

Evaluation of 3M™ Solar Acrylic Foam Tapes for Durability

Report Objectives

3M™ Solar Acrylic Foam Tapes have been characterized for durability in many studies in the past. Some of these studies have been general screening of a variety of tapes in a variety of exposure or stress conditions, and others have been in support of specific application or customer needs.

This report describes two specific test programs that have been completed which demonstrate the durability of the 3M™ Solar Acrylic Foam Tape products. These include:

- **Study 1:** Accelerated Aging Study of 3M™ Solar Acrylic Foam Tape 3230 up to 10,000 hours in an accelerated weathering cycle.
- **Study 2:** Natural Aging of 3M™ Solar Acrylic Foam Tape 3110 type of (5 years on weathering decks in Florida, Arizona and Minnesota)

In addition to the detailed results described in these studies, it is known in the industry that acrylic polymers have excellent durability. 3M has been a technological leader in acrylic pressure sensitive adhesive (PSA) technology for over 40 years. The Solar Acrylic Foam Tapes and adhesive transfer tapes represent examples of 3M's proprietary state-of-the-art products using this durable chemistry. The superior durability lies in the polymers that are used to make the products. The chemical bonds that make these polymer chains consist of carbon-carbon single bonds that are highly resistant to energy in the form of heat or ultraviolet light, as well as chemical attack. In less durable foams or adhesives, such conditions could lead to cleaving the polymer backbone and thus weakening the mechanical properties. In the case of the type of acrylic adhesives and foams developed by 3M, additional cross-linking is chemically favored over chain scission (cleavage). This means that rather than undergoing a process of decomposition, the acrylic materials will tend to build modulus very slightly over extended exposures. This translates to a stronger long lasting bond.

Overall Conclusions

Tapes representing the 3M™ Solar Acrylic Foam Tape 3000 product family (such as 3110 (45 mils thick) and 3230 (90 mils thick)) show excellent durability performance in accelerated and natural aging conditions that included temperature, UV and humidity exposure.

Important Note

While this data demonstrates the excellent durability capability of 3M's family of acrylic foam tapes, durability in any specific application is dependant on achieving a good level of adhesion to the substrates being bonded and in having a design where the static and dynamic stresses acting on the tape are within the product strength capability.

Study 1: Accelerated Aging Study of 3M™ Solar Acrylic Foam Tape 3230:

Test Method:

Accelerated aging was conducted at the 3M Weathering Resource Center in St Paul, MN, with exposure duration up to 10,000 hours. The exposure used a "3M Proprietary" test condition that has been found to be a good predictor of service durability and generally better than "industry" tests. Exposure was under high intensity UV radiation (Xenon Arc, full exposure). Black panel temperature is controlled at 70°C, with water sprayed on the sample for 18 minutes out of every 120 minute cycle. UV radiation was exposed on the sample the entire 120 minute cycle.

The tape was bonded between glass and metal (black anodized aluminum), with UV exposure direct through clear float glass (1/4" thick). Test configuration was 1" x 1" tensile (ASTM D897), 1" x 1" shear (ASDM D1002) and 1" width peel (ASTM D3330) mode. Samples were run in duplicate.

Results:

Dynamic Tensile Strength

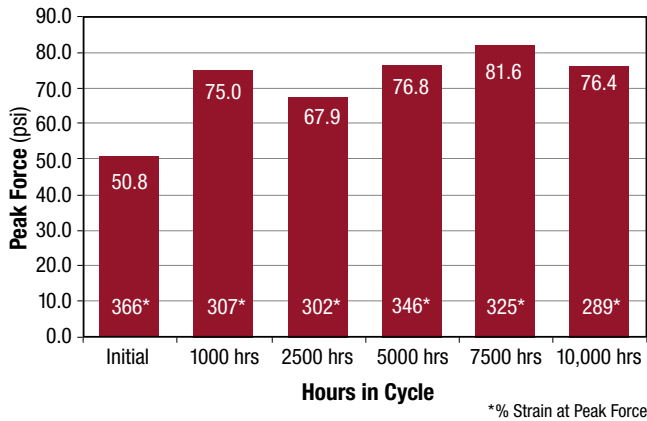
The increase in the initial vs. aged samples is associated with a failure mode change, changing from clean adhesion failure (most off glass) to foam split failure. The dynamic tensile peak strength is essentially unchanged upon exposure after the initial increase. Strength after 10,000 hours exposure is 76.4 lb/in².

Percent strain is also relatively unchanged, shifting from about 366% strain at peak force with unaged sample to 289% strain on 10,000 hour exposed sample.



UV Accelerated Aging–3230–Tensile Strength

Aging Conditions: High Intensity UV Light (Xenon Arc), Cycling Heat and Humidity
 Test Conditions: 0.5"/min@70°F/50% RH



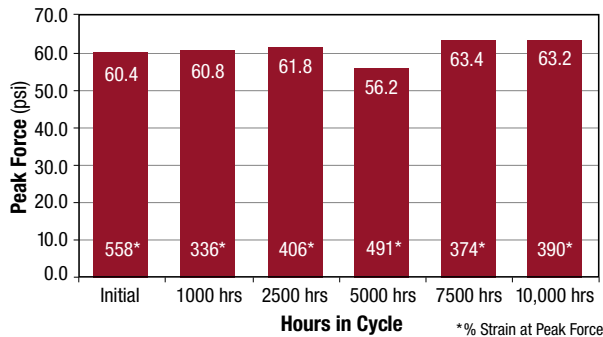
Dynamic Shear Strength

The dynamic shear strength is essentially unchanged. The 10,000 hours exposure is similar to the initial 3 day room temperature aged sample. Strength at 10,000 hours exposure is 63.2 lb/in².

Percent strain shifted with aging indicating a slight stiffening of the product over time, starting at about 558% strain at peak for the unaged control sample and dropped to 390% strain after 10,000 hours aging. Even at 390% strain the product would still be considered very flexible. For comparison silicone adhesive/sealant, cast in 3/8" thickness, reaches peak force at 108% strain after the same 10,000 hours aging.

UV Accelerated Aging–3230–Sheer Strength

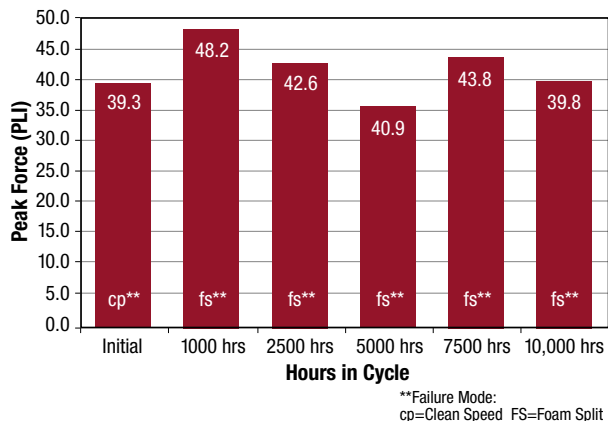
High Intensity UV Light (Xenon Arc), Cycling Heat and Humidity
 0.5"/min@70°F/50% RH Conditions



90° Peel Adhesion Strength

UV Accelerated Aging–3230–Peel Strength

High Intensity UV Light (Xenon Arc), Cycling Heat and Humidity
 12"/min@70°F/50% RH Conditions

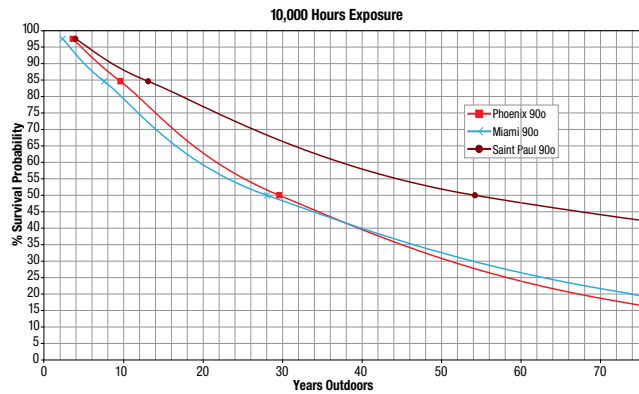


Peel adhesion strength is essentially unchanged after the exposure.

Test values after 10,000 hours exposure is about the same as it was for the initial 3 days room temperature aged sample. Failure mode did shift from clean peel from the glass initially to foam split failure.

Service Life Prediction (SLP)

The SLP graph below is based on testing a variety of other types of materials and other types of performance criteria than what was tested for 3M™ Solar Acrylic Foam Tape 3230. To use the SLP chart for 3M Solar Acrylic Foam Tape, it is assumed that the tape belongs to the same statistical weathering population as the other materials used to create this graph.



Disclaimer

The above plot is from a simulation test designed to demonstrate the risk that is assumed when trying to predict outdoor life for a material from a single exposure test result. The probability lines shown are based on many variables including material changes caused by light, heat, and water effects normally found outdoors and simulated in the accelerated test. Possible failures due to other stresses found outdoors but not simulated in the accelerated test such as biological agents like mold or mildew, pollution and other airborne contaminants, freeze-thaw cycles, or any other undefined stress factor are not accounted for in the accelerated test. Results under actual weather conditions may differ. The method for data compilation to construct a chart similar to the one depicted above can be found in the following reference: [Error Analyses and Associated Risk for Accelerated Weathering Results, Richard Fischer and Warren Ketola, Service Life Prediction: Changing the Status Quo, Jonathan Martin, Rose Ryntz, and Ray Dickie, Editors, Federation of Societies for Coating Technology, 2005 pp 79-91]

What does 10,000 hours exposure mean?

The graph above shows the survival probability as a function of years of outdoor exposure for a sample that failed after 10,000 hours exposure in the "3M Proprietary cycle". This represents a south facing exposure where the sample is mounted vertically. If failure was observed at 10,000 hours, the graph estimates that there would be a 50% chance of survival (or conversely a 50% chance of failure) in Miami at 28 years, in Phoenix at 30 years, and in St Paul at 54 years. The graph also depicts other probability levels based on the 10,000 hour exposure. For example, there is an 80% chance that material survival could be almost 18 years in a St. Paul exposure.

According to the 3M service life predictability model, there is a 50% chance that this 10,000 hour exposure in the “3M proprietary” cycle is at least as harsh as 28 years in Miami, 30 years in Phoenix and 54 years in Minnesota, and 50% chance that the exposure is less harsh. But a service life for the tape bond cannot be predicted from the testing because it continues to perform almost unchanged after the 10,000 hour exposure. We would need to see a failure caused by exposure in the testing to predict a specific service life from these models.

Conclusions of Accelerated Aging Test

3M™ Solar Acrylic Foam Tape 3230 performance in tensile, shear and peel is relatively unchanged after 10,000 hours of extreme exposure to high intensity UV radiation (xenon arc) with cycling heat and humidity.

An actual outdoor service life probability estimate only becomes fixed when failure occurs in the accelerated test at 10,000 hrs. If we assume the data for 3M Solar Acrylic Foam Tape 3230 material does not constitute failure we can say the following: Because failure has not been detected in the 10,000 hour exposure with this tape, longer exposures that lead to failure in the 3M proprietary test would shift these service life prediction curves to the right in the graph. The shear testing showed slight stiffening of the tape bond over the aging period, with strain at peak force dropping about 30% to 390% strain after 10,000 hours aging. This is still significantly more flexible than silicone adhesive/sealant, which showed about 108% strain at peak force.

Study 2: 3M™ Solar Acrylic Foam Tape 3110P Natural Aging in FL, AZ and MN

Test Method

Natural aging was conducted at weather deck facilities in Miami, FL (sub-tropical summer rain), Phoenix, AZ (hot, arid), and Cottage Grove, MN (temperate climate with temperature extremes). Samples are mounted at an angle to increase the degree of exposure to rain, sun and night cooling.

3M™ Solar Acrylic Foam Tape 3110P was used to bond 1" square chips of aluminum, PVC plastic and glass to an anodized aluminum back panel. Chips were pulled at a rate of 2 inches/minute in a tensile/pluck mode. Peak force to remove was measured. Exposure time at each location was 6 months, 12 months, 24 months and 5 years. Strength values were compared against unaged control samples that were made at the same time, with the first set tested after 3 days and a second set tested along side the 6 month exposed samples. The graph shows the average of these control sets. Three test samples of each condition were run and averaged.

The dynamic tensile peak strength measured in this survey is generally in the expected/typical range across the conditions and duration tested, with values ranging from about 80 lb/in² to about 120 lb/in². The typical value for this tape is about 85 lb/in².

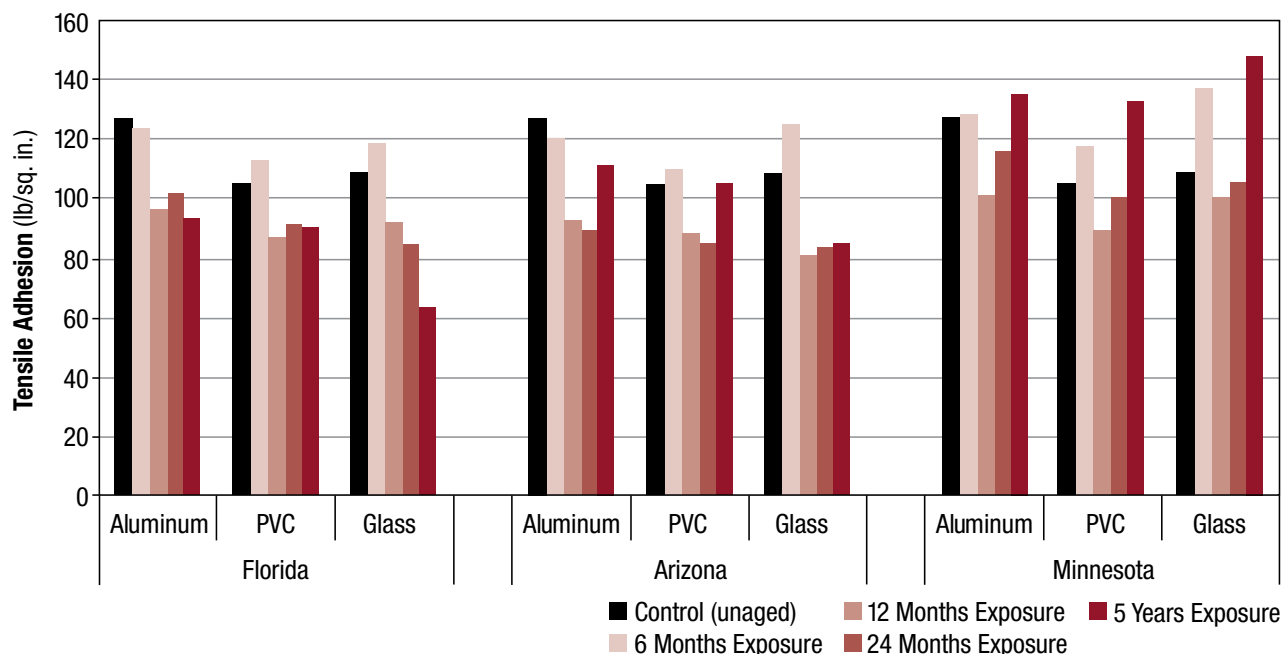
A slight trend is seen with higher test values across all conditions for the unaged control and the 6 month aged samples. It is not known if this represents an actual change in material behavior or if this is a bias caused by samples being tested at different time periods across 5 years. Performance is slightly lower on glass samples in Florida exposure for 5 years that is not predicted by the previous tests at that exposure (2 year values are normal), nor by the values on aluminum or PVC. A reason for the difference is not confirmed, the samples were inspected and there is no evidence of adhesive or polymer degradation. Failure on these samples was foam split.

Conclusions of Natural Aging Test

Tensile strength of 3110P remains excellent after 5 years in a variety of harsh exposure conditions including Florida, Arizona and Minnesota, even where there is a high degree of edge exposure and direct UV exposure.

Results

3M™ Solar Acrylic Foam Tape 3110P Tensile Adhesion vs. Exterior Weathering



United States

3M Renewable Energy Division
800 755 2654

Germany

49 2131 144450

Denmark

45 43 480100

Spain

34 91 3216000

France

33 1 30316161

United Kingdom

44 1344 858000

Italy

39 02 70351

Singapore

65 6450 8888

China

86 21 62753535

Korea

82 2 3771 4043

India

91 80 22231414

Canada

800 364 3577

Brazil

0800 13 23 33

Mexico

52 55 52702250

Taiwan

886 933 896752

Japan

81 3 3709 8283

Malaysia

603 78062888

Other Areas

800 755 2654

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