

# 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.<sup>1</sup>

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 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.

Thickness at 14000 Hours of QUV Weathering

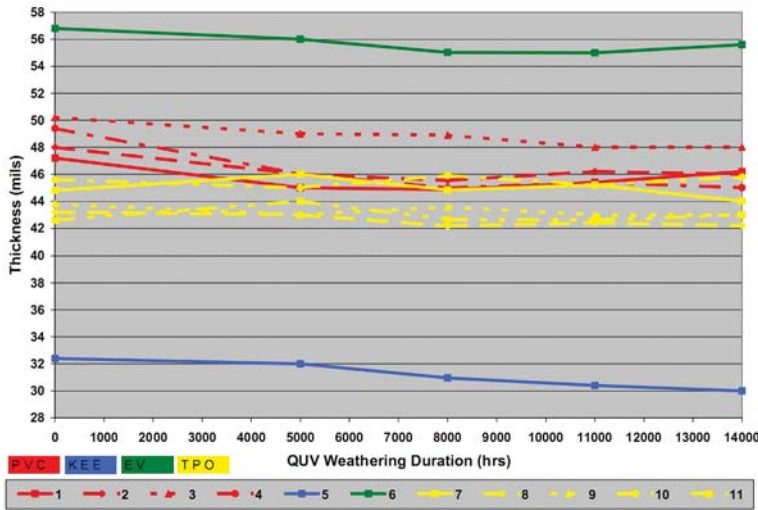
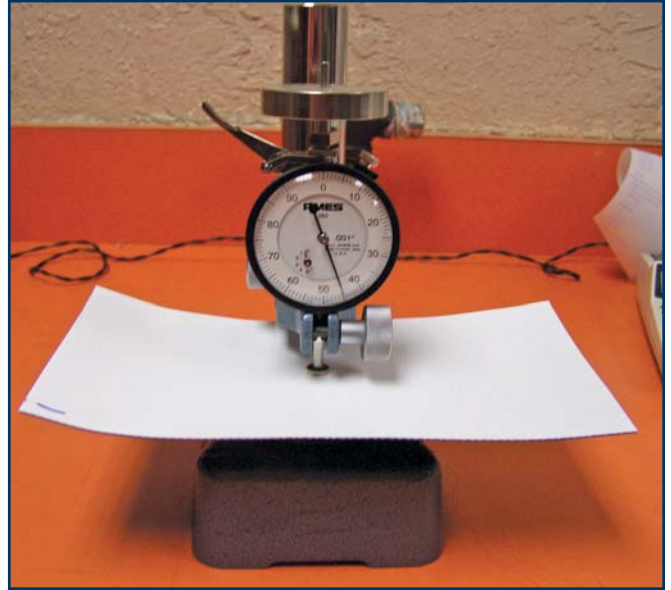


Table B

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 com-

pared 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.<sup>2</sup>

**SHEET MASS**

The two TPO membranes that had an increase in thickness also had a slight increase in mass (Photo 3). The TPO mem-

branes 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.

Sheet Mass at 14000 Hours of QUV Weathering

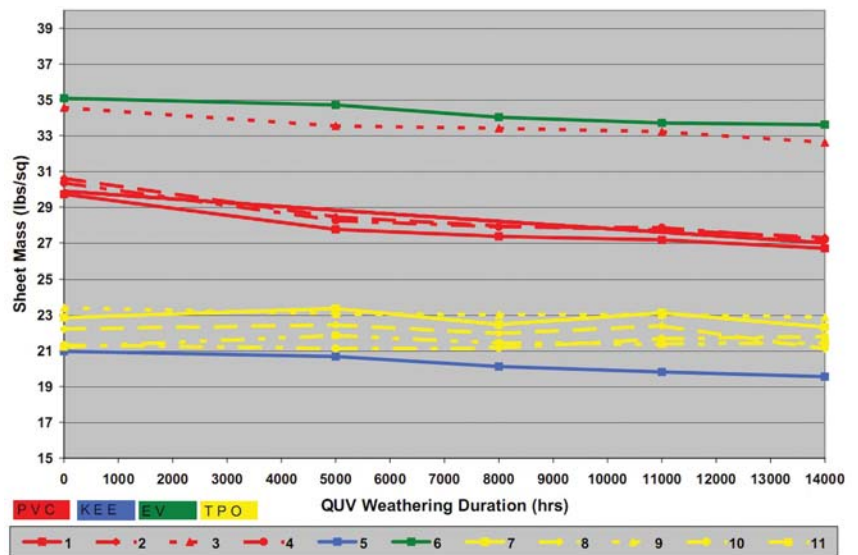


Table C

### 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  $-75^{\circ}\text{C}$  to  $0^{\circ}\text{C}$ , a  $75^{\circ}\text{C}$  increase ( $-103^{\circ}\text{F}$  to  $+32.0^{\circ}\text{F}$ , a  $135^{\circ}\text{F}$  increase). On average, the PVC had an increase of  $51.8^{\circ}\text{C}$  ( $93.2^{\circ}\text{F}$ ). The TPO membranes experienced an average increase of  $21.8^{\circ}\text{C}$  ( $39.2^{\circ}\text{F}$ ). See Table E. The range of variation within the TPO membranes, however, was from a low of  $16.1^{\circ}\text{C}$  ( $29.0^{\circ}\text{F}$ ) to a high of  $33.3^{\circ}\text{C}$  ( $60.0^{\circ}\text{F}$ ). The variations observed within the five TPO samples are attributable to formulation differences. The KEE membrane had an overall increase of  $36.1^{\circ}\text{C}$  ( $65.0^{\circ}\text{F}$ ).

### 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. Cracking 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	Cracking 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

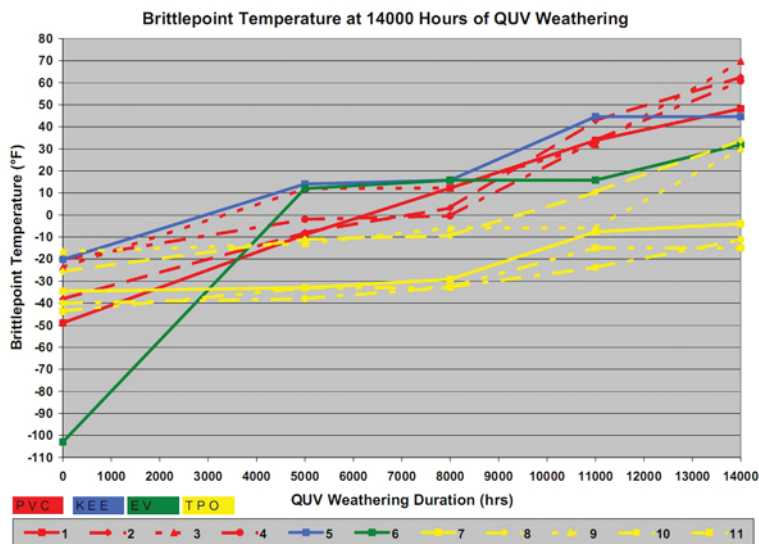


Table E



Photo 5 – Brittle-point temperature testing.

Photo 6 – PVC membrane #3 (initial).



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



changes in the durability and albedo (solar reflectance) can occur.<sup>3</sup> (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



Photo 8 – TPO membrane #10 (initial).




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

**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 develop-

ing new and remodeled stores and distribution centers' details and specifications, along with scopes for reroofing projects.