Evaluation of the Effects of Long-Term UV Exposure on Single-Ply Membranes

By Jim D. Koontz, RRC, PE; and John Erland, RRO

The use of PVC, KEE, EV, and TPO single-ply membranes makes up a substantial portion of the commercial roofing market. Manufacturers of the various single-ply products publish the physical properties of their membranes at the time of manufacture. Owners, designers, and contractors often select a single-ply system based upon the marketing claims of the manufacturers. The ability of a membrane to maintain its initial physical properties over an extended period of time can be a predictor of performance. Identifying and measuring how these properties change have been the subjects of prior research.[1]

Jim D. Koontz & Associates, in conjunction with Target Corporation, undertook a 1½-year study to evaluate the relative performance level of 11 single-ply membranes when subjected to long-term ultraviolet light (UV) exposure in the laboratory. New samples of various membranes – polyvinyl chloride (PVC), ketone ethylene ester (KEE), Elvaloy® (EV), and thermoplastic polyolefin (TPO) – were collected from seven different manufacturers. PVC, KEE, EV, and TPO are product designations assigned by the material manufacturers. The roofing materials selected for the testing have been commonly used throughout the United States.

The initial physical properties of the sin-membranes were determined for thickness, hardness, specific gravity, and brittle point temperature (see *Table A*). The visual appearance of the samples was documented photographically by microscopic examination.

A Q-Panel (QUV) Weatherometer oven (*Photo 1*) manufactured by Q-Lab Corporation was used to test some of the properties of the membranes. A test-cycle duration of eight hours of UV exposure with a black panel temperature set point of 63˚C

QUV - Long Term Accelerated Weather Testing

Membrane ID	Starting Test Results: Sheet Thickness, mils	Sheet Mass, lbs/sq	Durometer Hardness, units	Brittleness Point, °F
1	47	29.72	81	-49
2	48	30.61	80	-38
3	50	34.56	84	-24
4	49	30.36	80	-20
5	32	20.97	85	-20
6	57	35.09	83	-103
7	45	22.86	86	-35
8	43	22.22	86	-26
9	44	23.40	87	-17
10	46	21.32	80	-40
11	43	21.21	83	-44

PVC KEE EV TPO

Table A

Photo 1 – QUV oven.

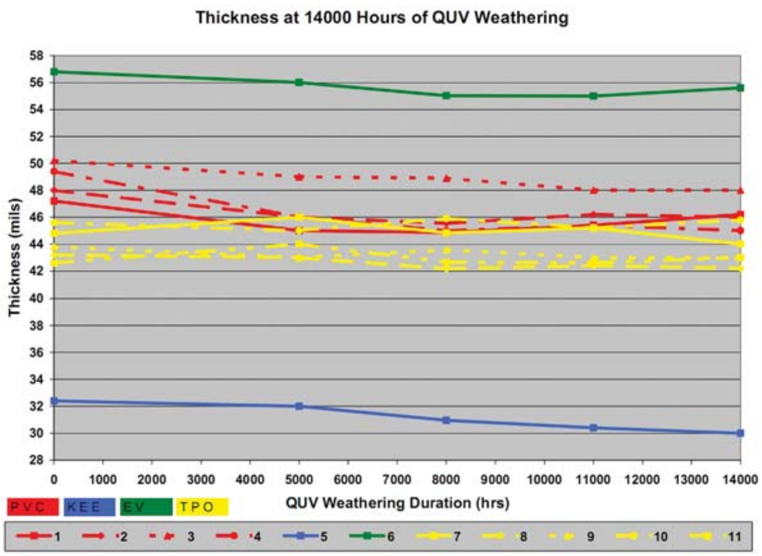
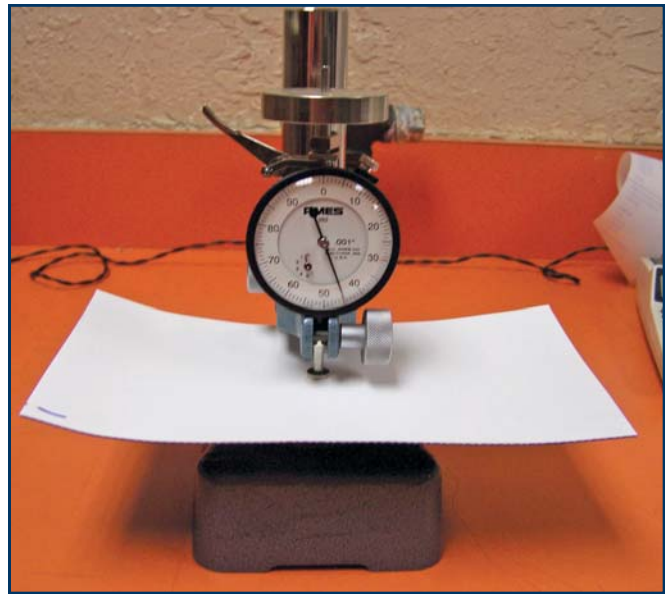


Table B

Photo 2 – Membrane sheet thickness testing.



(145˚F) was followed by four hours of water condensation on the samples' surfaces at 50˚C (122˚F).

The procedure utilized for the tests followed the general guidelines of American Society for Testing and Materials procedure ASTM D4434. The single-ply membranes were removed and periodically tested at 5,000, 8,000, 11,000, and 14,000 hours, for a total of 1½ years. Distinct variations in the performance characteristics of the various membranes were observed.

MEMBRANE SHEET THICKNESS

Two of the TPO single-ply membranes gained a slight amount of thickness (*Photo 2*), most likely due to water absorption. The PVC membranes as a group had the largest drop in thickness (average 4.9%) when compared to the TPO membranes (average 0.92%). See *Table B*. One of the PVC membranes had a loss of up to 8.5% of thickness. The KEE- and EV-based membranes decreased in thickness by 7.4% and 2.1%, respectively. Important performance characteristics for single-ply membranes include original thickness and the ability to maintain thickness over the scrim.[2]

SHEET MASS

The two TPO membranes that had an increase in thickness also had a slight increase in mass (*Photo 3*). The TPO membranes on average had a decrease in mass of 1.3%. The four PVC membranes had an average decrease in mass of 9.3% (see *Table C*). The KEE- and EV-based membranes had a decrease in mass of 6.8% and 4.2%, respectively – numerical changes based on too many significant figures.

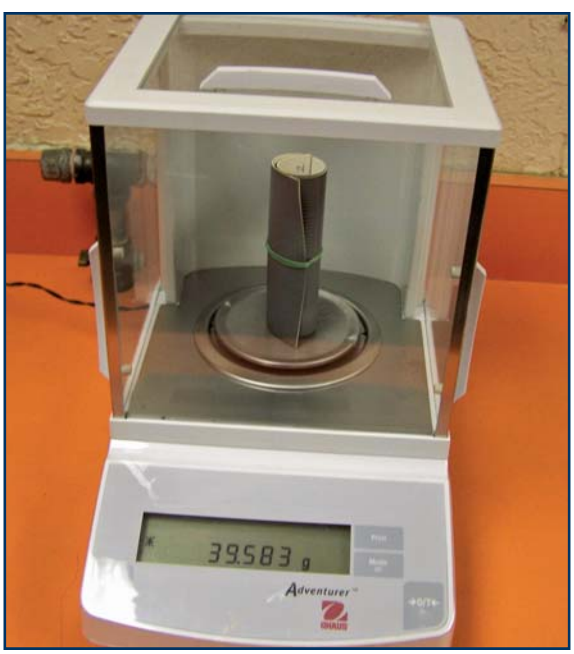


Photo 3 – Sheet mass.

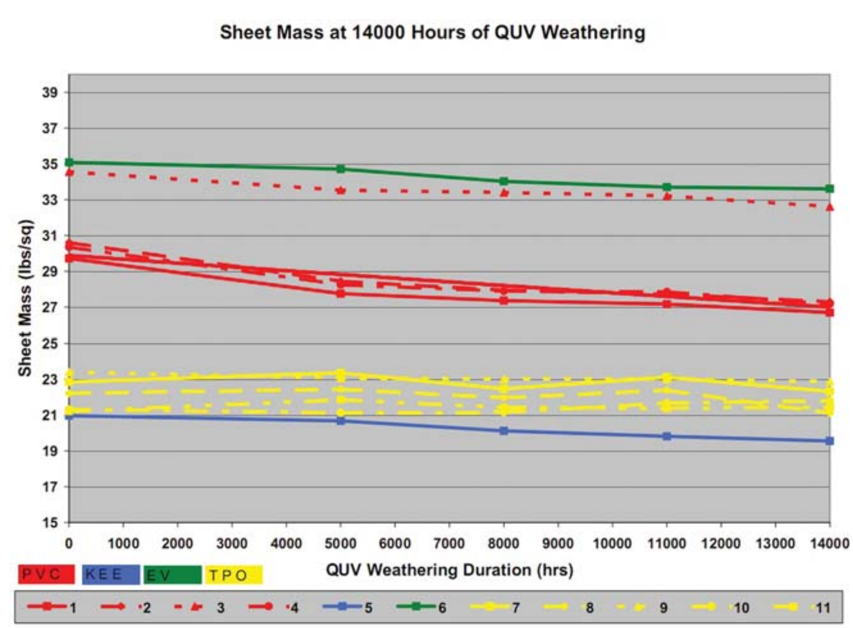


Table C

Durometer Hardness
Type A

Sample	Initial	5000	8000	11000	14000
1	81	83	83	83	85
2	80	82	83	83	84
3	84	85	84	85	86
4	80	84	85	85	85
5	85	86	86	86	87
6	83	84	83	85	84
7	86	86	86	86	85
8	86	86	86	86	86
9	87	87	87	87	87
10	80	82	82	83	84
11	83	83	83	83	82

PVC KEE EV TPO

Table D

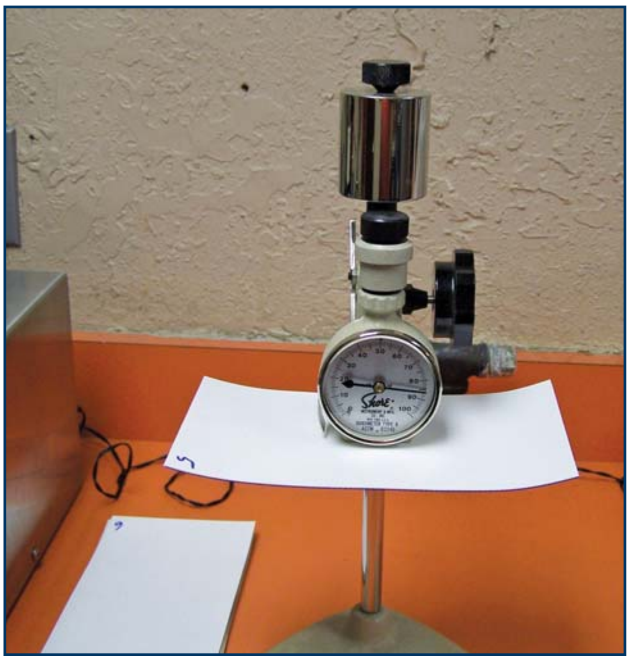


Photo 4 – Durometer hardness testing.

DUROMETER HARDNESS (ASTM D2240)

The changes in Shore Durometer Hardness for the various single-ply membranes were not as profound as observed in other test procedures. On average, the PVC membranes increased in hardness by 3.5. The TPO membranes had an average increase in hardness of 0.4 (see *Table D*). The KEE- and EV-based membranes had increases of 2.0 and 1.0, respectively.

BRITTLE-POINT TEST (ASTM D2137)

In some cases, fairly dramatic changes occurred in the brittle-point temperature of the different single-ply membranes. Sample 6, the 57-mil EV-based membrane, had an increase in brittle-point temperature from -75˚C to 0˚C, a 75˚C increase (-103˚F to +32.0˚F, a 135˚F increase). On average, the PVC had an increase of 51.8C˚ (93.2˚F). The TPO membranes experienced an average increase of 21.8˚C (39.2˚F). See *Table E*. The range of variation within the TPO membranes, however, was from a low of 16.1˚C (29.0˚F) to a high of 33.3˚C (60.0˚F). The variations observed within the five TPO samples are attributable to formulation differences. The KEE membrane had an overall increase of 36.1˚C (65.0˚F).

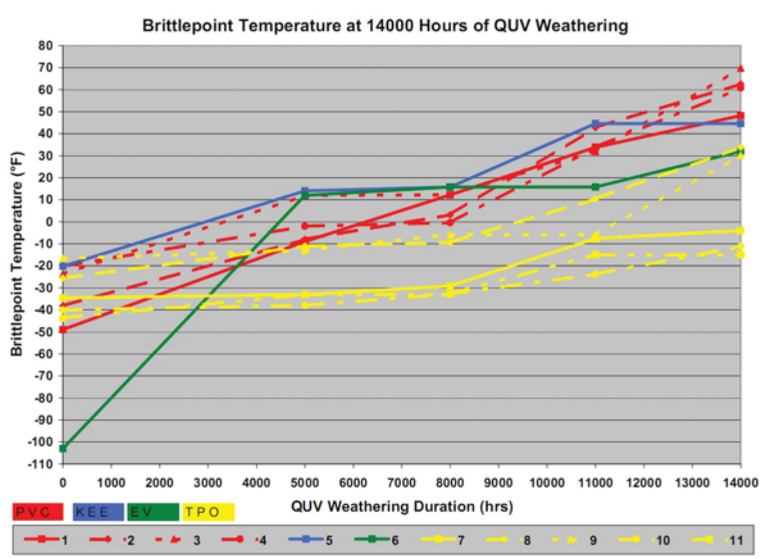


Table E

MICROSCOPIC EXAMINATION

Each membrane was initially photographed microscopically and then rephotographed at each test interval. During the course of the test, chalking was detected on the surface of all 11 single-ply samples. Crazing was detected in seven of the 11 samples, and cracking was detected in one PVC sample. All of the samples exhibited some color variation, from a tanning appearance to a pinkish appearance (*Table F*). As a greater surface color change occurs,

Sample	14000 Hours - Microscopic - Visual Examination				
	Chalking Detected	Crazing Detected	Cracking Detected	Color Change Detected	Color Change Noted
1	X	X		X	Tan
2	X	X	X	X	Tan
3	X	X		X	Light Tan
4	X	X		X	Light Tan
5	X			X	Pink
6	X			X	Light Tan
7	X			X	Slight Pink
8	X	X		X	Slight Pink
9	X	X		X	Slight Pink
10	X			X	Slight Pink
11	X	X			Slight Pink

PVC KEE EV TPO

Table F

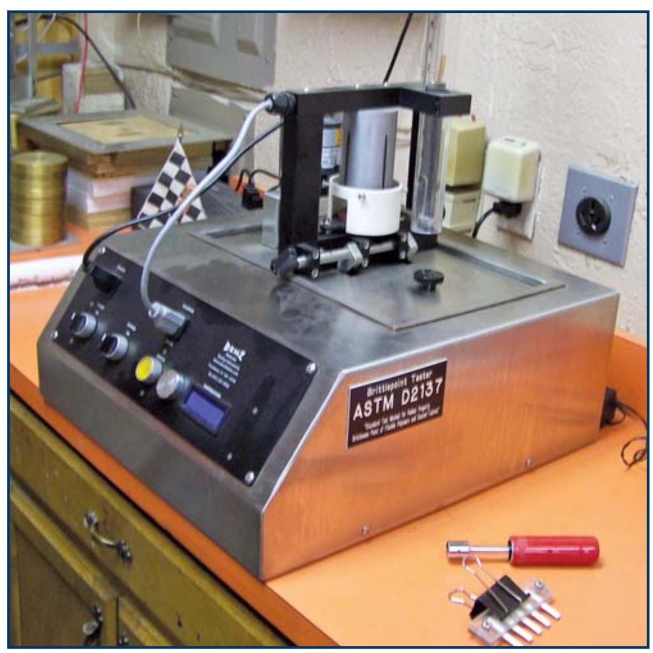


Photo 5 – Brittle-point temperature testing.

Photo 6 – PVC membrane #3 (initial).

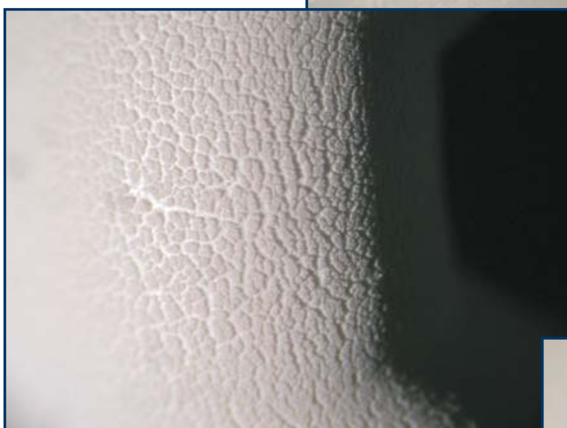


Photo 7 – PVC membrane #3 (14,000 hours).

Photo 8 – TPO membrane #10 (initial).

Photo 9 – TPO membrane #10 (14,000 hours).

changes in the durability and albedo (solar reflectance) can occur.[3] (See *Photos 6, 7, 8,* and *9.*)

SUMMARY

Relative performance attributes have long been recognized in the roofing industry as critical parts of comparing and evaluating roofing membranes. On average, the TPO membranes have a greater propensity for retaining physical properties when compared to PVC, KEE, and EV membranes. Substantial variations, however, were observed within the TPO group.

Of the membranes tested, significant variation exists in how the products performed. The loss of thickness was the greatest for a PVC sample, at 8.9%, compared to one of the TPO samples that gained a slight amount of thickness at 0.9%. The increase in brittle-point temperature ranged from a low of 16.1˚C (29.0˚F) in a TPO sample to a high of 75˚C (135˚F) in the EV-based sample.

Single-ply manufacturers perform in-house testing on their products and are aware of the relative long-term performance characteristics of their products when compared to other manufacturers' products. Typically, the manufacturers only provide the initial product characteristics at the time of manufacture. The long-term performance data should be made available by

QUV - Long Term Accelerated Weathering

Sample	Starting Test Results				14000 Hours Test Results				Start to 14000 Hours Change / Variation				14000 Hours - Microscopic - Visual Examination				
	Mil Thickness, mils	Sheet Mass, lbs/sq	Durometer Hardness, units	Brittleness Point, °F	Mil Thickness, mils	Sheet Mass, lbs/sq	Durometer Hardness, units	Brittleness Point, °F	Mil Thickness, %	Sheet Mass, %	Durometer Hardness, units	Brittleness Point, °F	Chalking Detected	Crazing Detected	Cracking Detected	Color Change Detected	Color Change Noted
1	47	29.72	81	-49	46	26.70	85	48	-2.1	-10.2	4	97	X	X		X	Tan
2	48	30.61	80	-38	46	27.30	84	63	-4.2	-10.8	4	101	X	X	X	X	Tan
3	50	34.56	84	-24	48	32.62	86	70	-4.0	-5.6	2	94	X	X		X	Light Tan
4	49	30.36	80	-20	45	27.17	85	61	-8.2	-10.5	5	81	X	X		X	Light Tan
5	32	20.97	85	-20	30	19.55	87	45	-6.3	-6.8	2	65	X			X	Pink
6	57	35.09	83	-103	56	33.61	84	32	-1.8	-4.2	1	135	X			X	Light Tan
7	45	22.86	86	-35	44	22.32	85	-4	-2.2	-2.4	-1	31	X			X	Slight Pink
8	43	22.22	86	-26	42	21.10	86	34	-2.3	-5.0	0	60	X	X		X	Slight Pink
9	44	23.40	87	-17	43	22.88	87	30	-2.3	-2.2	0	47	X	X		X	Slight Pink
10	46	21.32	80	-40	46	21.80	84	-11	0.0	2.3	4	29	X			X	Slight Pink
11	43	21.21	83	-44	43	21.43	82	-15	0.0	1.0	-1	29	X	X			Slight Pink

PVC KEE EV TPO

Table G

the manufacturers to owners, designers, and contractors so that informed decisions can be made in the selection of single-ply products.

FOOTNOTES

1. Taylor Pierce, "Key Indicators of Performance for Thermoplastic Polyolefin Membranes," *Proceedings of the RCI 24th International Convention and Trade Show*, March 2009.
2. Mark Graham, "Is Thicker Better?" *Professional Roofing*, October 2009.
3. Hashem Akbari, Asmeret A. Berhe, Ronnen Levinson, Stanley Graveline, Kevin Foley, Ana H. Delgado, and Ralph M. Paroli, "Aging and Weathering of Cool Roofing Membranes," *Proceedings of Cool Roofing: Cutting Through the Glare*, RCI Foundation, May 2005.
4. C.W. Griffin, Richard Fricklas, *Manual of Low-Slope Roof Systems, Fourth Edition*, Chapter Two, 2006.

Jim D. Koontz, RRC, PE

Jim D. Koontz, RRC, PE, has been involved in the roofing industry since 1960. His experience encompasses the role of roofer, estimator, manager of a roofing company, consultant, lecturer, and researcher. As a consultant, Jim Koontz has worked in over 40 states, Canada, Mexico, and the Caribbean. Koontz holds bachelor's and master's degrees from Tulane University.

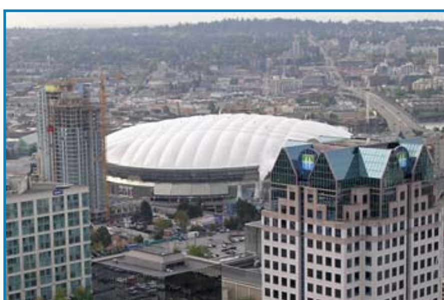
John Erland, RRO

John Erland, RRO, has been in the roofing industry for 30 years – the last 11 as a senior technical specialist with Target Corporation. Erland's first experience in the roofing industry was as summer job for a contractor. John had worked with manufacturers, contractors, and consultants before joining Target. His current responsibilities include preconstruction collaboration, inspection, investigations, and continuous improvement efficiencies. John works in close partnership with Target property development and roofing teams developing new and remodeled stores and distribution centers' details and specifications, along with scopes for reroofing projects.

New Fabric Roofs for BC Place and Canada Place

Two iconic landmarks in Vancouver are scheduled to be replaced with new fabric roofs by 2011. The BC Place Stadium will be replaced by a 10-acre, fully retractable fabric roof, while Canada Place's 1986 Teflon roof will be replaced with more energy-efficient material.

A $458 million (Canadian dollars) contract has been let to PBC Pavilion Corporation (PavCo) and PCL Constructors Canada Inc. for replacement of BC Place, scheduled to be completed in time for the 2011 Grey Cup. A temporary facility (Empire Stadium) will accommodate the BC Lions and the Vancouver Whitecaps for the 2010 season.



BC Place (above) and Canada Place (right). Photos courtesy of Uli Harder.

The new roof will be the largest cable-supported, fully retractable, fabric roof in the world, with the roof retracting into the center of the roof opening and hidden inside a suspended, four-sided electronic video board. It will be capable of opening in 20 minutes and is expected to offer an additional 41 event days to Vancouver each year and save up to 25% in energy costs for the stadium.

At Canada Place, the outer roof fabric of the '86 installation will be replaced with new, more energy-efficient materials. Funding will come from Canada's $4-billion Infrastructure Stimulus Fund for construction-ready infrastructure rehabilitation projects.

— Roofing BC

EPA Approves Alternative Solvent for Method 5A Testing

The Asphalt Roofing Manufacturers Association (ARMA) has been notified that the Environmental Protection Agency (EPA) has approved the use of 1-bromopropane as an alternative to the 1,1,1-trichlorethane specified in Method 5A. The EPA says that this modification is acceptable for use at any asphalt processing or manufacturing facility covered by the following regulations: 40 CFR Part 60, Subpart UU; 40 CFR Part 63, Subpart LLLLL; and 40 CFR Part 60, Subpart AAAAAAA. This solvent replacement will reduce the use of a potential ozone-depleting substance that has historically been required for roofing industry environmental compliance-related testing.

ARMA members are required by the EPA to use Method 5A testing to demonstrate compliance with particulate matter emissions limits required by the Clean Air Act. The Montreal Protocol and the Clean Air Act required the phasing out of production of 1,1,1-trichlorethane, a chlorinated solvent thought to contribute to the depletion of the earth's ozone layer, and until recently the only solvent approved by the EPA for Method 5A emissions testing.

— ARMA