



ASPHALT TECHNOLOGIES, INC.



TEST & EVALUATION REPORT Shingle Rejuvenator Benchmark Life-Cycle Study

April 17, 2023

Report For: Greener Shingles Rejuvenator
Saskatchewan, Canada

Email: info@greenershinglesrejuvenator.com

Sample Data/Information:

SAMPLE ID	GRADE/TYPE	DATE SAMPLED	DATE RECEIVED	SOURCE
Aged Asphalt Shingles	Architectural – Post Consumer	*Note 1	9/15/22	Roofing Contractor
Shingle Rejuvenator	Greener Shingles	9/2022		
Shingle Rejuvenator	Competition	9/2022		

*Shingles removed from a home in Crystal River, FL approximately 14 years after installation

OBJECTIVES:

Conduct a Benchmark Life-Cycle Study of two rejuvenators utilizing aged asphalt shingles that were removed from a home after approximately 14 years of exposure in Crystal River, Florida. Determine the estimated contribution to the shingles life-cycle made by both rejuvenators and quantify the differences.

The study used a miniature steep sloped roof, constructed at PRI made with commonly used stock material (2X4's, plywood, peel-n-stick underlayment, and stainless-steel roofing nails). Both slopes were roofed with the aged shingles, with one side being treated with Greener Shingles rejuvenator and the other side being treated with a competitive rejuvenator. Both were applied according their manufacturer's recommendations. See appendix for photos and details of construction

The miniature roof was weathered according to ASTM D4798 – "Standard Practice for Accelerated Weathering Test Conditions and Procedures for Bituminous Materials" using a modified exposure cycle consisting of, 51 minutes of light only and 9 minutes of light with rain. Studies have shown that 3000 Hours of APWS aging can be correlated to 10 years of normal outdoor exposure.



CONCLUSIONS: Primary Property Assessment

- **Mass Loss:** Mass loss in asphalt shingles is due to both the oxidative aging of the binder and granular loss during the accelerated weathering process.
 - After 1,500 hours of exposure the mass loss of the competitive rejuvenator was 2.8% compared to 0.5% for the Greener Shingles' rejuvenator.
 - **Greener Shingles Rejuvenator performs 5.6 times better than the competition.**
 - After 3,000 hours of exposure the competitive rejuvenator was 3.8% compared to 1.0% for the Greener Shingles' rejuvenator.
 - **Greener Shingles Rejuvenator performs 3.8 times better than the competition.**
- **Wash off Material:** The exposure cycles consistently contained particulate material and shingle granules that were washed off by the accelerated weathering process.
 - After 1,500 hours of exposure the mass of the collected particulate from the competitive rejuvenator was 1.78g compared to 0.70g for the Greener Shingles' rejuvenator.
 - **Greener Shingles Rejuvenator performs 2.5 times better than the competition.**
 - After 3,000 hours of exposure the mass of the collected particulate from the competitive rejuvenator was 9.86g compared to 3.94g for the Greener Shingles' rejuvenator.
 - **Greener Shingles Rejuvenator performs 2.5 times better than the competition.**
- **Granular Loss (Dry):** The granular loss test measures the amount of granules lost when a shingle surface is exposed to friction (the "rub" test).
 - After 1,500 hours of exposure, the granular loss of the shingles increased by 88% with the competitive rejuvenator, compared to a 23% increase with the Greener Shingles rejuvenator.
 - **Greener Shingles Rejuvenator performs 3.8 times better than the competition.**
 - After 3,000 hours of exposure, the granular loss of the shingles increased by 147% with the competitive rejuvenator, compared to a 50% increase with the Greener Shingles rejuvenator.
 - **Greener Shingles Rejuvenator performs 2.9 times better than the competition.**
- **Oxidative Aging (Measured by Carbonyl Indices):** Oxidative aging in asphalt-based products can be quantified by a peak in a specific position on an FT-IR spectrum (See Appendix B-1 through B-7).
 - After 1,500 hours of exposure the competitive rejuvenator exhibited a 22.8% increase in carbonyl index, compared to Greener Shingle's 7.8% increase.
 - **Greener Shingles Rejuvenator performs 2.9 times better than the competition.**
 - After 3,000 hours of exposure the competitive rejuvenator exhibited a 49.5% increase in carbonyl index, compared to Greener Shingle's 9.6% increase.
 - **Greener Shingles Rejuvenator performs 5.2 times better than the competition.**
- **Shingle Flexibility:** After 1,500 and 3,000 hours of exposure, both rejuvenators improved low temperature flexibility from -22°F (pre-treatment) to -31°F post rejuvenator applications
- **Shingle Color and Appearance:** After 3,000 hours of exposure, both rejuvenators resulted in shingles that have similar appearances and colors.



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DATA / RESULTS:

PROPERTIES	TEST METHODS	RESULTS, EXPOSURE HOURS			
		Untreated, 0 Hours	Treated, 0 Hours	Treated, 1,500	Treated, 3,000
Properties of Shingles Treated with Competitive Rejuvenator					
Visual Inspection of shingles (Photos)	PRI	See Appendix			
Weight of 5"x10" Sample, g	D751	147.8	137.7	133.8	132.41
Mass Change, % (Note 2)		---	---	-2.8	-3.8
Low Temperature Flexibility, °F (Note 3)	D5147-12	-22	-31	-31	-31
Granular Adhesion (Loss), %	Wet	3.5	2.8	2.8	2.3
	Dry	3.4	1.7	3.2	4.2
Carbonyl Index	E7214	0.95	1.01	1.24	1.51
Increase in Carbonyl Index from 0 Hours, %	Calculation	N/A	N/A	22.77	49.50
Material Lost during Exposure Cycles, g (Note 4)	PRI	N/A	N/A	1.78	9.86
Properties of Shingles Treated with Greener Shingles Rejuvenator					
Visual Inspection of shingles (Photos)	PRI	See Appendix			
Weight of 5"x10" Sample, g	D751	147.8	146.4	145.7	145.0
Mass Change, % (Note 2)		---	---	-0.5	-1.0
Low Temperature Flexibility, °F (Note 3)	D5147-12	-22	-31	-31	-31
Granular Adhesion (Loss), %	Wet	3.5	3.2	5.4	0.9
	Dry	3.4	2.2	2.7	3.3
Carbonyl Index	E7214	0.95	1.67	1.80	1.83
Increase in Carbonyl Index from 0 Hours, %	Calculation	N/A	N/A	7.78	9.58
Material Lost during Exposure Cycles, g (Note 4)	PRI	N/A	N/A	0.70	3.94

Note 2 – Mass Change is calculated from the mass loss of a representative 5"x10" representative sample of shingle taken at each inspection interval, mass loss is expected with aging, lower mass loss is desirable.

Note 3 – Low temperature flexibility is the lowest temperature at which the shingle remains flexible – lower temperatures are more desirable.

Note 4 – Loss during exposure was measured by collecting granules and particulate matter from the collection system attached to the APWS weatherometer (See Appendix X-1 for collection apparatus & sample photos).

Note 5 – Untreated samples were not exposed to additional aging in the APWS.

DISCUSSION:

Although both rejuvenators exhibited efficacy via improving granule adhesion and shingle flexibility, Greener Shingles rejuvenator exhibited better overall comparative life-cycle properties. Based on the primary data Greener Shingle's reduced oxidative aging (Carbonyl Index), less dry granule loss and mass loss suggest the life-cycle of Greener Shingle's rejuvenation would be greater than the competitors.

- **Carbonyl Index Note:** when initially treated an increase in Carbonyl Index results this is due to the addition of bio-based oils (rejuvenators) that give an FT-IR response in the same peak area as the oxidative aging.



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RECCOMENDATIONS:

1. Assess runoff water from shingles collected at 0, 1,500, and 3000 hours to assess possible differences in environmental impact of the different rejuvenators.
2. Extract and recover the binder from shingle material from 0, 1,500, and 3,000 hours to determine the effects on the physical properties of the asphalt remaining in the shingle that are most related to roofing performance properties (Softening point, Penetration, SARA Fractions)
3. Consider the addition of another interval (4,500 hours) to assess the longevity / life cycle of the effects of the rejuvenators.

NEXT STEP:

1. Review and discuss with Greener Shingles

Tested by:



Greg Lavin, Laboratory Technician

Date: April 17, 2023

Reported by:



Steven Loeffler, Client Services Manager

Date: April 17, 2023



APPENDIX

APPENDIX A-1 (Roof Deck Construction):

Step 1 – Deck Frame Construction:

Roof Deck before application of Peel-n-Stick and Shingles



DISCUSSION:

Standard ½” plywood, 2x4s, and stainless-steel roofing nails were used to construct the framework for a miniature “roof” measuring 36” wide, by 26” in height on each side. Both sides were set at an angle of 20° of pitch.



APPENDIX

APPENDIX A-2 (Roof Deck Construction):

Step 2 – Underlayment Installation:

Roof Deck after Application of Peel-n-Stick



DISCUSSION:

A common, commercially used underlayment (peel-n-stick) was then applied to both sides of the roof deck.



APPENDIX

APPENDIX A-3 (Roof Deck Construction):

Step 3 – Shingle Installation:

Roof Deck after Shingle Installation (No Cap)



DISCUSSION:

Shingles were then evaluated and selected for consistency in wear and general condition and were nailed to the roof deck, using 3 nails per shingle. The shingles were added to the roof in order of the numbers below on their corresponding side, with the lowest ID numbers starting from the bottom and progressing to the top (4 shingles each side, each spanning the full length of the roof).



APPENDIX

APPENDIX A-4 (Roof Deck Construction):

SHINGLE SELECTION:

SHINGLE SELECTION AND IDENTIFICATION				
Shingle ID#	Length (in.)	Width (in.)	Thickness (in.)	Weight (g)
<i>Shingles Selected for Competitor's Side of Deck</i>				
1	38.75	13.25	0.110	1444
2	38.75	13.25	0.110	1401
3	38.75	13.25	0.110	1460
4	38.75	13.25	0.110	1393
<i>Shingles Selected for Greener Shingle's Side of Deck</i>				
5	38.75	13.25	0.110	1430
6	38.75	13.25	0.110	1410
7	38.75	13.25	0.110	1395
8	38.75	13.25	0.110	1475
<i>Control Shingles (Not Added to deck)</i>				
9	38.75	13.25	0.110	1415
10	38.75	13.25	0.110	1425
11	38.75	13.25	0.110	1402

DISCUSSION:

The stock of shingles received were separated and assessed for overall quality and level of damage such as tears, holes, and imperfections likely cause by their removal. The shingles in the table above were selected for consistency and lower levels of damage,

The roof deck was completed using shingles 1-8 and shingles 9, 10, and 11 were retained for testing of control samples.

- Shingle #9 was used for testing properties of an un-treated control
- Shingle #10 was used for testing properties after application of Competitor's Rejuvenator
- Shingle #11 was used for testing properties after application of Greener Shingles Rejuvenator



APPENDIX

APPENDIX A-5 (Roof Deck Construction):

Step 4 – Ridge Cap Installation:

Completed Roof Deck Before Rejuvenator Application



DISCUSSION:

A type of common, commercially used ridge-cap shingles were then cut and applied to the cap of the roof deck. The cap was selected for the closest visual match to the shingles used.



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APPENDIX

APPENDIX A-6 (Roof Deck Construction):

Step 5 – Application of Rejuvenators:



REJUVENATOR APPLICATION DATA:

PROPERTY	TEST METHODS	RESULTS, SAMPLE ID	
		Competitive	Greener Shingles
Rejuvenator Application Data			
Dilution Rate, (%Water : %Product)	PRI Measurements	50:50	70:30
Volume Applied, mL		266	266
Weight Applied, g		263.6	257.1
Specific Gravity of Diluted Product	ASTM D70	0.9920	0.9674
Calculated Application Rate, gal/ft ²	Calculation	0.0099	0.0099

DISCUSSION:

Both rejuvenators were prepared and applied according to manufacturer guidelines using common garden spray bottles and allowed to cure for 24 hours:

- Competitive rejuvenator – A mixture of 50% water and 50% Rejuvenator concentrate stirred by hand to homogeneity
- Greener Shingles rejuvenator – A mixture of 70% water and 30% Rejuvenator concentrate stirred by hand to homogeneity
- Both diluted products were applied to their respective side of the roof deck at a target rate of 1 gallon per 100ft² using simple spray bottles.



APPENDIX

APPENDIX A-7 (Spray Bottles):



DISCUSSION:

Common commercially available garden spray bottles with adjustable nozzles were used for application of the rejuvenators. Each product was prepared (diluted) and placed in its own new, cleaned and labeled spray bottle to avoid possible contamination.

APPENDIX

APPENDIX A-8 (PRI – Asphalt Pavement Weathering System):



ACCELERATED AGING PARAMETERS:

PARAMETER	SETTING
<i>APWS Cycle and Climate Information</i>	
Cycle Reference Method	ASTM D4798, Cycle A
Time of UV Light Exposure, mins	51
Time of UV Exposure with Rain Cycle, mins	9
Average Maximum Shingle Temperature, °F (Note 1)	149.5
Average “Rain Rate”, gal/hr	12.6

Note 1 – Average Maximum Shingle Temperature is measured by taking the average of the temperature readings immediately before the beginning of the “rain cycle” when the temperature is at its highest level.



APPENDIX

APPENDIX A-9 (PRI – Asphalt Pavement Weathering System):



DISCUSSION:

An open view of PRI's Asphalt Pavement Weathering System with the roof deck positioned in the front chamber (right).

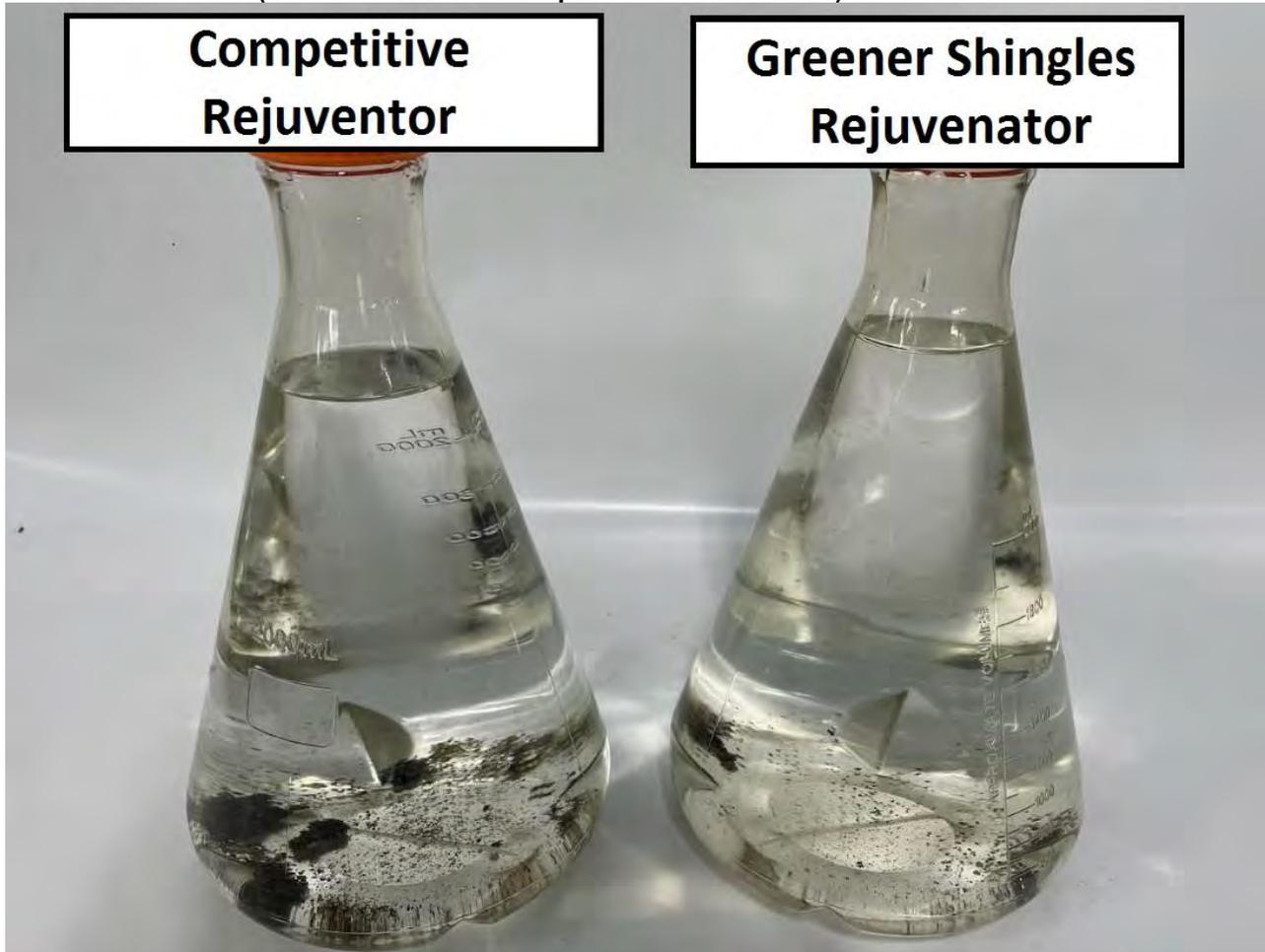
PRI's APWS was used for accelerated weathering of the roof deck after the application and curing of the rejuvenators. The weatherometer is monitored daily for even light distribution and water spray coverage, while temperature of the chamber, roof surface, water, ambient temperature and relative humidity are all tracked continuously.

The valves observed at the bottom of the chamber collect runoff materials from the inside of the chamber. Each valve is connected to a divided, sloped chamber, designed to only collect material from one section of the weatherometer.



APPENDIX

APPENDIX A-11 (Granular Wash off Comparison – ~1500 hours):



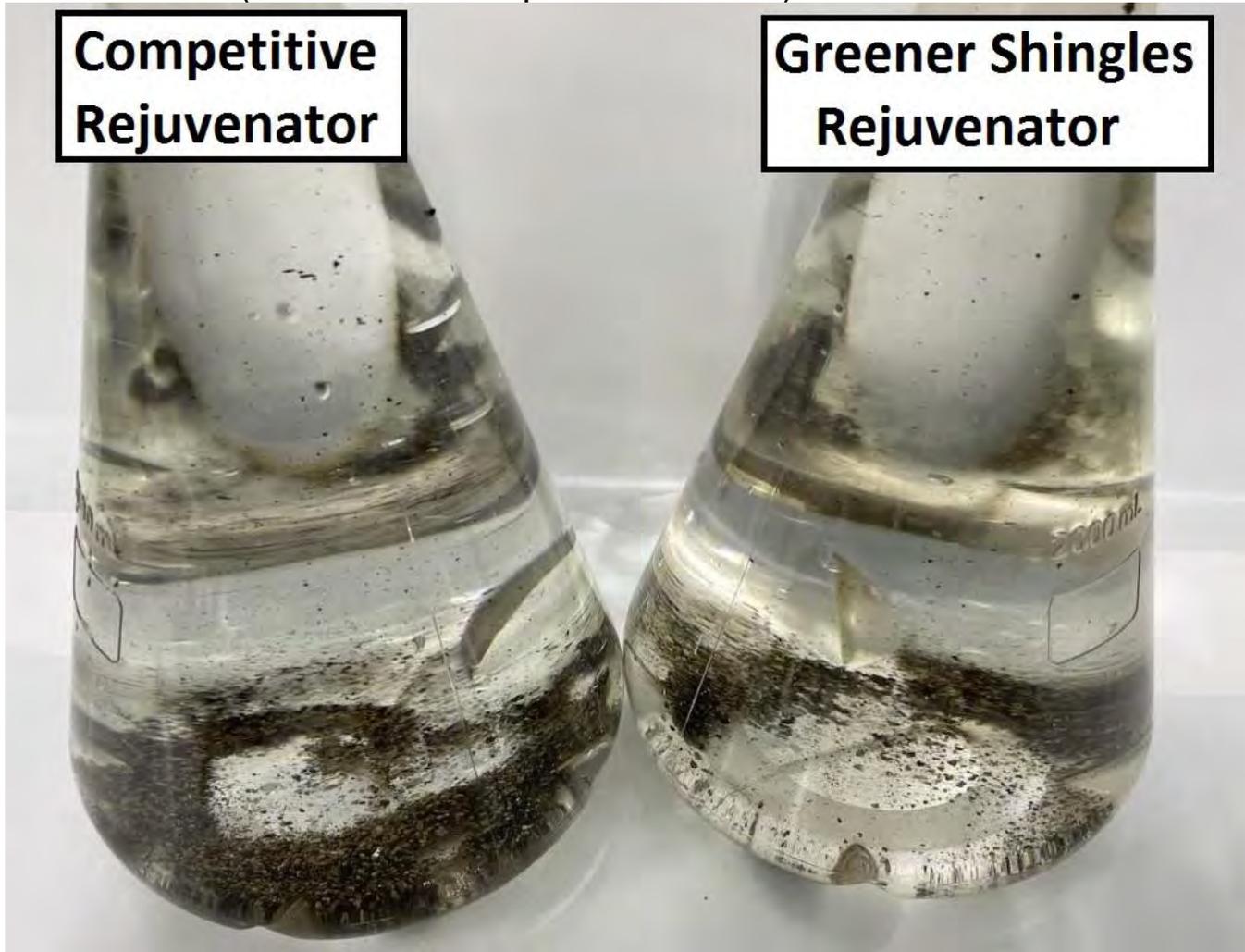
DISCUSSION:

Another set of samples of runoff water was taken after 1500 hours of exposure and again there were visually more granules present in the water samples from the Competitive product than in the water from the Greener Shingles Product.



APPENDIX

APPENDIX A-11 (Granular Wash off Comparison – ~3000 hours):



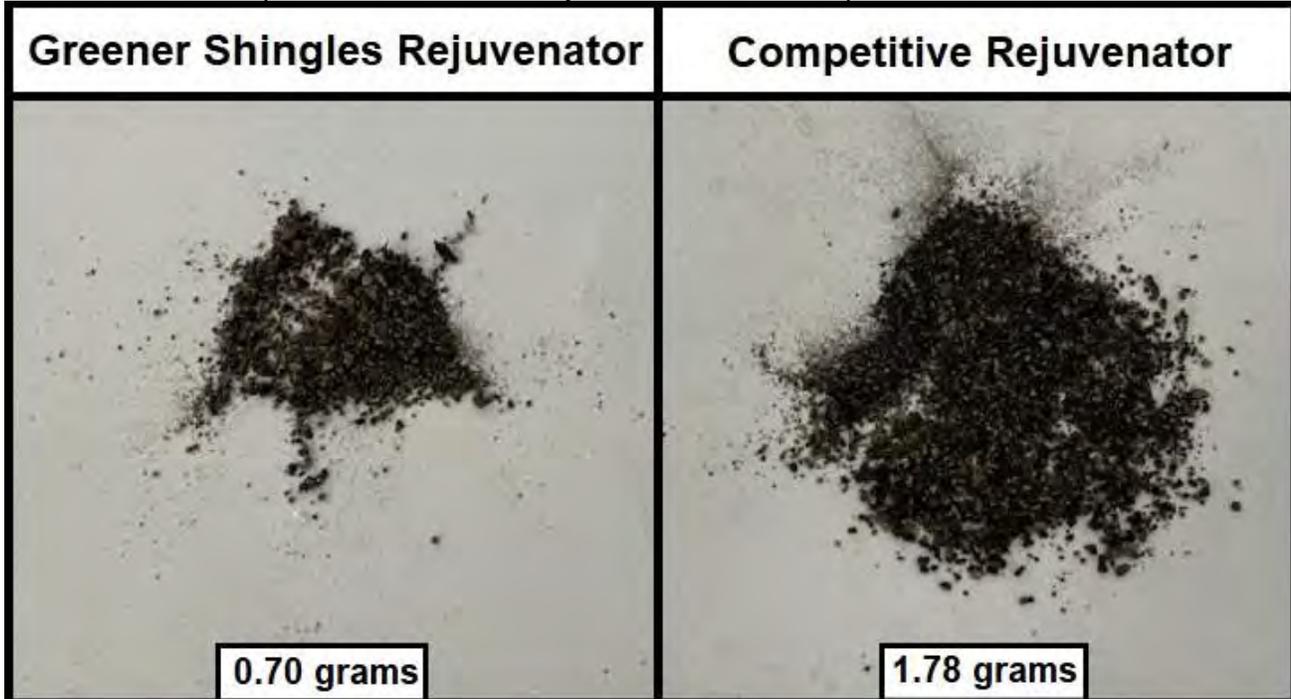
DISCUSSION:

Another set of samples of runoff water was taken after 3000 hours of exposure and again there were visually more granules present in the water samples from the Competitive product than in the water from the Greener Shingles Product.



APPENDIX

APPENDIX A-11 (Granular Wash off Comparison – ~1500 hours):



DISCUSSION:

Granules and particulate washed from the roof decks after 1500 hours of exposure. Particles have been filtered from the accompanying runoff water and dried for quantification.



APPENDIX

APPENDIX A-11 (Granular Wash off Comparison – ~3000 hours):

Greener Shingles Rejuvenator	Competitive Rejuvenator
 <p data-bbox="337 1192 570 1255">3.94 grams</p>	 <p data-bbox="997 1192 1229 1255">9.86 grams</p>

DISCUSSION:

Granules and particulate washed from the roof decks after 3000 hours of exposure. Particles have been filtered from the accompanying runoff water and dried for quantification.



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APPENDIX

APPENDIX A-12 (Color Comparison – 0 hours):

Untreated Control	Treated with Competitive Product - 0 Hours	Treated with Greener Shingles Product - 0 Hours
		

DISCUSSION:

Close-up inspection of the treated shingles with the control indicate that both rejuvenators slightly lighten the color of the granules after application and curing.



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APPENDIX

APPENDIX A-13 (Color Comparison – 1500 hours):

Untreated Control	Treated with Competitive Product - 1500 hours	Treated with Greener Shingles Product - 1500 hours
		

DISCUSSION:

Close-up inspection of the treated shingles with the control after 1500 hours of exposure indicate that both rejuvenators slightly lighten the color of the granules, with a slightly lighter color exhibited by the granules treated with the Greener Shingles product.



APPENDIX

APPENDIX A-13 (Color Comparison – 3000 hours):

Untreated Control	Treated with Competitive Product - 3000 hours	Treated with Greener Shingles Product - 3000 hours
		

DISCUSSION:

Close-up inspection of the treated shingles with the control after 3000 hours of exposure indicate that both rejuvenators slightly lighten the color of the granules, with no noticeable visual difference between the products after 3000 hours.



APPENDIX

APPENDIX A-14 (Roof Deck with Competitor's Product– 0 hours):

Competitive Rejuvenator - Immediately before the start of weathering



APPENDIX A-15 (Roof Deck with Greener Shingles' Product – 0 hours):

Greener Shingles Rejuvenator - Immediately before the start of weathering



DISCUSSION:

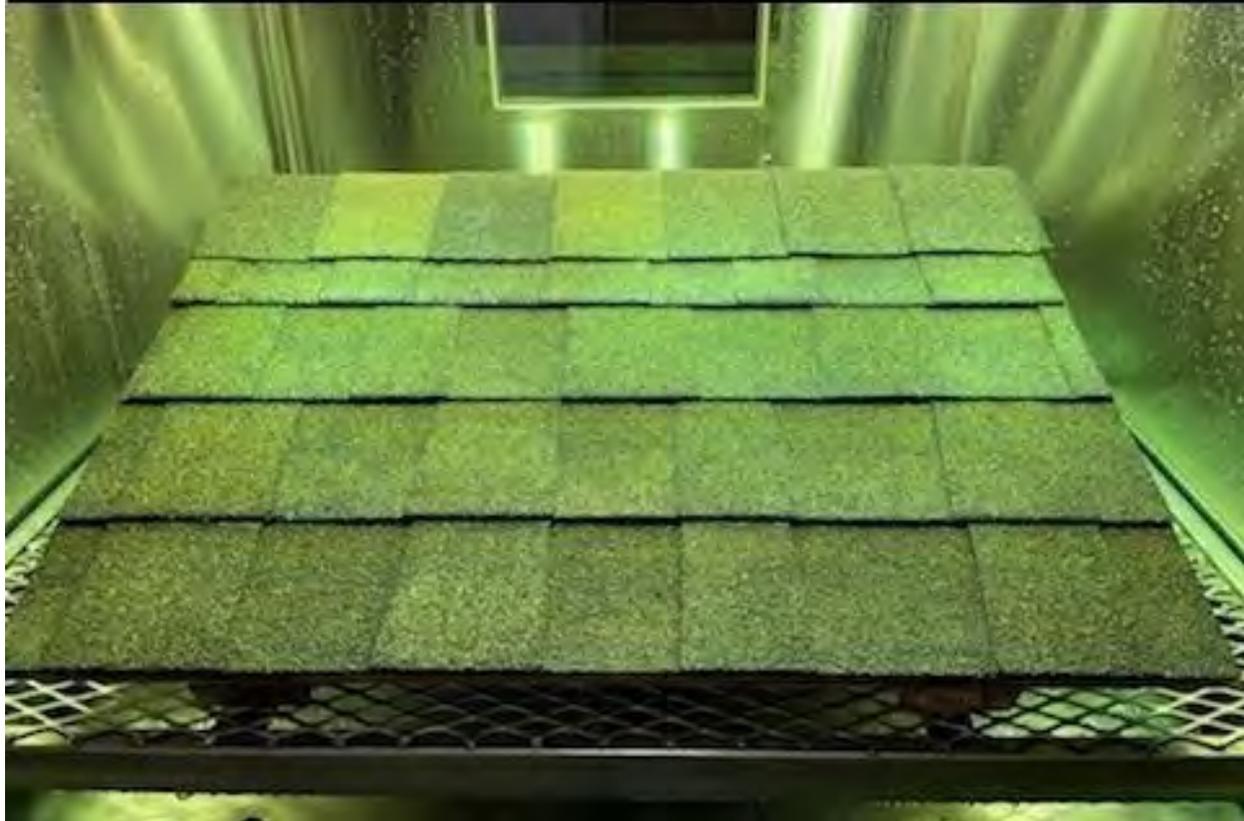
Photographs taken of both sides of the roof deck immediately before the start of the accelerated weathering process.



APPENDIX

APPENDIX A-16 (Competitor's Product During First Light Cycle – 0 hours):

Competitive Rejuvenator - Light Cycle



DISCUSSION:

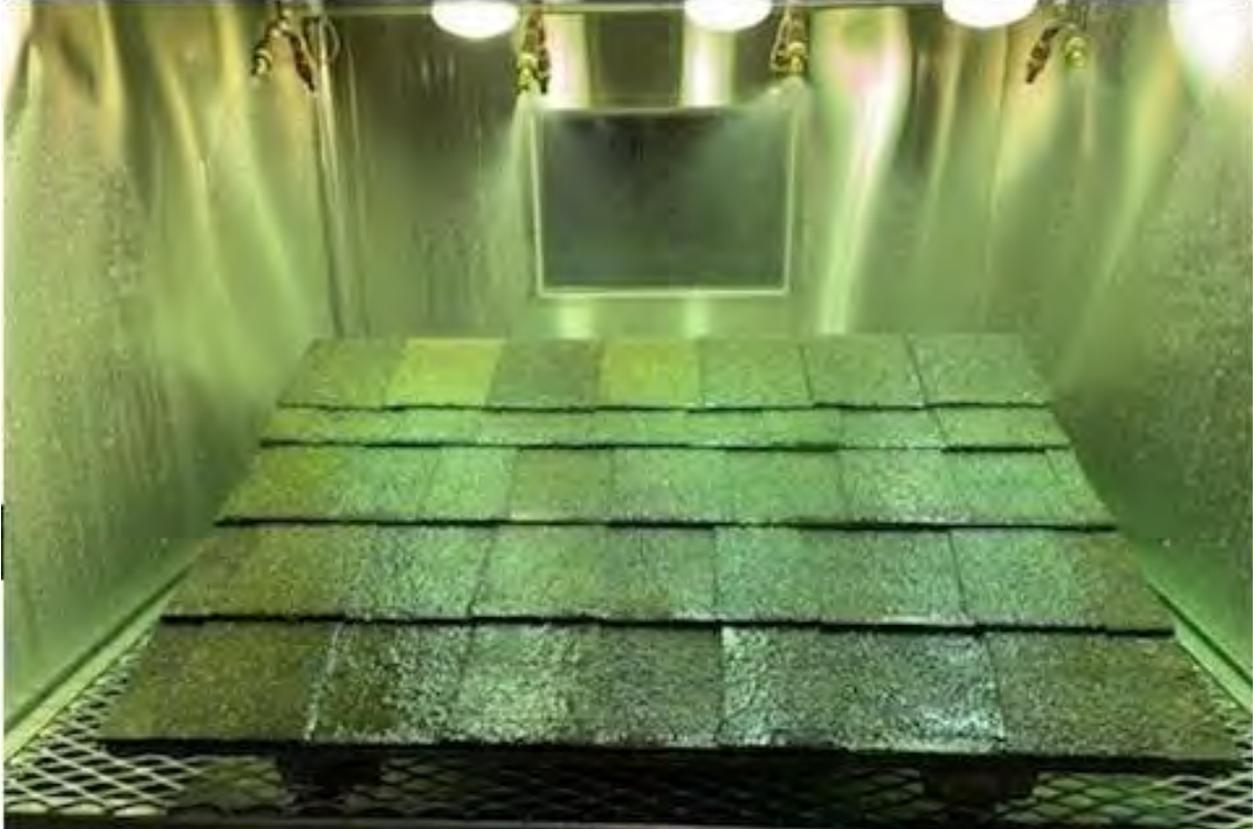
Photographs taken of the samples during a “Light Cycle” of the weathering process.



APPENDIX

APPENDIX A-17 (Competitor's Product During First Rain Cycle – 0 hours):

Competitive Rejuvenator - Rain Cycle



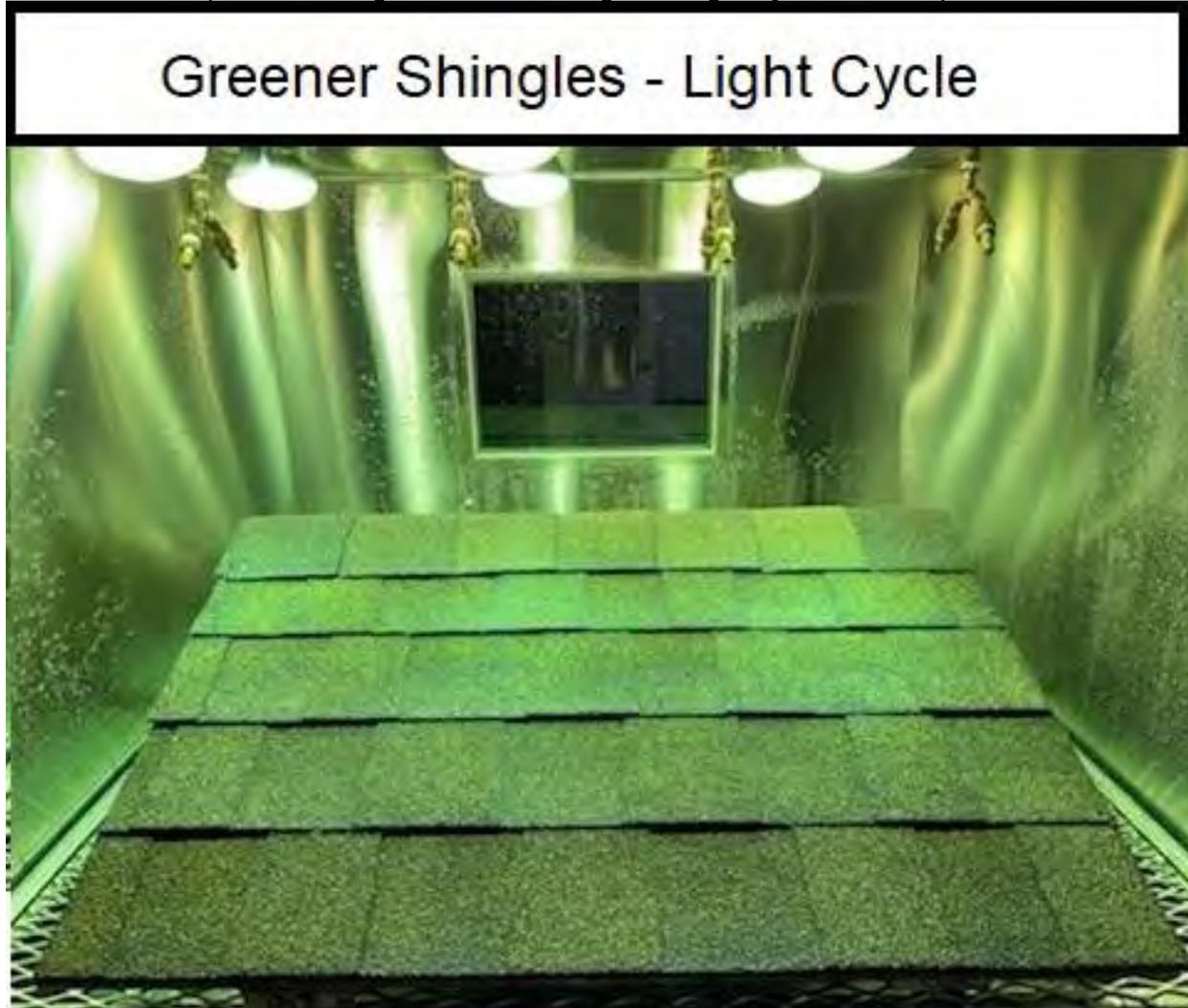
DISCUSSION:

Photographs taken of the samples during a “Rain Cycle” of the weathering process.



APPENDIX

APPENDIX A-18 (Greener Shingles Product During First Light Cycle – 0 hours):



DISCUSSION:

Photographs taken of the samples during a “Light Cycle” of the weathering process.



APPENDIX

APPENDIX A-19 (Greener Shingles Product During First Rain Cycle – 0 hours):

Greener Shingles - Rain Cycle



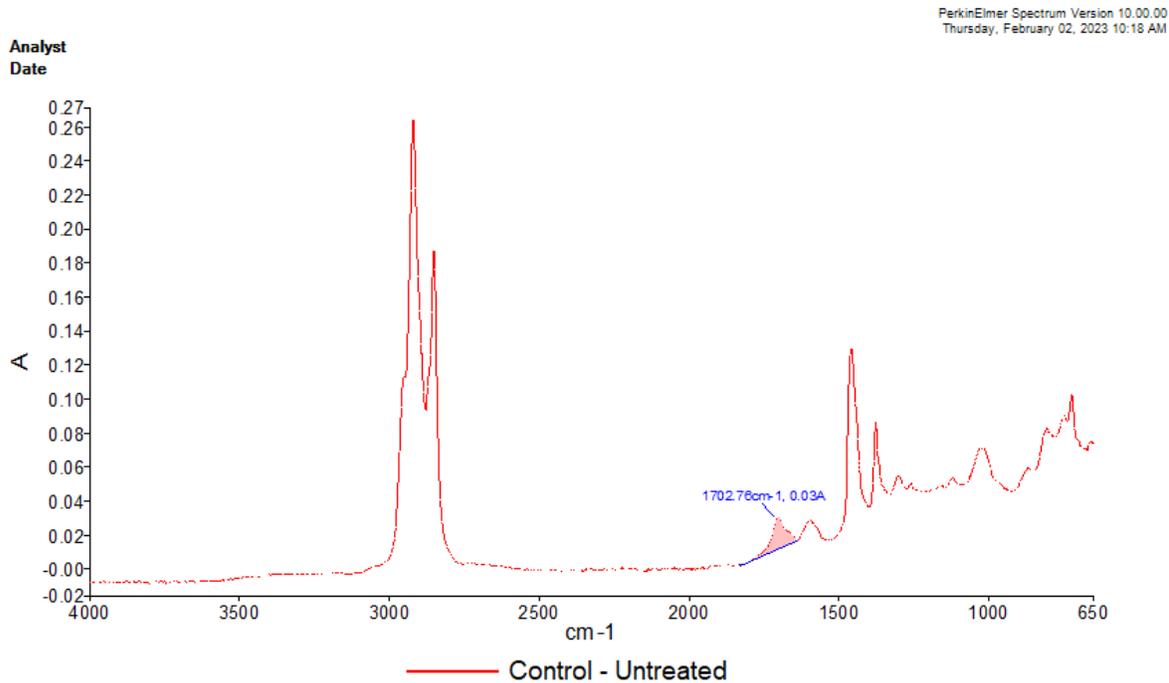
DISCUSSION:

Photographs taken of the samples during a “Rain Cycle” of the weathering process.



APPENDIX

APPENDIX B-1 (Carbonyl Index – Untreated Control):



DISCUSSION:

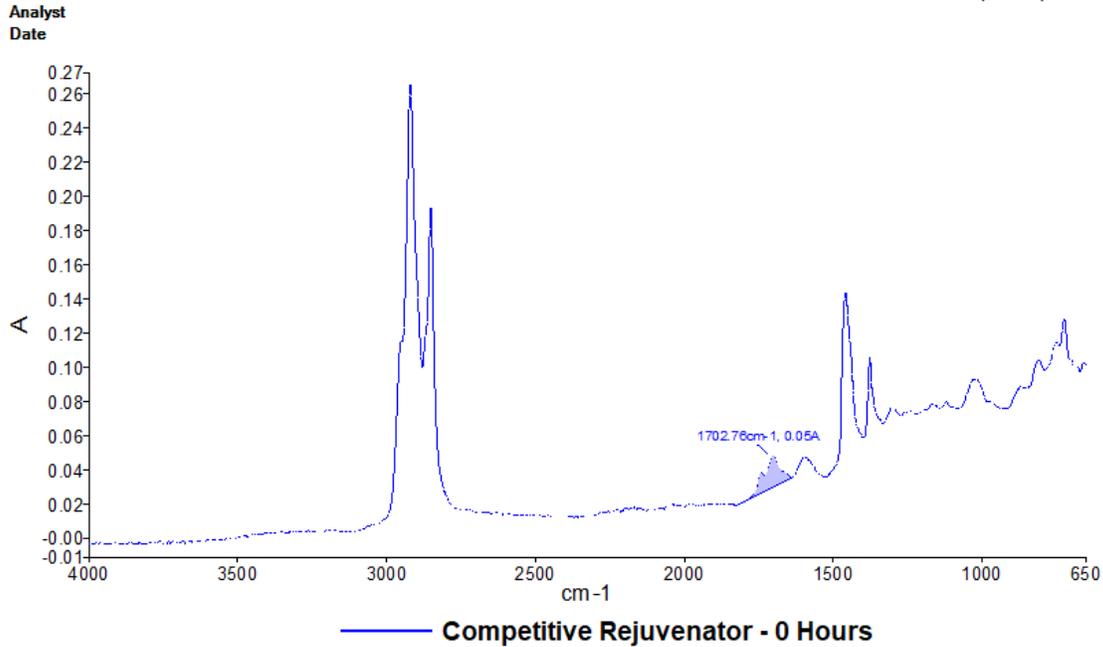
FT-IR Spectra with the peak indicative of carbonyl index highlighted.



APPENDIX

APPENDIX B-2 (Carbonyl Index – Competitor - 0 Hours):

PerkinElmer Spectrum Version 10.00.00
Thursday, February 02, 2023 10:19 AM



DISCUSSION:

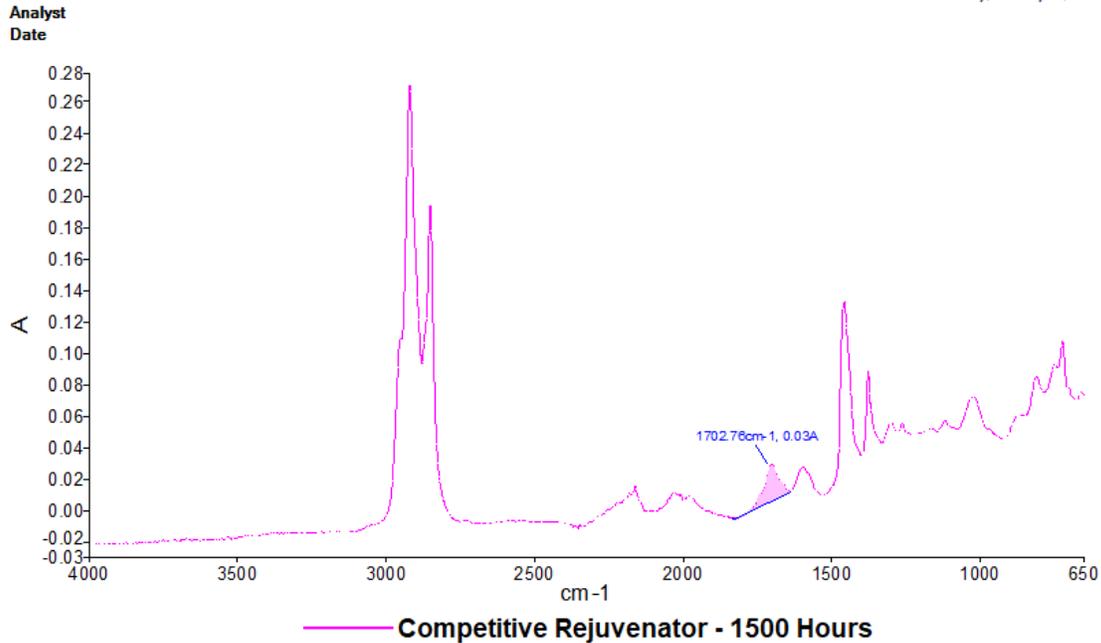
FT-IR Spectra with the peak indicative of carbonyl index highlighted.



APPENDIX

APPENDIX B-3 (Carbonyl Index – Competitor - 1500 Hours):

PerkinElmer Spectrum Version 10.00.00
Thursday, February 02, 2023 10:19 AM



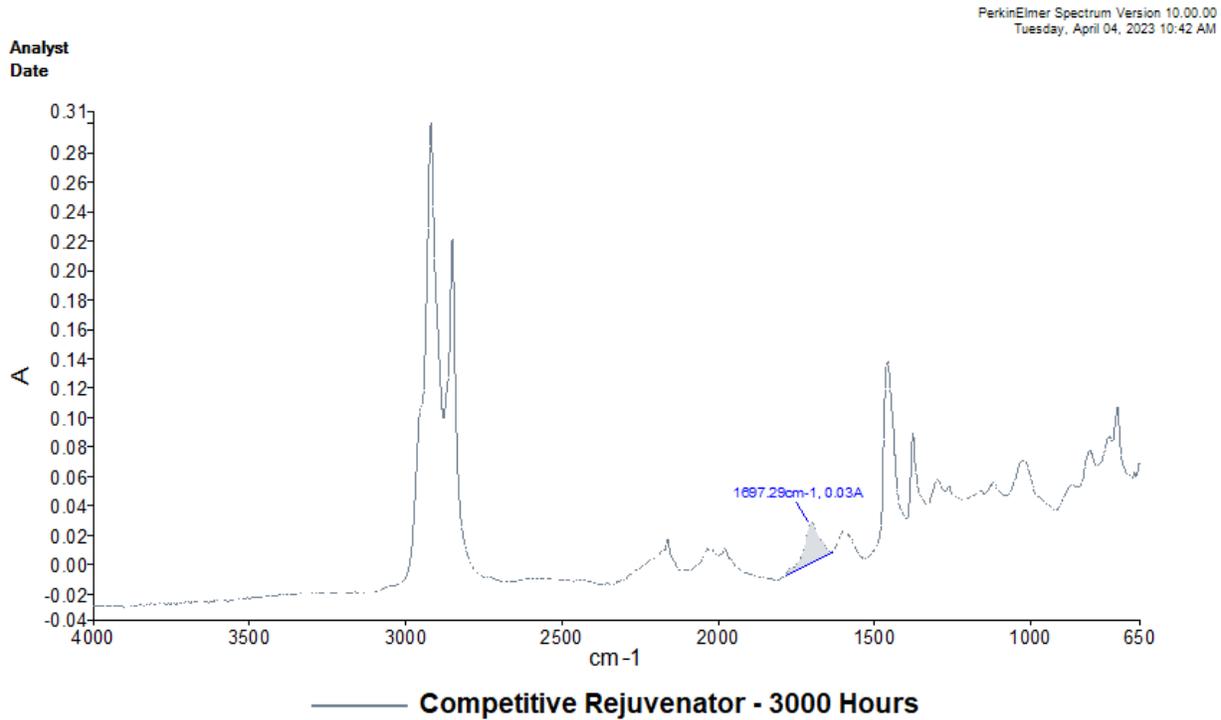
DISCUSSION:

FT-IR Spectra with the peak indicative of carbonyl index highlighted.



APPENDIX

APPENDIX B-4 (Carbonyl Index – Competitor - 3000 Hours):



DISCUSSION:

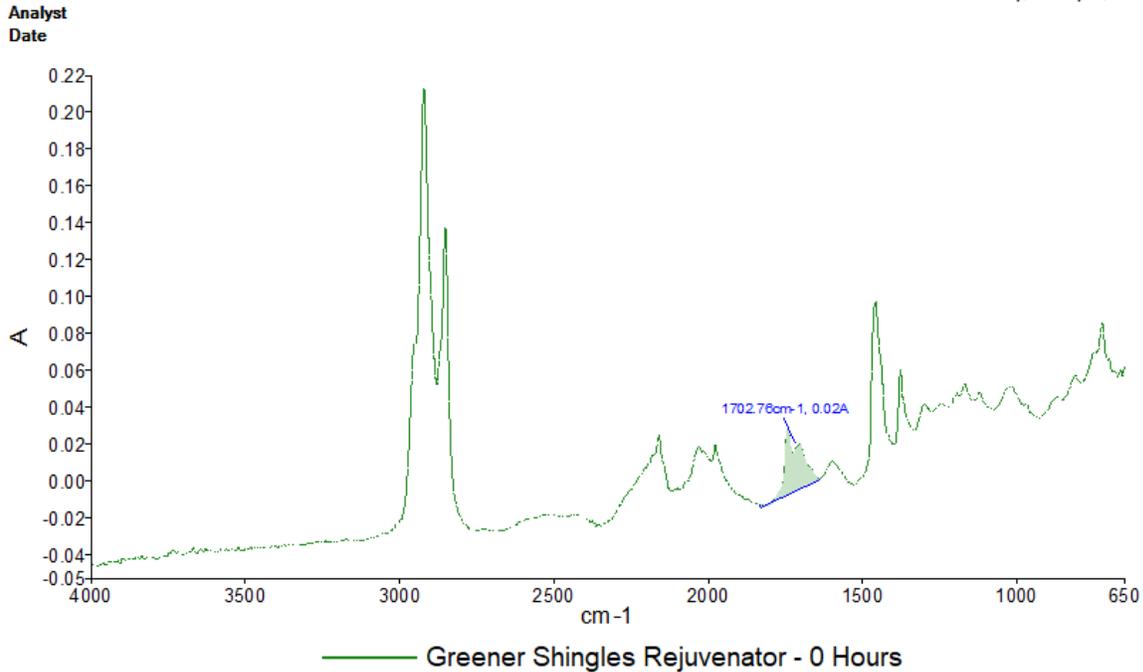
FT-IR Spectra with the peak indicative of carbonyl index highlighted.



APPENDIX

APPENDIX B-5 (Carbonyl Index – Greener Shingles - 0 Hours):

PerkinElmer Spectrum Version 10.00.00
Thursday, February 02, 2023 10:20 AM



DISCUSSION:

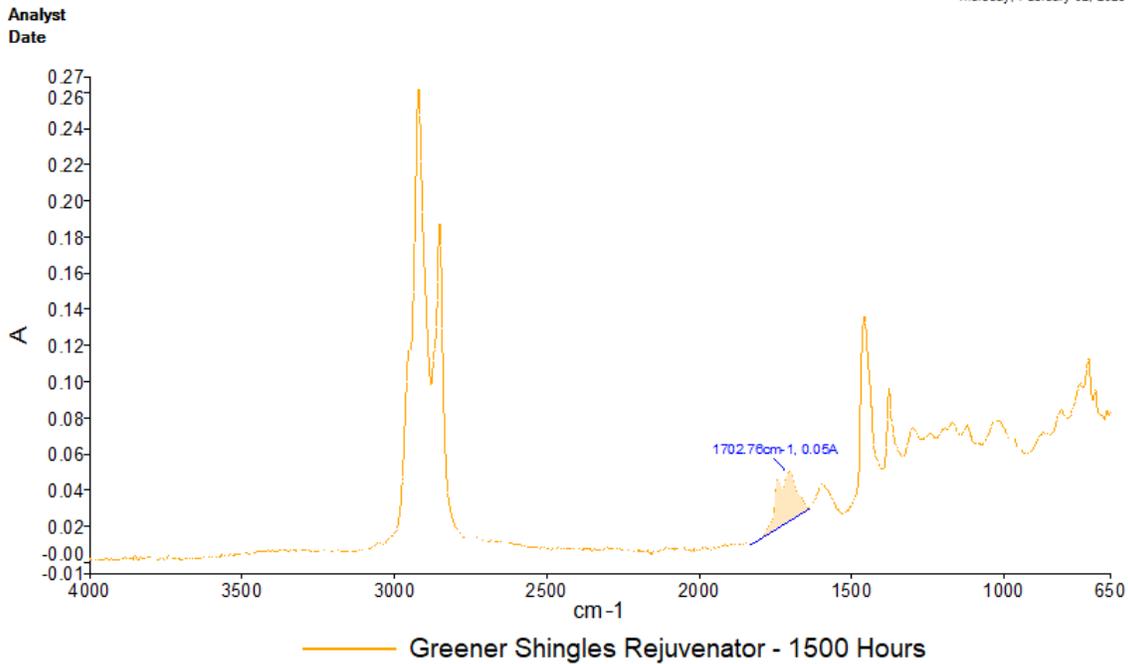
FT-IR Spectra with the peak indicative of carbonyl index highlighted.



APPENDIX

APPENDIX B-6 (Carbonyl Index – Greener Shingles - 1500 Hours):

PerkinElmer Spectrum Version 10.00.00
Thursday, February 02, 2023 10:20 AM



DISCUSSION:

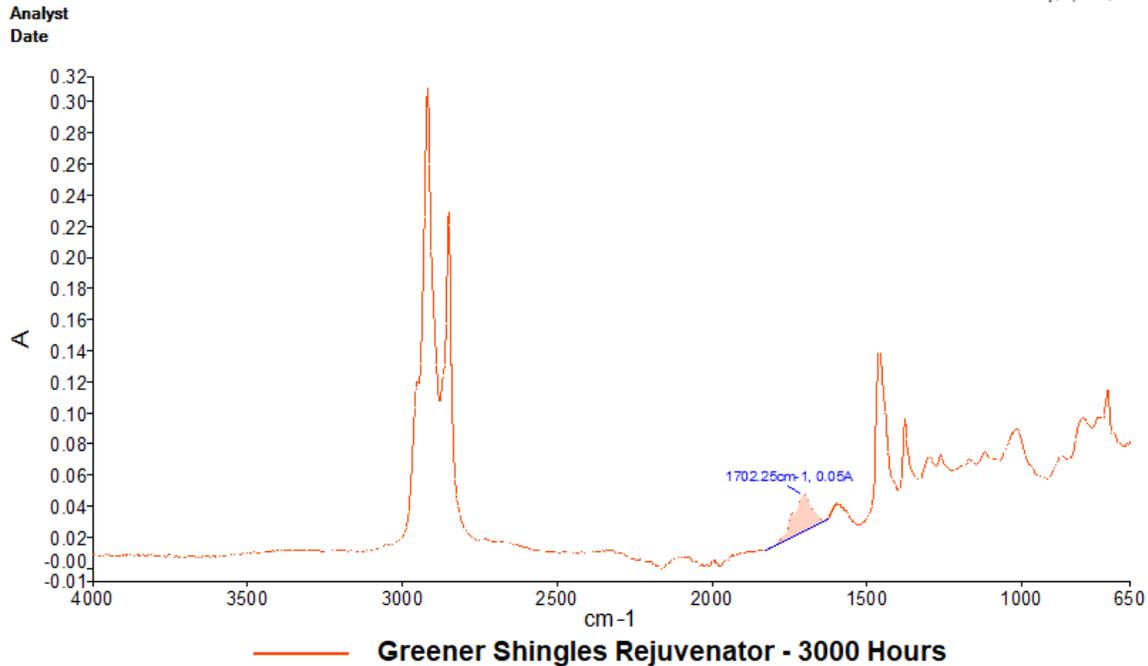
FT-IR Spectra with the peak indicative of carbonyl index highlighted.



APPENDIX

APPENDIX B-7 (Carbonyl Index – Greener Shingles - 3000 Hours):

PerkinElmer Spectrum Version 10.00.00
Tuesday, April 04, 2023 10:44 AM



DISCUSSION:

FT-IR Spectra with the peak indicative of carbonyl index highlighted.