Applying Science to Weathering and Durability

Understanding Marine Environments to Maximize Sealant Performance

What if you could know the lifespan of your car before you purchased it? Or your boat? At 3M, we can anticipate the durability of marine sealant products, which gives us a preview of how long the material will perform long-term.

We don't look into a crystal ball to get this preview – instead we use science to predict the performance of the sealants and pinpoint areas for improvement. Using state-of-the-art Weathering Science, 3M scientists can reliably determine the probability of product failure as a function of application, time and in-service location.

Accelerated exposure testing is used to study the relationship between stress and degradation, and to predict outdoor weathering. The results of the weathering tests allow the formulation of more durable marine sealants. After all, understanding the root causes of failure is key to achieving product success.

Fundamentals of Weathering

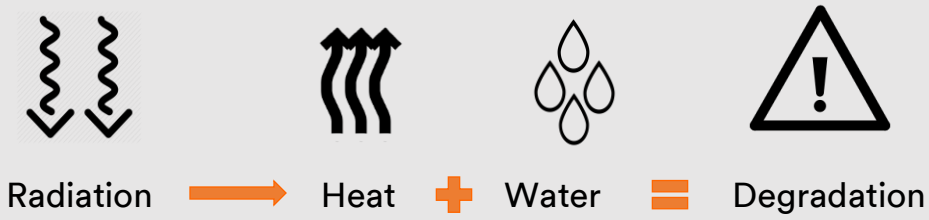
We apply all the tools at our disposal to answer the question: "How long will this product last?"

Weatherability tests are especially important for marine sealants because of the environments in which they are used. Sealants that are used on boats are typically exposed to elements like water, UV rays, wind, heat, humidity and more, so we must understand how the sealant will respond and if its seal will last under these conditions.

While there are several seasonal variables that add to the weathering of a product, the fundamental principles of weather include:

- Light (solar UV radiation), which initiates some type of degradation reaction
- Heat, which accelerates the reaction rate from light
- Water, as the presence of moisture adds additional stresses

WEATHERING PROCESS



(Photochemistry + materials science + reaction kinetics + climatology)

Of all the weathering principles, water poses a special challenge for scientists that develop these sealants, and it is the most difficult stress to quantify because it plays multiple roles, including:

- A solvent to extract additives
- A reactant
- A mechanical stress

When a film absorbs water it swells; when the film dries, it contracts. This expansion and contraction induces a mechanical force within the film that, as the polymer degrades, can result in cracking, crazing and fracturing. These kinds of degradations are evidence of product stress, as shown below.

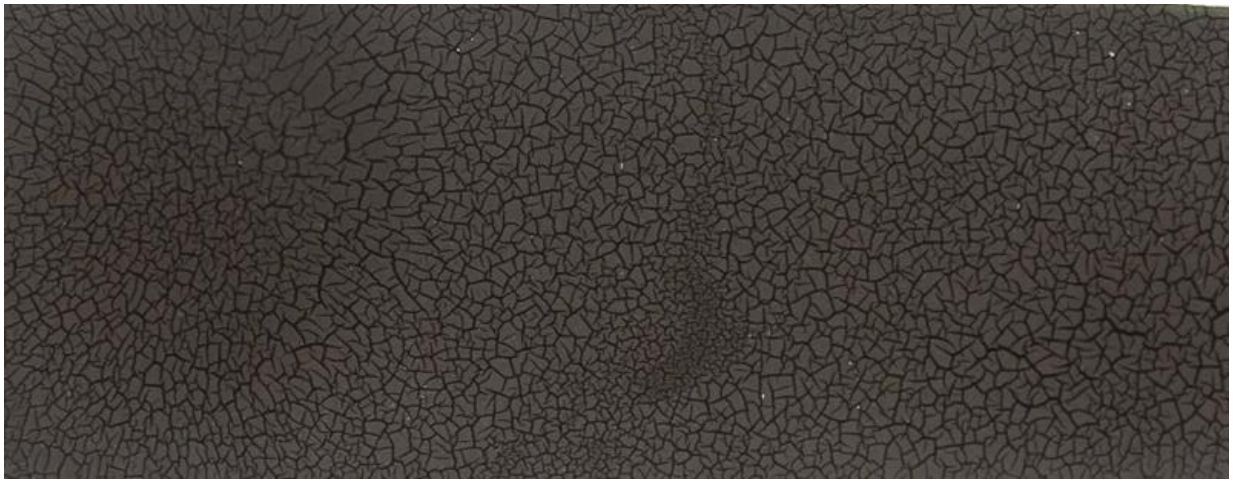


Figure 1: Cracks in the sealant can often be an indication of premature degradation.

Marine Environments

A sunny day out on the water may seem relaxing, but it can put adhesive sealants under great stress. Not only are they exposed to intense weather conditions, the products must also offer durability above and below the waterline and be able to match the aesthetic look of the vessel.

Marine environments and applications also vary greatly across materials and climates. When choosing an adhesive sealant, customers want a trustworthy product that they can rely on year after year.

Simulating Weather Conditions

3M's weatherability testing is completed at the Weathering Research Center (WRC) – the world's largest single-site accelerated weathering facility. The WRC is the hub of durability testing, and runs approximately 100 artificial weathering machines that operate 24/7.

Additional outdoor weathering programs are conducted in five major climates: tropical monsoon, desert, tropical savanna, Mediterranean and humid continental.

While other industrial weathering test methods exist, many of these rely too heavily on UV exposure alone, ignoring the combined effect of light, water and heat. At the WRC, 3M has honed the art of recreating climates by adjusting combinations of light, UV, temperature and moisture cycles.

3M's marine adhesive sealants are weathered under simulated conditions that match those of South Florida – a region that is said to be one of the harshest environments in the United States due to the lasting effects of extreme wind, humidity, heat, moisture and sunlight.

Figure 2: 3M performs long-term fresh water and salt water laboratory immersion testing on marine sealants

Results of the accelerated weathering tests have directly impacted products in the portfolio like 3M™ Marine Adhesive Sealant Fast Cure 4000 UV, which is designed for above-and below- waterline applications like port hole sealing, drain plug bonding and center console sealing. It is color-stable in both black and white formulations, and is proven to withstand intense UV exposure in both forms.

Identifying Signs of Failure
For marine sealant users, it's important to understand and identify the tell-tale signs of weathering and failure. At the WRC, 3M evaluates weathered adhesive sealants for two main things:

1. Altered appearance
2. Mechanical property retention

In some instances, degradation is just cosmetic, and does not significantly change the effectiveness of the seal. In other cases, weathering can cause surface cracks that become stress concentration points, resulting in poor tensile strength and poor elongation.

It is important to be able to visually identify the difference between a simple cosmetic issue, and what is more seriously detrimental to the seal. If this distinction is not made, users could end up wasting time and money reapplying or replacing a sealant, or worse, ignore degradation that could render the vessel unsafe.

Below are images of two black adhesive sealants that were weathered for the same amount of time under the same conditions. Figure 3 has a blotchy appearance with evidence of chalking. It clearly shows signs of aging, but the degradation that has occurred is cosmetic and does not compromise the integrity of the sealant.

Figure 4, however, shows a weathered sealant that is riddled with cracks. Even though there is no chalking or whitening, this adhesive has not retained its mechanical properties.

Figure 3: Sealant is aged, but impact is only cosmetic

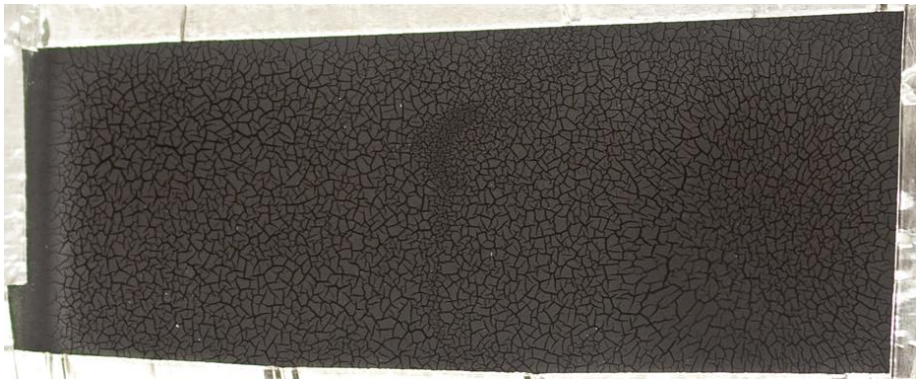


Figure 4: Seal is compromised and needs to be reapplied or replaced

Figure 5 provides the data of retention from the two black adhesives that were weathered under the same conditions. Again, the cracked adhesive shown in Figure 4 resulted in significant loss of retention and overall properties.

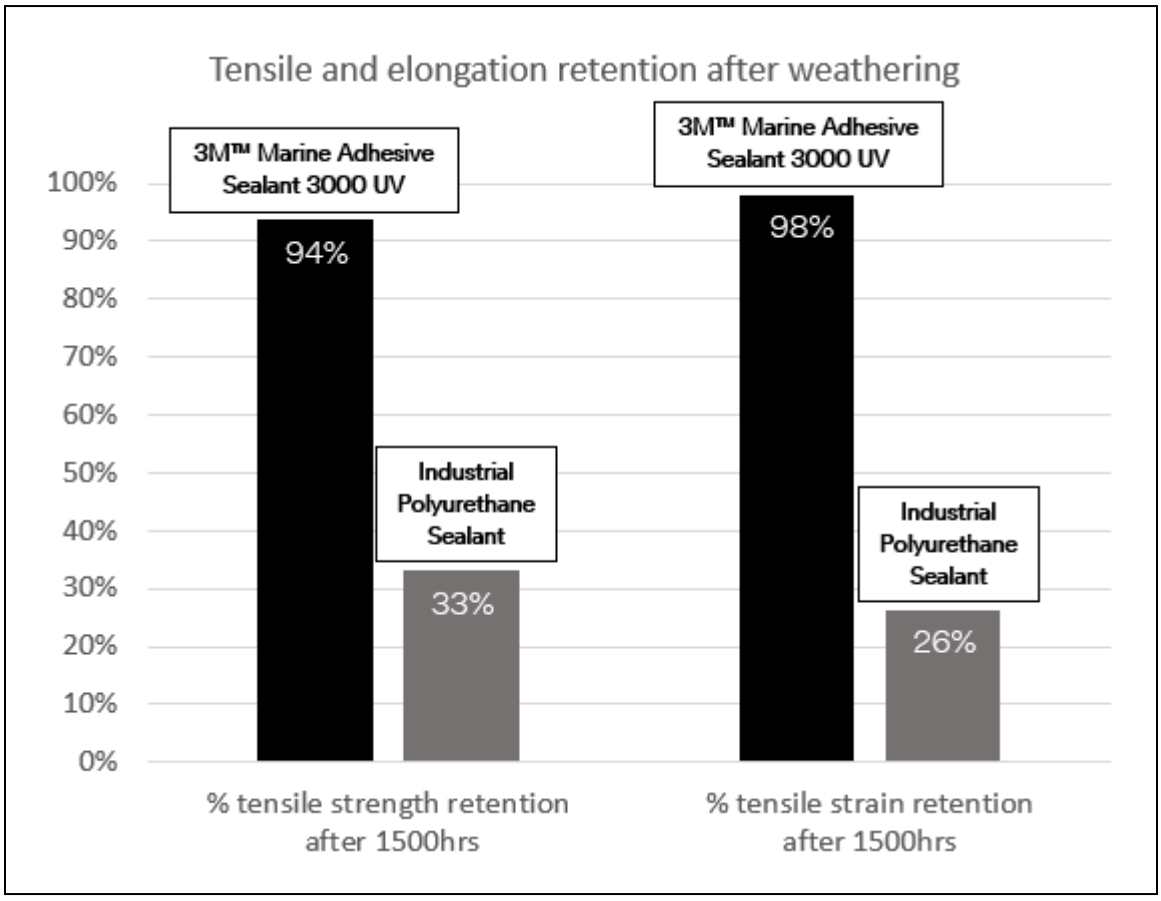


Figure 5: 3M scientists use data like this to determine what the issues are with a sealant, improve formulations and increase adhesive stability.

Sealant Selection

The chosen sealant can make or break an application, depending on what the sealant is intended to do. 3M's testing focuses on balancing three factors in every sealant formulation: catalysts, filler and resins. Resin selection, pigment grade and UV stabilizer package are all critical to developing a weatherable sealant.

The performance levels and cost of a sealant depends on the rigors of its end use. For example, less expensive resins should not be used for consistent outdoor exposure, because they can crack and chalk when frequently exposed to direct sunlight.

Marine applications demand reliability. 3M's relentless pursuit of improved material performance through laboratory and field-testing results in industry leading quality and performance.

Figure 7: 3M 5200 Marine Adhesive Sealant provides the strength required to bond through-hull fittings and reliably seal below-waterline applications over the long term.

Figure 8: Above-waterline applications face unique challenges because sunlight becomes the dominant force. 3M 4000UV Marine Adhesive Sealant is formulated to provide UV-resistant watertight sealing for on-deck compartment attachment.

Both sealants shown in figures 7 and 8 were formulated with high-quality components to withstand the harsh marine environment, but each was specifically modified to enhance performance under different conditions.

Our Commitment to the Science of Weathering & Durability

3M's expertise in weathering science came about through the desire to provide customers with highly engineered, durable products. Durability is a core 3M Brand Promise for a large number of 3M's businesses, including automotive, marine, building and construction, safety and graphics and renewable energy. All of these industries rely on products that can face the elements and withstand the test of time.

Approximately 25% of 3M's sales come from products with some type of environmental durability requirement. Our company depends upon our portfolio of products being able to deliver the durability we promise. By putting our products through an accelerated aging process, we can ensure that promise is upheld.

3M's unique weathering program has been in operation for more than 50 years, helping to advance adhesives and to understand the science behind durability. Since the 1930's, 3M has practiced accelerated aging tests to predict outdoor weathering effects and enhance products. We can't predict the future for many things, but this research gives us a glimpse, and thus we can confidently ensure our customers that our marine sealants can weather the storm – and many to come!

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