two-component urethanes, polyvinyl acetate latex, thermoplastic rubber, black and white silicone, solvent-type acrylic and latex acrylic. Replicate sets of sealants were exposed to direct Florida weathering and two accelerated devices. Test conditions are summarized in the following paragraphs.

Natural Weathering. The outdoor tests were performed in accordance with ASTM G-7 *(2)*. Samples were exposed in Homestead, Fla. Replicate specimens were exposed at 45° south, open back mounting (i.e. non-insulated), for intervals of 6, 12 and 18 months.

QUV Weathering, UVA-340 Lamps. The second set of sealants was exposed in a QUV weathering tester per ASTM G-53 *(3)*. The light source was the UVA-340 lamp. The test cycle consisted of 8 hr of UV exposure at 65°C (149°F), alternating with 4 hr of condensation at 50°C (122°F). Specimens were exposed for 250, 500, 1,000 and 2,000 hr.

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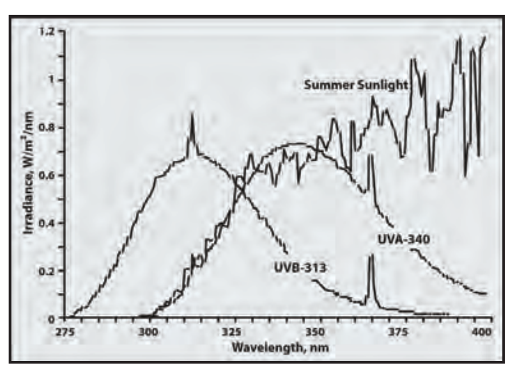

Figure 1 - UVA-340 and UVB-313 lamps compared to noon summer sunlight.

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Q-LAB

Xenon Arc Weathering. The final set of sealants was exposed in a Ci 65 xenon arc per ASTM G-26 *(4)*. The burner used borosilicate inner and outer filters and was operated at 0.35 W/m²/nm (at 340 nm). The test cycle consisted of continuous irradiance with 18 min of water spray every 2 hr. Black panel temperature was 63°C (145°F). Spray water temperature was 42°C (108°F).

Exposure Variables

The damaging forces of UV light, moisture and temperature are different in each of the exposure methods. Each of these differences is briefly examined to lend some understanding as to the differences in test results.

LIght Sources. Because the UV in natural sunlight is filtered by air mass, cloud cover, pollution, etc., the amount and spectral distribution of a natural UV exposure is extremely variable. Because the sun is lower in the sky during the winter months, it is filtered through a greater air mass. The shorter, more damaging UV wavelengths are filtered out during winter. For example, the intensity of UV at 320 nm changes about 8 to 1 from summer to winter. Consequently, materials sensitive to UV below 310 nm would degrade only slightly, if at all, during the winter months.

Using light sources that emit UV wavelengths shorter (i.e. more severe) than those found in natural sunlight is one of hte most common methods used for acceleration. However, if the spectral sensitivity of the materials tested is pirmarily in these short wavelengths, the results may be unnaturally severe, particularly in comparison to materials that are not sensitive to short wave UV. Sources that are a good match with sunlight, especially in this short wave UV region, are slower but may allow better correlation with outdoor results.

The QUV uses different types of lamps, with different spectrums, for different exposure applications. The QUV does not attempt to reproduce sunlight itself, just the damaging effects of sunlight. This is effective because short wave UV causes almost all of the damage to durable materials exposed outdoors. Fluorescent testers confine their emission to the UV portion of the spectrum. Figure 1 shows the UVA-340 and the UVB-313 compared to noon summer sunlight.

The UVA-340 was introduced in 1987 to improve correlation between QUV and natural weathering. It has been tested on both plastics and coatings and, in many cases, greatly improves the correlation possible with these devices. This lamp is a good simulation of sunlight from about 365 nm down to the solar cut-off of 295 nm.

The UVB-313 is the most widely used light source for the QUV. It has demonstrated good correlation to outdoor exposures for both material integrity and physical properties. However, the short wave output below the solar cut-off can occasionally cause anomalous results, especially for color retention.

Xenon arcs use a combination of filters to reduce unwanted radiation. The study used the most common combination, borosilicate inner and outer filters. Figure 2 shows the same summer sunlight compared to a xenon arc with boro/boro filters.

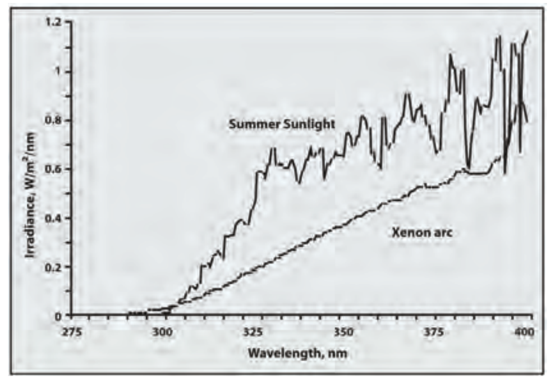

Figure 2 - Summer sunlight compared to a xenon arc with boro/boro filter.

Moisture. Another variable was the amount of time the samples were wet. Figure 3 summarizes the differences. The outdoor data shown is the measured time of wetness during the study period *(5)*. Sealants in Florida were wet approximately 45% of the time. QUV samples were exposed to about 33% wet time. Xenon arc samples were wet about 15% of the time.

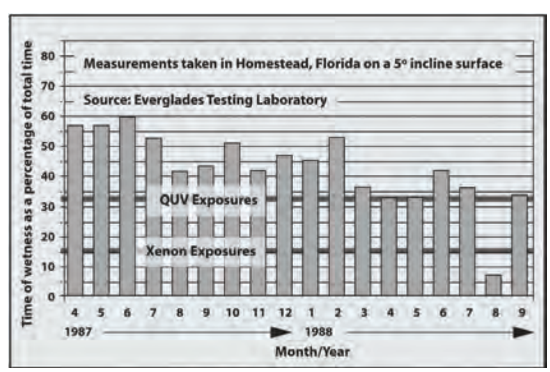

Figure 3 - Differences in the time the samples were wet

Most of the wetness that a material encounters outdoors comes in the form of dew, not rainfall. Table 1 shows the daily time of wetness compared to the amount of rainfall for one typical month during the Florida exposures.

Date July 1987	Time of wetness (hr)	Rainfall (in.)
1	15.3	0.04
2	17.0	-
3	15.8	-
4	17.0	-
5	16.2	0.31
6	21.1	-
7	13.3	0.04
8	15.1	-
9	15.8	-
10	7.2	-
11	4.1	-
12	3.2	-
13	2.6	-
14	15.2	-
15	5.5	0.94
16	18.0	0.31
17	17.4	0.2
18	14.8	0.59
19	17.2	0.39
20	13.3	0.04
21	14.7	0.08
22	13.0	-
23	11.2	-
24	10.7	-
25	10.1	-
26	14.2	0.2
27	11.5	-
28	13.7	0.16
29	9.2	-
30	10.0	-
31	9.0	-

Source: Everglades Testing Service, July 1987 climatological dataMeasurements taken in Homestead, Fla., on a 5° inclined surface.

Table 1 - Daily Time of Wetness vs Rainfall

This has significance for accelerated simulations. The QUV uses relatively long (4 hr) cycles of condensation to reproduce the effects of naturally occurring moisture. The xenon arc uses short cycles (18 min) of water spray.

Temperature. Temperature is the third variable among the exposure conditions. Accelerated testing is normally run at temperatures higher than what a material is normally exposed to, but not so high as to cause abnormal degradation. This is done because higher temperatures usually increase the rate of degradation.

The Florida samples were mounted on an open rack (i.e. not insulated); the maximum surface temperature recorded was 48°C (110°F). In most actual service applications the samples would be insulated, leading to temperatures as high as 66°C. The maximum temperature of the accelerated tests was 65°C. Consequently, the accelerated test temperatures are closer to the maximum temperatures that the sealant would be exposed to in normal service.

Thermal shock is a consideration when surface cracking is an important factor. Depending on the exposure method, the samples were subject to varying rates of temperture change. The predominant temperature change for Florida samples occurs gradually between day and night. The rate of change for the QUV samples also is very gradual, because it takes about an hour for the chamber to reach equilibrium after a cycle change. Xenon arc samples were exposed to direct water spray at the beginning of the moisture cycle, creating a high rate of temperature change.

Results

The exposed sealants were evaluated for visual deterioration (cracking, pitting, etc.), changes in hardness (durometer) and flexibility.

Visual Surface Degradation. One of the most significant differences in exposure results was the growth of micro-organisms. In Florida, all but one of the sealants showed at least slight micro-organism growth. Several showed significant or even severe growth. For obvious reasons, the laboratory samples exhibited no signs of micro-organism growth. The amount of growth on the polyvinyl acetate latex and the solvent-type acrylic sealants was severe enough that its presence on the sample may actually have protected the sealant from further UV exposure (Figure 4).

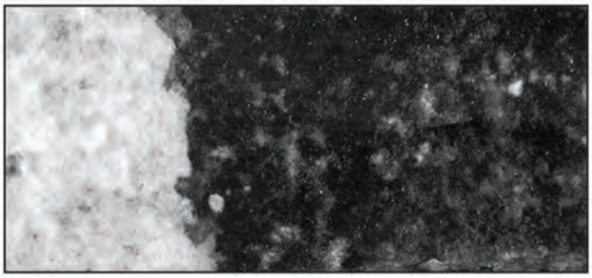

Figure 4 - Micro-organism growth on polyvinyl acetate latex after 18 months in Florida at 45°S.

In general, the QUV did a somewhat better job than the xenon arc in reproducing the changes seen in the Florida exposures, particularly in regard to cracking and pitting (Figure 5). However, a number of the sealants exhibited blistering or bubbling in the lab but not in Florida. This may have been due to the difference in exposure temperatures. Except for the thermoplastic rubber sealant, the color change was almost identical for Florida and all the lab testers. Relative to Florida, the rate of acceleration was dependent on sealant type in

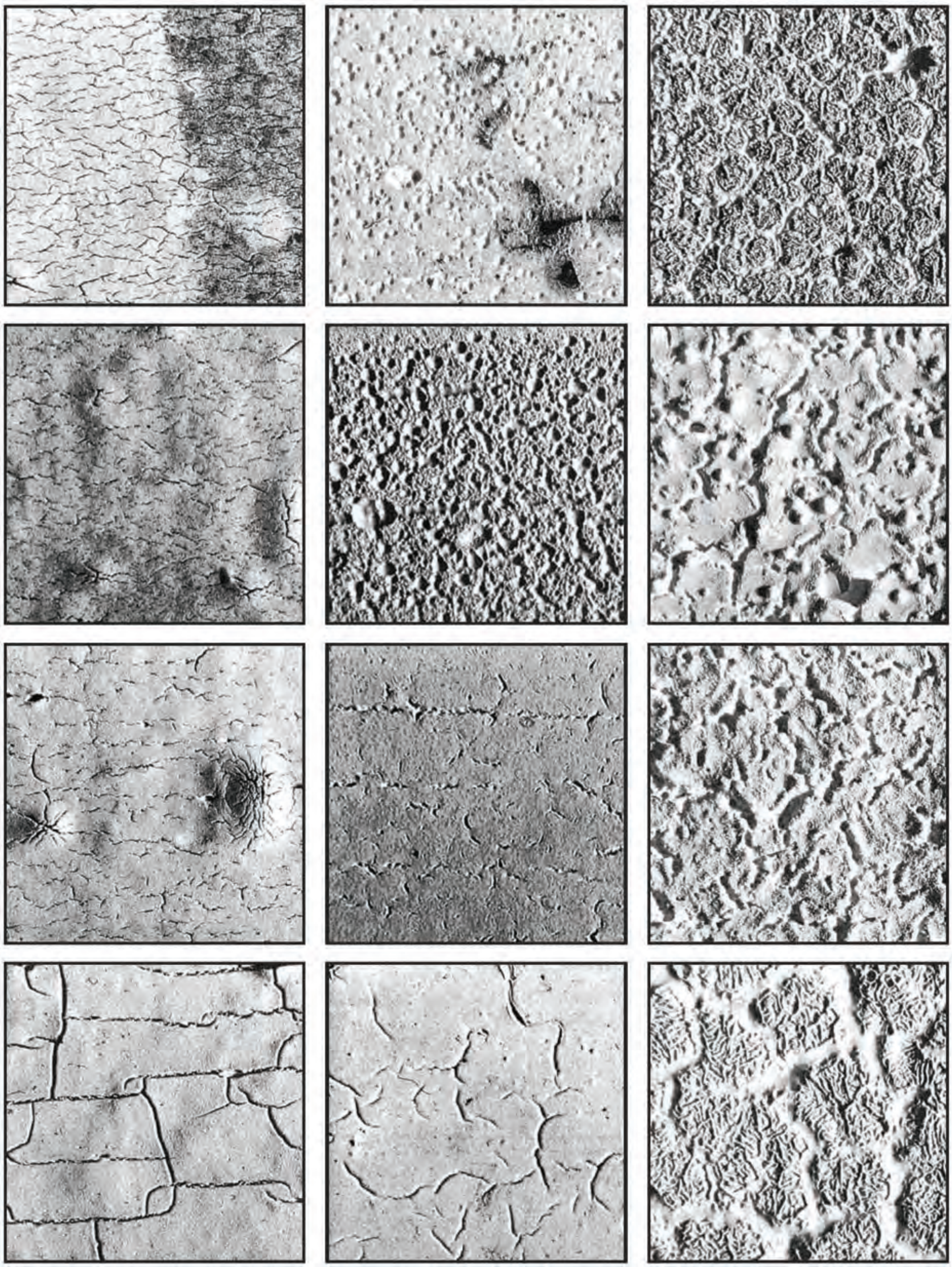

Figure 5 - Left column shows visual surface degradation of the one-component urethane after (top to bottom) 18 months at 45°S; UVA-340, 2,000 hours QUV; UVB-313, 2,000 hours QUV; and 2,000 hours xenon arc exposure with boro/boro filter. Center column shows visual surface degradation of the acrylic latex after (top to bottom) 18 months at 45°S; UVA-340, 2,000 hours QUV; UVB-313, 2,000 hours QUV; and 2,000 hours xenon arc exposure with a boro/boro filter. The right column shows visual surface degradation of the thermoplastic rubber after (top to bottom) 18 months at 45°S; UVA-340, 2,000 hours QUV; UVB-313, 2,000 hours QUV; and 2,000 hours xenon arc exposure with a boro/boro filter.

Sealant Type	Florida	UVA-340	UVB-313	Xenon arc
One-component urethane	Fine, dense, one-direction cracking	Fine, dense, one-direction cracking, mild blistering	Fine, dense, one-direction cracking, mild blistering	Course, severe two-direction cracking
Two-component urethane	Fine, dense, one-direction cracks, mild mildew	Fine, dense, one-direction cracks, blisters	Fine, dense, one-direction cracks, blisters	Course, severe two-direction cracks, blisters
Polyvinyl acetate latex	Severe mildew, no other change	Severe bubbling, slight pitting	Moderate bubbling, slight pitting	Moderate bubbling, slight pitting
Thermoplastic rubber	Fine cracks become coarse with time, severe dirt/mildew, no yellowing	Fine cracks become coarse with time, slight yellowing, slight bubbling	Fine cracks become coarse with time, yellowing	Fine cracks become coarse with time, no yellowing
Silicone (black)	No change	No change	No change	No change
Silicone (white)	Moderate mildew, no other change	No change	No change	No change
Acrylic, solvent type	Severe mildew, no other change	Moderate blistering	Moderate bubbling	Small bubbles and pitting
Acrylic, latex	Severe pitting, dirt/mildew	Severe pitting	Pitting and fine cracks	Fine serpentine cracks

Table 2 - Visual Surface Degradation

the laboratory exposures. The UVB-313 tests showed the greatest range in acceleration rates. This was probably due to the varying sensitivities of the different sealants to the UVB-313's short wave UV emission below 295 nm (i.e. the solar cut-off). The UVA-340 and the xenon arc gave more consistent results on rate of acceleration. Descriptions of the visual changes for each sealant type and each exposure condition are given in Table 2.

Hardness. To determine how well the accelerated methods predict changes in hardness, Shore A durometer measurements were taken in accordane with AASTM D-2240 *(6)* on each sealant, at each exposure interval. The data shown in Table 3 is an average of three readings with a repeatability of ±2 points. Due to blistering, accurate measurements were not possible for some samples. In most cases, the change that took place in Florida was duplicated by the accelerated methods. ASTM D-2240 was a useful method of assessing the effects of weathering.

Flexibility. Flexibility of the exposed specimens was compared to the unexposed control in accordance with ASTM C-793. This method calls for the sample to be frozen to -26°C and bent around a 1/2 in mandrel. With only one exception, comparisons of exposed samples vs. the unexposed control showed no differences. If the exposed sample exhibited loss of adhesion and/or cohesion, so did the control samples. This indicates that temperature, not exposure to weathering, is the overriding factor in this test. We do not recommend that the cold temperature test be used to evaluate the effects of weathering.

The test was repeated at room temperature using a 1/4 in mandrel. All of the unexposed control samples passed the test. However, many of the exposed sealants exhibited stretch marks, indicating some loss of cohesion (Figure 6). In addition, the existing cracks in the thermoplastic rubber and acrylic latex sealants were elongated. They polyvinyl acetate latex showed partial cracking. With only one exception (the two-component urethane), both the UVA-340 and the UVB-313 (QUV) results were in exact agreement with the Florida results (Table 4).

		Florida, 45°S			UVA-340			UVB-313			Xenon arc	
Sealent type	Control	6 mo	12 mo	18 mo	500 hr	1000 hr	2000 hr	500 hr	1000 hr	2000 hr	1000 hr	2000 hr
One-component urethane	46	47	45	47	53	52	50	51	50	49	52	50
Two-component urethane	29	26	25	24	27	23		24	23		26	26
Polyvinyl acetate latex	66	94	92	95	84	83	86	85	86	85	90	92
Thermoplastic rubber	33	34	35	35	34	33	31	32	32	31	35	39
Silicone (black)	41	41	41	40	41	38	39	39	37	38	39	41
Silicone (white)	46	49	48	49	46	47	46	47	48	47	47	47
Acrylic, solvent type	56	54	63	68	56	59		55	56	58	61	61
Acrylic, latex	71	79	80	78	75	81	81	80	82	82	80	82

Table 3 - Durometer Data

Sealent Type	18 month Florida	2000 hr UVA-340	2000 hr UVB-313
One-component urethane	Very slight stretch marks	Very slight stretch marks	Very slight stretch marks
Two-component urethane	Very slight stretch marks	No cracks, no stretch marks	No cracks, no stretch marks
Polyvinyl acetate latex	Surface cracking	Surface cracking	Surface cracking
Thermoplastic rubber	Stretching	Stretching	Stretching
Silicone (black)	No cracks, no stretch marks	No cracks, no stretch marks	No cracks, no stretch marks
Silicone (white)	No cracks, no stretch marks	No cracks, no stretch marks	No cracks, no stretch marks
Acrylic, solvent type	Stretch marks	Stretch marks	Stretch marks
Acrylic, latex	Stretching	Stretching	Stretching

Table 4 - Flexibility at Room Temperature (25°C)

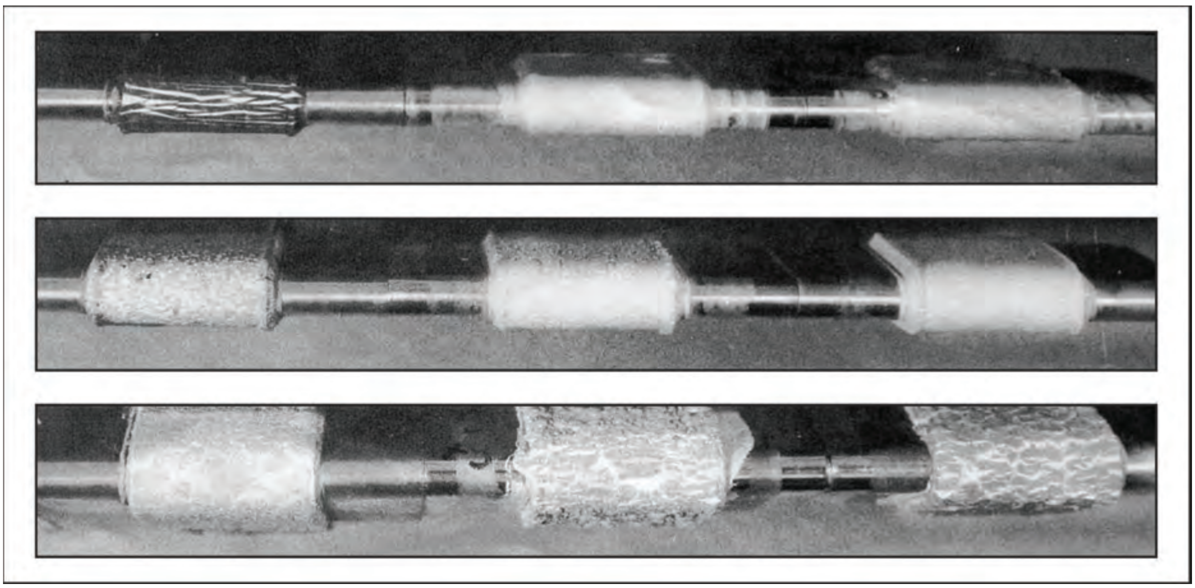

Figure 6 - Flexibility tests conducted by bending the specimens over a 1/4 in mandrel at 25°C. Photos show (left to right) 18 months in Florida, 2,000 hours of UVA-340 exposure and 2,000 hours of UVB-313 exposure. The top photo shows partial cracking on the polyvinyl acetate latex. The center photo shows stretching and some loss of cohesion on acrylic latex, and the bottom photo shows stretching and some loss of cohesion on thermoplastic rubber.

Correlation Summary

The correlation between laboratory and natural weathering probably will always be controversial. Results from accelerated tests should be used with care. In fact, the relationship between different types of natural exposures also is problematic. No one really knows how a Florida test fence exposure at 5° south correlates with a year on a buliding in Arizona or New Jersey. So even Florida gives only relative indications of actual service performance. It is asking too much of a laboratory device to do more.

With a weathering tester, there are a number of parameters that must be programmed: UV spectrum, moisture, humidity, temperature and test cycle. Because no one test cycle or device can reproduce all the variables found outdoors in different climates, altitudes and latitudes, the accelerated conditions that one chooses are, to a certain extent, arbitrary. In order to achieve rapid test results, an accelerated tester must often exaggerate the naturally degrading forces found in nature. Material formulations that differ significantly may react in various ways to these artificially severe stresses. Consequently, generically different sealant types may exhibit different acceleration factors. In fact, even within one individual sealant sample there may be different acceleration rates for different properties examined.

Table 5 is a summary of the correlation between the natural vs. accelerated weathering on the sealants in this study. It does not include the effects of micro-organisms. The "acceleration rate" shown is an average of the various properties tested. Where no acceleration rate is shown,

Sealant Type	Evaluation Method	Q-U-V UVA-340	Q-U-V UVB-313	Xenon arc
One-component urethane	Visible:	Good	Good	Fair
	Durometer:	Fair	Fair	Fair
	Flexibility:	Excellent	Excellent	No data
	Acceleration rate:	2600 hr ≅ 1 yr	2600 hr ≅ 1 yr	—
Two-component urethane	Visible:	Good	Good	Fair
	Durometer:	Good	Good	Good
	Flexibility:	Fair	Fair	No data
	Acceleration rate:	1200 hr ≅ 1 yr	500 hr ≅ 1 yr	1300 hr ≅ 1 yr
Polyvinyl acetate latex	Visible:	Fair	Fair	Fair
	Durometer:	Good	Good	Good
	Flexibility:	Excellent	Excellent	No data
	Acceleration rate:	1000 hr ≅ 1 yr	1000 hr ≅ 1 yr	1000 hr ≅ 1 yr
Thermo-plastic rubber	Visible:	Good	Fair	Excellent
	Durometer:	Fair	Fair	Fair
	Flexibility:	Excellent	Excellent	No data
	Acceleration rate:	1300 hr ≅ 1 yr	1300 hr ≅ 12 mo	2000 hr ≅ 1 yr
Silicone (black)	Visible:	Good	Good	Good
	Durometer:	Good	Good	Good
	Flexibility:	Excellent	Excelent	No data
	Acceleration rate:	—	—	—
Silicone (white)	Visible:	Good	Good	Good
	Durometer:	Good	Good	Good
	Flexibility:	Excellent	Excelent	No data
	Acceleration rate:	—	—	—
Acrylic, solvent type	Visible:	Poor	Poor	Poor
	Durometer:	Fair	Fair	Fair
	Flexibility:	Excellent	Excellent	No data
	Acceleration rate:	1000 hr ≅ 1 yr	2000 hr ≅ 1 yr	1000 hr ≅ 1 yr
Acrylic, latex	Visible:	Excellent	Fair	Fair
	Durometer:	Good	Good	Good
	Flexibility:	Excellent	Excellent	No data
	Acceleration rate:	1200 hr ≅ 1 yr	1000 hr ≅ 1 yr	1000 hr ≅ 1 yr
* — = evidence inconclusive				

Table 5 - Correlation Study

there was either not enough change in the properties tested, or the change was not similar enough to warrant a conclusion. This summary is intended to be valid only for this one specific set of sealants exposed during a specific time in Florida. Extrapolations based on this data should be made with great care.

Conclusion

The following conclusions were made based on the work described above.

Accelerated Tests Compared to Florida. Although accelerated testing is widely used to predict product durability, there are limitations to its use. For the sealants in this study, the most obvious was the inability of the laboratory tests to reproduce the micro-organism growth seen in Florida. Also, the lab devices are unable to reproduce degradation caused by pollution or windbourne contaminates. In spite of this, these test results indicate that accelerated weathering testing is a useful tool. On the whole, there was good correlation between the accelerated tests and Florida on surface changes (i.e. cracking, pitting, etc.), flexibility and hardness (durometer). However, different generic sealant types exhibited different acceleration factors.

QUV Compared to Xenon Arc. The sealants gave somewhat mixed results. Of the eight types tested, the QUV gave the best correlation to Florida on two and the xenon arc gave the best results on one. They gave essentially equivalent results on the remainder. The QUV, especially with UVB-313 lamps, caused the sealants to deteriorate faster than the xenon arc. In conclusion, the QUV gave slightly superior results on the test array.

UVB-313 Compared to UVA 340. On two of the sealants tested, the UVA-340 lamps gave better correlation to Florida than the UVB-313. For the remainder, the results were similar. The UVA-340 was slower than the UVB-313, but the acceleration rate (relative to sealant type) was more consistent. In conclusion, the UVA-340 lamp is the most useful for correlation to Florida or for comparisons to generically different sealants. The UVB-313 gives faster results and may be most useful for durable formulations or QC applications.

Duration of Accelerated Exposures for Test Methods and Specifications. The results of this study indicate that, for most sealants, the exposure requirements in the existing specifications and test methods are inadequate. A realistic minimum exposure time would be 2,000-3,000 hr of accelerated testing. For silicones, 5,000 hr is probably a minimum figure.

Acknowledgment

The authors would like to thank the members of ASTM Committee C-24 for aiding in the study. The authors also would like to acknowledge Jerry Klosowski of Dow Corning, Saul Spindel of DL Laboratories, and Dave Massey and Mary Walker of H.B. Fuller for special assistance.

References

(1) ASTM C-793, Standard Test Method for Effects of Accelerated Weathering on Elastomeric Joint Sealants.
(2) ASTM G-7, Standard Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials.
(3) ASTM G-53, Standard Practice for Operating Light and Water Exposure Apparatus (Fluorescent UV - Condensation Type) for Exposure of Nonmetallic Materials.
(4) ASTM G-26, Standard Practice for Operating Light Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials.
(5) DSET Laboratories Inc. 32:8-34:1.
(6) ASTM D-2240, Standard Test Method for Rubber Property-Durometer Hardness.

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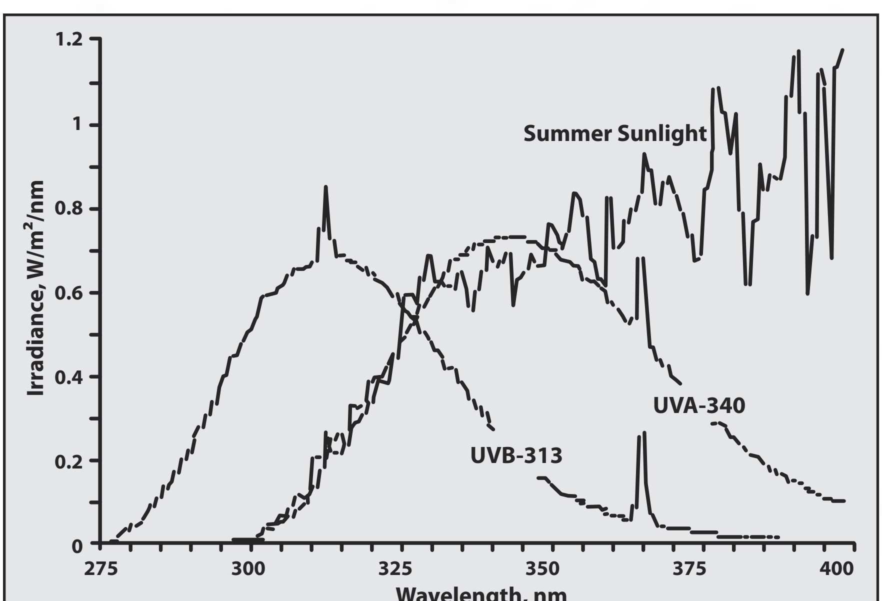

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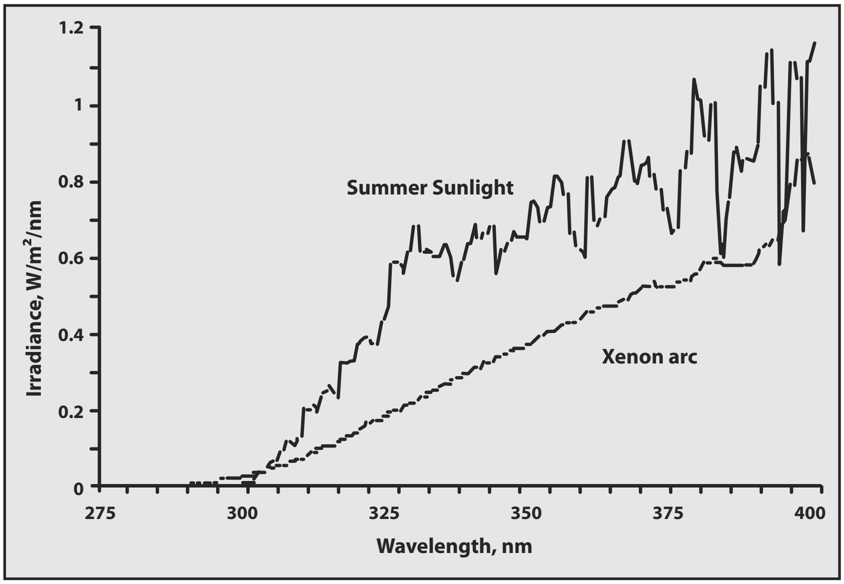
The UVB-313 is the most widely used light source for the Q-U-V. It has demonstrated good correlation to outdoor exposures for both material integrity and physical properties. However, the short wave output below the solar cut-off can occasionally cause anomalous results, especially for color retention.

Xenon arcs use a combination of filters to reduce unwanted radiation. The study used the most common combination, borosilicate inner and outer filters. Figure 2 shows the same summer sunlight compared to a xenon arc with boro/boro filters.

Moisture. Another variable was the amount of time the samples were wet. Figure 3 summarizes the differences. The outdoor data shown is the measured time of wetness during the study period *(5)*. Sealants in Florida were wet approximately 45% of the time. Q-U-V samples were exposed to about 33% wet time. Xenon arc samples were wet about 15% of the time.

Most of the wetness that a material encounters outdoors comes in the form of dew, not rainfall. Table I shows the daily time of wetness compared to the amount of rainfall for one typical month during the Florida exposures.



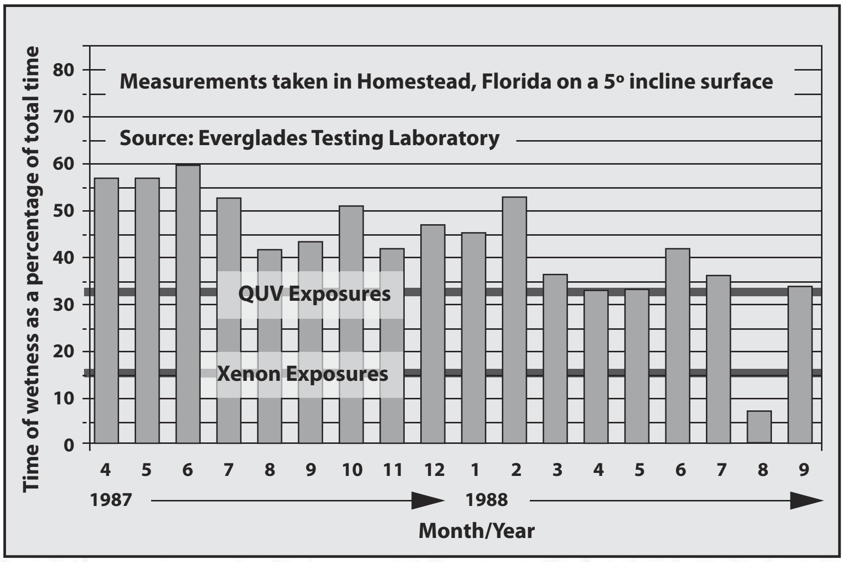


Figure 2 (top). Summer sunlight compared to a xenon arc with boro/boro filter. Figure 3 (bottom). Differences in the time the samples were wet.

Table I — Daily Time of Wetness vs. Rainfall

Date July 1987	Time of wetness (hr)	Rainfall (in.)
1	15.3	0.04
2	17.0	-
3	15.8	-
4	17.0	-
5	16.2	0.31
6	21.1	-
7	13.3	0.04
8	15.1	-
9	15.8	-
10	7.2	-
11	4.1	-
12	3.2	-
13	2.6	-
14	15.2	-
15	5.5	0.94
16	18.0	0.31
17	17.4	0.2
18	14.8	0.59
19	17.2	0.39
20	13.3	0.04
21	14.7	0.08
22	13.0	-
23	11.2	-
24	10.7	-
25	10.1	-
26	14.2	0.2
27	11.5	-
28	13.7	0.16
29	9.2	-
30	10.0	-
31	9.0	-

Source: Everglades Testing Service, July 1987 climatological dataMeasurements taken in Homestead, Fla., on a 5° inclined surface.

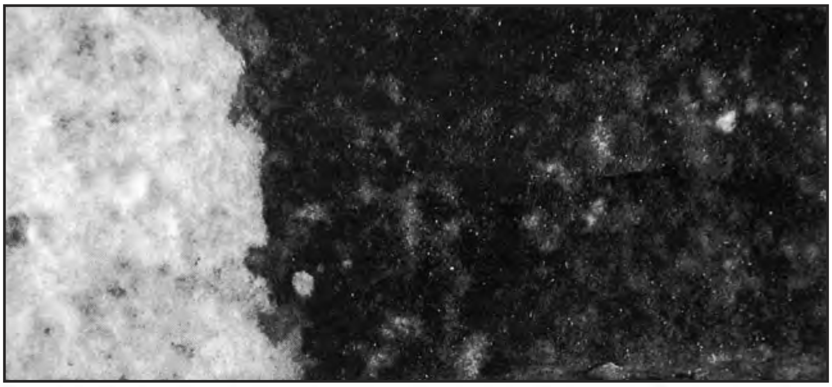


Figure 4. Micro-organism growth on polyvinyl acetate latex after 18 months in Florida at 45°S.

This has significance for accelerated simulations. The Q-U-V uses relatively long (4 hr) cycles of condensation to reproduce the effects of naturally occurring moisture. The xenon arc uses short cycles (18 min) of water spray.

Temperature. Temperature is the third variable among the exposure conditions. Accelerated testing is normally run at temperatures higher than what a material is normally exposed to, but not so high as to cause abnormal degradation. This is done because higher temperatures usually increase the rate of degradation.

The Florida samples were mounted on an open rack (i.e. not insulated); the maximum surface temperature recorded was 48°C (110°F). In most actual service applications the samples would be insulated, leading to temperatures as high as 66°C. The maximum temperature of the accelerated tests was 65°C. Consequently, the accelerated test temperatures are closer to the maximum temperatures that the sealant would be exposed to in normal service.

Thermal shock is a consideration when surface cracking is an important factor. Depending on the exposure method, the samples were subject to varying rates of temperature change. The predominant temperature change for Florida samples occurs gradually between day and night. The rate of change for the Q-U-V samples also is very gradual, because it takes about an hour for the chamber to reach equilibrium after a cycle change. Xenon arc samples were exposed to direct water spray at the beginning of the moisture cycle, creating a high rate of temperature change.

Results

The exposed sealants were evaluated for visual deterioration (cracking, pitting, etc.), changes in hardness (durometer) and flexibility.

Visual Surface Degradation. One of the most significant differences in exposure results was the growth of micro-organisms. In Florida, all but one of the sealants showed at least slight micro-organism growth. Several showed significant or even severe growth. For obvious reasons, the laboratory samples exhibited no signs of micro-organism growth. The amount of growth on the polyvinyl acetate latex and the solvent-type acrylic sealants was severe enough that its presence on the sample may actually have protected the sealant from further UV exposure (Figure 4).

In general, the Q-U-V did a somewhat better job than the xenon arc in reproducing the changes seen in the Florida exposures, particularly in regard to cracking and pitting (Figure 5). However, a number of the sealants exhibited blistering or bubbling in the lab but not in Florida. This may have been due to the difference in exposure temperatures. Except for the thermoplastic rubber sealant, the color change was almost identical for Florida and all the lab testers. Relative to Florida, the rate of acceleration was dependent on sealant type in the laboratory exposures. The UVB-313 tests showed the greatest range in acceleration rates. This was probably due to the varying sensitivities of the different sealants to the UVB-313's short wave UV emission below 295 nm (i.e. the solar cut-off). The UVA-340 and the xenon arc gave more consistent results on rate of acceleration. Descriptions of the visual changes for each sealant type and each exposure condition are given in Table II.

Hardness. To determine how well the accelerated methods predict changes in hardness, Shore A durometer measurements were taken in accordance with ASTM D-2240 *(6)* on each sealant, at each exposure interval. The data shown in Table III is an average of three readings with a repeatability of ±2 points. Due to blistering, accurate measurements were not possible for some samples. In most cases the change that took place in Florida was duplicated by the accelerated methods. ASTM D-2240

Table II — Visual Surface Degradation

Sealant Type	Florida	UVA-340	UVB-313	Xenon arc
One-component urethane	Fine, dense, one-direction cracking	Fine, dense, one-direction cracking, mild blistering	Fine, dense, one-direction cracking, mild blistering	Course, severe two-direction cracking
Two-component urethane	Fine, dense, one-direction cracks, mild mildew	Fine, dense, one-direction cracks, blisters	Fine, dense, one-direction cracks, blisters	Course, severe two-direction cracks, blisters
Polyvinyl acetate latex	Severe mildew, no other change	Severe bubbling, slight pitting	Moderate bubbling, slight pitting	Moderate bubbling, slight pitting
Thermoplastic rubber	Fine cracks become coarse with time, severe dirt/mildew, no yellowing	Fine cracks become coarse with time, slight yellowing, slight bubbling	Fine cracks become coarse with time, yellowing	Fine cracks become coarse with time, no yellowing
Silicone (black)	No change	No change	No change	No change
Silicone (white)	Moderate mildew, no other change	No change	No change	No change
Acrylic, solvent type	Severe mildew, no other change	Moderate blistering	Moderate bubbling	Small bubbles and pitting
Acrylic, latex	Severe pitting, dirt/mildew	Severe pitting	Pitting and fine cracks	Fine serpentine cracks

Table III — Durometer Data

Sealent type	Control	Florida, 45°S			UVA-340			UVB-313			Xenon arc	
		6 mo	12 mo	18 mo	500 hr	1000 hr	2000 hr	500 hr	1000 hr	2000 hr	1000 hr	2000 hr
One-component urethane	46	47	45	47	53	52	50	51	50	49	52	50
Two-component urethane	29	26	25	24	27	23		24	23		26	26
Polyvinyl acetate latex	66	94	92	95	84	83	86	85	86	85	90	92
Thermoplastic rubber	33	34	35	35	34	33	31	32	32	31	35	39
Silicone (black)	41	41	41	40	41	38	39	39	37	38	39	41
Silicone (white)	46	49	48	49	46	47	46	47	48	47	47	47
Acrylic, solvent type	56	54	63	68	56	59		55	56	58	61	61
Acrylic, latex	71	79	80	78	75	81	81	80	82	82	80	82

Table IV - Flexibility at Room Temperature (25°C)

Sealent Type	18 month Florida	2000 hr UVA-340	2000 hr UVB-313
One-component urethane	Very slight stretch marks	Very slight stretch marks	Very slight stretch marks
Two-component urethane	Very slight stretch marks	No cracks, no stretch marks	No cracks, no stretch marks
Polyvinyl acetate latex	Surface cracking	Surface cracking	Surface cracking
Thermoplastic rubber	Stretching	Stretching	Stretching
Silicone (black)	No cracks, no stretch marks	No cracks, no stretch marks	No cracks, no stretch marks
Silicone (white)	No cracks, no stretch marks	No cracks, no stretch marks	No cracks, no stretch marks
Acrylic, solvent type	Stretch marks	Stretch marks	Stretch marks
Acrylic, latex	Stretching	Stretching	Stretching

was a useful method of assessing the effects of weathering.

Flexibility. Flexibility of the exposed specimens was compared to the unexposed control in accordance with ASTM C-793. This method calls for the sample to be frozen to −26°C and bent around a ½-in. mandrel. With only one exception, comparisons of exposed samples vs. the unexposed control showed no differences. If the exposed sample exhibited loss of adhesion and/or cohesion, so did the control sample. This indicates that temperature, not exposure to weathering, is the overriding factor in this test. We do not recommend that the cold temperature test be used to evaluate the effects of weathering.

The test was repeated at room temperature using a ¼-in. mandrel. All of the unexposed control samples passed the test. However, many of the exposed sealants exhibited stretch marks, indicating some loss of cohesion (Figure 6). In addition, the existing cracks in the thermoplastic rubber and acrylic latex sealants were elongated. The polyvinyl acetate latex showed partial cracking. With only one exception (the two-component urethane), both the UVA-340 and UVB-313 (Q-U-V) results were in exact agreement with the Florida results (Table IV).

Correlation Summary

The correlation between laboratory and natural weathering probably will always be controversial. Results from accelerated tests should be used with care. In fact, the relationship between

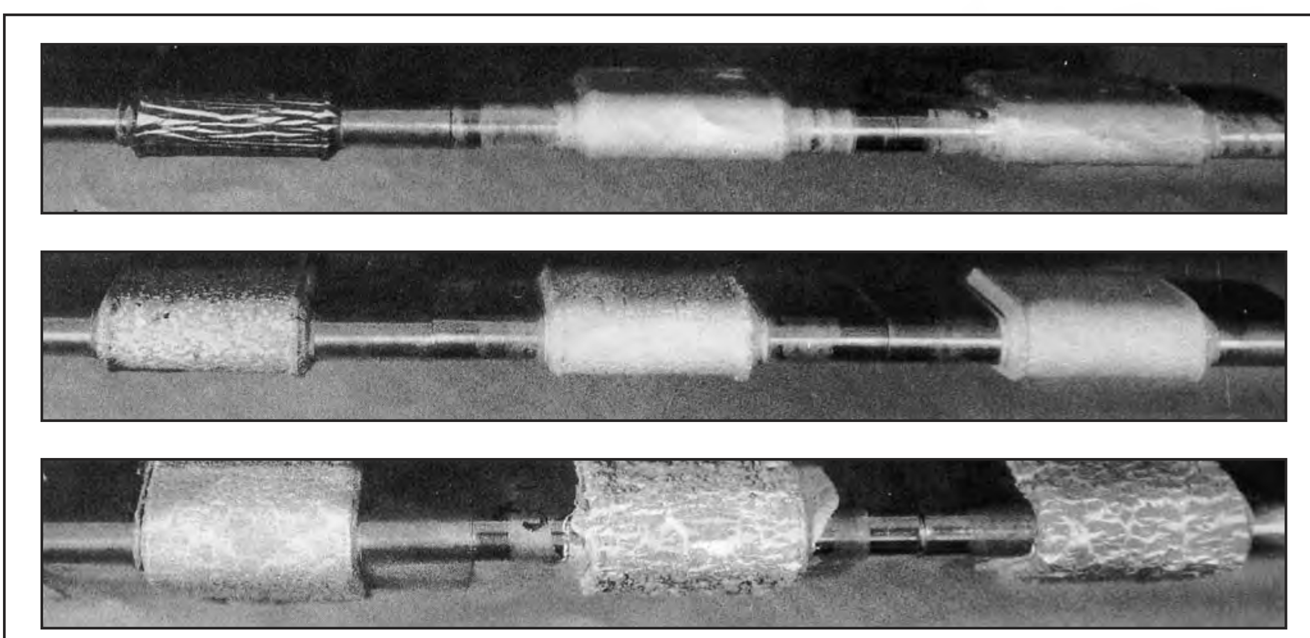


Figure 6. Flexibility tests conducted by bending the specimens over a ¼-in. mandrel at 25°C. Photos show (left to right) 18 months in Florida, 2,000 hours of UVA-340 exposure and 2,000 hours of UVB-313 exposure. The top photo shows partial cracking on the polyvinyl acetate latex. The center photo shows stretching and some loss of cohesion on acrylic latex, and the bottom photo shows stretching and some loss of cohesion on thermoplastic rubber.

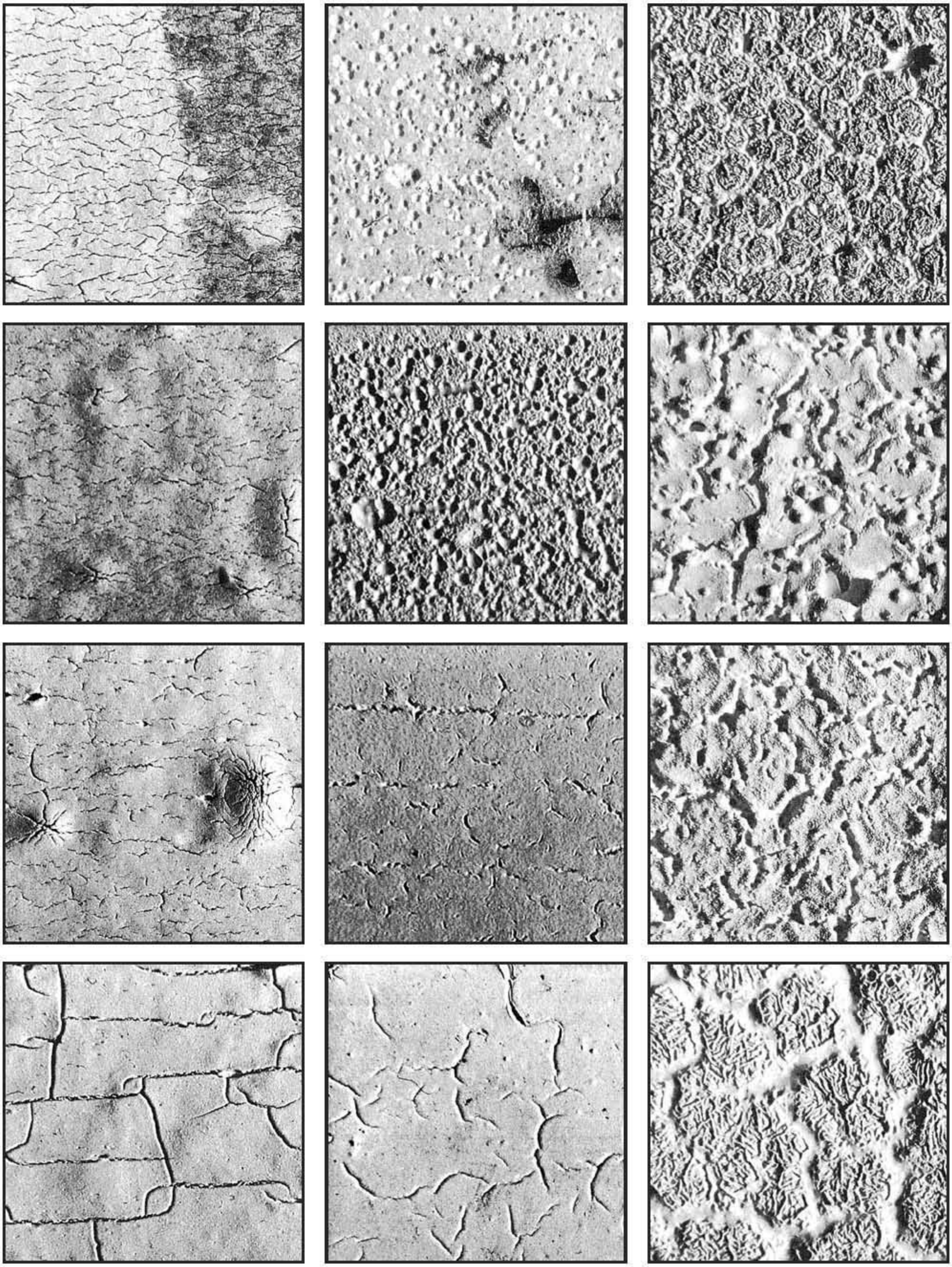


Figure 5. Left column shows visual surface degradation of the one-component urethane after (top to bottom) 18 months at 45°S; UVA-340, 2,000 hours Q-U-V; UVB-313, 2,000 hours Q-U-V; and 2,000 hours xenon arc exposure with a boro/boro filter. Center column shows visual surface degradation of the acrylic latex after (top to bottom) 18 months at 45°S; UVA-340, 2,000 hours Q-U-V; UVB-313, 2,000 hours Q-U-V; and 2,000 hours xenon arc exposure with a boro/boro filter. The right column shows visual surface degradation of the thermoplastic rubber after (top to bottom) 18 months at 45°S; UVA-340, 2,000 hours Q-U-V; UVB-313, 2,000 hours Q-U-V; and 2,000 hours xenon arc exposure with a boro/boro filter.

different types of natural exposures also is problematic. No one really knows how a Florida test fence exposure at 5° south correlates with a year on a building in Arizona or New Jersey. So even Florida gives only relative indications of actual service performance. It is asking too much of a laboratory device to do more.

With a weathering tester, there are a number of parameters that must be programmed: UV spectrum, moisture, humidity, temperature and test cycle. Because no one test cycle or device can reproduce all the variables found outdoors in different climates, altitudes and latitudes, the accelerated conditions that one chooses are, to a certain extent, arbitrary. In order to achieve rapid test results, an accelerated tester must often exaggerate the naturally degrading forces found in nature. Material formulations that differ significantly may react in various ways to these artificially severe stresses. Consequently, generically different sealant types may exhibit different acceleration factors. In fact, even within one individual sealant sample there may be different acceleration rates for different properties examined.

Table V is a summary of the correlation between the natural vs. accelerated weathering on the sealants in this study. It does not include the effects of micro-organisms. The "acceleration rate" shown is an average of the various properties tested. Where no acceleration rate is shown, there was either not enough change in the properties tested, or the change was not similar enough to warrant a conclusion. This summary is intended to be valid only for this one specific set of sealants exposed during a specific time in Florida. Extrapolations based on this data should be made with great care.

Table V — Correlation Summary

Sealant Type	Evaluation Method	Q-U-V UVA-340	Q-U-V UVB-313	Xenon arc
One-component urethane	Visible:	Good	Good	Fair
	Durometer:	Fair	Fair	Fair
	Flexibility:	Excellent	Excellent	No data
	Acceleration rate:	2600 hr ≅ 1 yr	2600 hr ≅ 1 yr	—
Two-component urethane	Visible:	Good	Good	Fair
	Durometer:	Good	Good	Good
	Flexibility:	Fair	Fair	No data
	Acceleration rate:	1200 hr ≅ 1 yr	500 hr ≅ 1 yr	1300 hr ≅ 1 yr
Polyvinyl acetate latex	Visible:	Fair	Fair	Fair
	Durometer:	Good	Good	Good
	Flexibility:	Excellent	Excellent	No data
	Acceleration rate:	1000 hr ≅ 1 yr	1000 hr ≅ 1 yr	1000 hr ≅ 1 yr
Thermo-plastic rubber	Visible:	Good	Fair	Excellent
	Durometer:	Fair	Fair	Fair
	Flexibility:	Excellent	Excellent	No data
	Acceleration rate:	1300 hr ≅ 1 yr	1300 hr ≅ 12 mo	2000 hr ≅ 1 yr
Silicone (black)	Visible:	Good	Good	Good
	Durometer:	Good	Good	Good
	Flexibility:	Excellent	Excelent	No data
	Acceleration rate:	—	—	—
Silicone (white)	Visible:	Good	Good	Good
	Durometer:	Good	Good	Good
	Flexibility:	Excellent	Excelent	No data
	Acceleration rate:	—	—	—
Acrylic, solvent type	Visible:	Poor	Poor	Poor
	Durometer:	Fair	Fair	Fair
	Flexibility:	Excellent	Excellent	No data
	Acceleration rate:	1000 hr ≅ 1 yr	2000 hr ≅ 1 yr	1000 hr ≅ 1 yr
Acrylic, latex	Visible:	Excellent	Fair	Fair
	Durometer:	Good	Good	Good
	Flexibility:	Excellent	Excellent	No data
	Acceleration rate:	1200 hr ≅ 1 yr	1000 hr ≅ 1 yr	1000 hr ≅ 1 yr

* — = evidence inconclusive

Conclusion

The following conclusions were made based on the work described above.

Accelerated Tests Compared to Florida. Although accelerated testing is widely used to predict product durability, there are limitations to its use. For the sealants in this study, the most obvious was the inability of the laboratory tests to reproduce the micro-organism growth seen in Florida. Also, the lab devices are unable to reproduce degradation caused by pollution or wind-borne contaminates. In spite of this, these test results indicate that accelerated weathering testing is a useful tool. On the whole, there was good correlation between the accelerated tests and Florida on surface changes (i.e. cracking, pitting, etc.), flexibility and hardness (durometer). However, different generic sealant types exhibited different acceleration factors.

Q-U-V Compared to Xenon Arc. The sealants gave somewhat mixed results. Of the eight types tested, the Q-U-V gave the best correlation to Florida on two and the xenon arc gave the best results on one. They gave essentially equivalent results on the remainder. The Q-U-V, especially with UVB-313 lamps, caused the sealants to deteriorate faster than the xenon arc. In conclusion, the Q-U-V gave slightly superior results on the test array.

UVB-313 Compared to UVA-340. On two of the sealants tested, the UVA-340 lamps gave better correlation to Florida than the UVB-313. For the remainder, the results were similar. The UVA-340 was slower than the UVB-313, but the acceleration rate (relative to sealant type) was more consistent. In conclusion, the UVA-340 lamp is most useful for correlation to Florida or for comparisons to generically different sealants. The UVB-313 gives faster results and may be most useful for durable formulations or QC applications.

Duration of Accelerated Exposures for Test Methods and Specifications. The results of this study indicate that, for most sealants, the exposure requirements in the existing specifications and test methods are inadequate. A realistic minimum exposure time would be 2,000-3,000 hr of accelerated tesing. For silicones, 5,000 hr is probably a minimum figure.

Acknowledgment

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References

(1) ASTM C-793, Standard Test Method for Effects of Accelerated Weathering on Elastomeric Joint Sealants.

(2) ASTM G-7, Standard Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials.

(3) ASTM G-53, Standard Practice for Operating Light and Water Exposure Apparatus (Fluorescent UV - Condensation Type) for Exposure of Nonmetallic Materials.

(4) ASTM G-26, Standard Practice for Operating Light Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials.

(5) DSET Laboratories Inc. 32:8-34:1.

(6) ASTM D-2240, Standard Test Method for Rubber Property-Durometer Hardness.

This article is adapted from a presentation made to ASTM Committee C-24 on Building Seals and Sealants, June 28, 1989.