Accelerated Aging Performance Evaluation of “Smart Vapor Retarder”

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ABSTRACT

The smart vapor retarder (SVR) is primarily a vapor barrier membrane that is sensitive to ambient relative humidity (RH) and controls water vapor diffusion through the insulated exterior walls. This paper presents experimental findings from accelerated aging tests, simulating long-term performance indicators, on SVR and compares them with similar observations made on a traditional 6-mil poly (i.e., polyethylene) vapor and air barrier. Elevated temperature and ultraviolet (UV) light were the two primary environmental agents used to accelerate the aging process. The performance of the vapor barrier was assessed from water vapor permeance, air permeance, and tensile strength properties at various stages of aging. The results from these tests indicate that water vapor permeance, air permeance and mechanical properties of SVR do change due to accelerated aging. In aged SVR material, compared to the original specimens, the RH dependency of the water vapor permeance at higher RH levels appears to be less evident. However, overall performance of SVR, compared to 6-mil poly, does not exhibit significant concerns about its accelerated weathering performance or serviceability.

INTRODUCTION

The “smart vapor retarder” (SVR) is an innovative proprietary 2 mil (50 μm) thick, nylon-6 vapor barrier that controls water vapor diffusion through insulated exterior walls, as required by the National Building Code of Canada (NBC 2005), Subsection 9.25.4. Unlike a more traditional vapor barrier like polyethylene film (≈6 mil or 150 μm thick), the water vapor permeance of SVR increases with increasing ambient relative humidity, as shown in Figure 1. It has been demonstrated through hygrothermal simulation that the use of SVR and appropriate design methodology can lead to satisfactory moisture management performance of exterior wall systems in compliance with the NBC 2005 (Maref et al. 2008, 2009; Tariku et al. 2009). However, in order to ensure durability and serviceability of the exterior wall systems, it is also important to demonstrate satisfactory accelerated weathering water vapor transmission, airflow, and mechanical performance of SVR, in response to various natural aging factors prevalent in the field applications.

This paper presents the critical analysis of the results obtained from the accelerated aging performance assessment conducted on SVR and traditional 6-mil poly vapor barrier, carried out at the National Research Council Canada–Institute for Research in Construction (NRC-IRC).

RESEARCH OBJECTIVE

The objective of this research was to carry out accelerated aging tests on SVR and 6-mil poly and generate required information (i.e., water vapor permeance, air permeance, and tensile strength) as stipulated in Table 1 of Di Lenardo et al. (2005), which is based on existing evaluation protocols for similar construction materials and experience of the NRC-IRC researchers with the performance of building materials.

EXPERIMENTAL PROGRAM

In order to determine the aging characteristics of SVR and 6-mil poly, three performance indicators, representing primary field performance requirements, were set for tracking any degradation before and after accelerated aging: water

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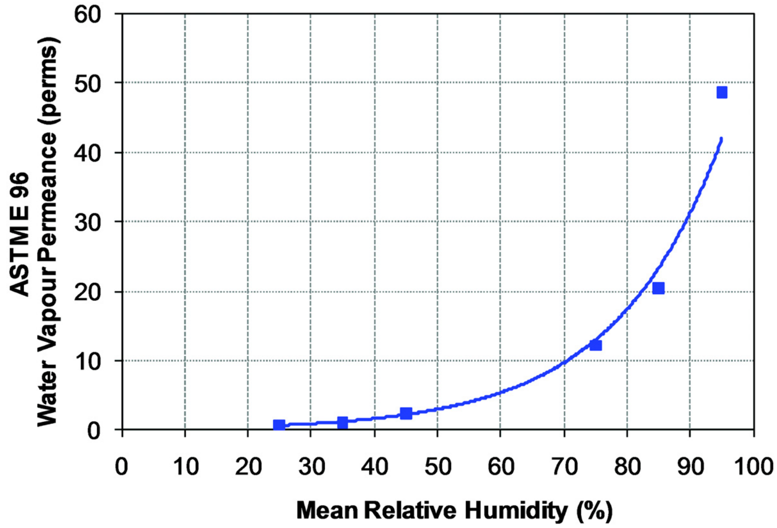


Figure 1 *Water vapor permeance (WVP) of smart vapor retarder vs. percent mean relative humidity (Gatland 2005).*

Table 1. Accelerated Aging Protocol

Property Testing	UV (level 1) and Heat Aging	UV (level 2) and Heat Aging
Tensile Strength Water Vapor Permeance Air Permeance	Original values	Original values
UV Testing (2 levels)	48 h	72 h
Tensile Strength Water Vapor Permeance Air Permeance	Residual values after 48 h UV exposure	Residual values after 72 h UV exposure
Heat Aging 1 (of UV-exposed specimens)	168 h	168 h
Tensile Strength Water Vapor Permeance Air Permeance	Residual values after 48 h UV exposure and 168 h heat aging	Residual values after 72 h UV exposure and 168 h heat aging
Heat Aging 2 (of UV-exposed and 168 h heat-aged specimens)	168 h	168 h
Tensile Strength Water Vapor Permeance Air Permeance	Residual values after 48 h UV exposure & 336 h heat aging	Residual values after 72 h UV exposure and 336 h heat aging

vapor permeance, air permeance, and tensile strength. The details of the durability protocol (i.e., accelerated aging process) and the characterized material properties are outlined below.

Durability Protocol

UV Exposure Test. The specimens were tested for tensile strength, water vapor permeance, and air permeance after UV-exposure testing and heat aging in accordance with the following protocols.

The specimens were exposed to UVA-340 lamps in a Q-UV apparatus operated in accordance with ASTM *Standard* G53. Each cycle of UV testing included both UV exposure and condensation, as outlined below. Two sets of specimens were exposed to two different levels of UV testing, specifically

- Level 1 specimens were subjected to 48 h of UV/condensation (i.e., 4 cycles)
- Level 2 were subjected to 72 h UV/condensation (i.e., 6 cycles) with the following pattern:
    - 8 hours of UV radiation at 60°C
    - 4 hours of condensation at 40°C

Heat Aging. The specimens exposed to UV radiation were subsequently subjected to heat aging at 90°C in accordance with ASTM *Standard* D3045 for one week (168 h) and subsequently another week (168 h).

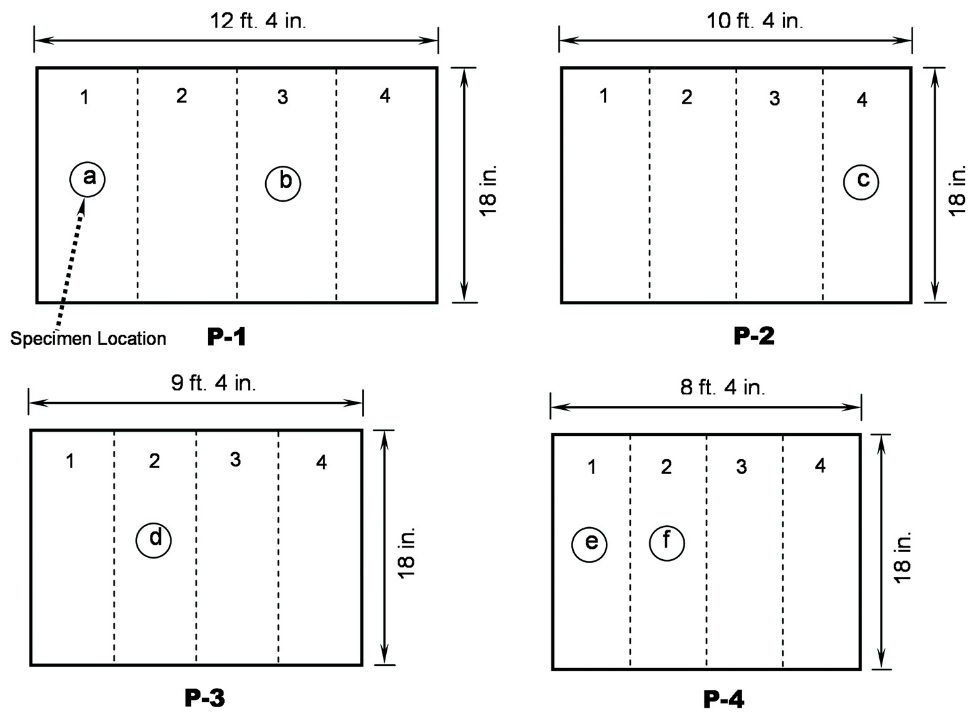


Figure 2 *Specimen locations.*

Performance Indicators—Material Properties

Water Vapor Permeance (WVP).

Original WVP Before Aging. To characterize the vapor barrier materials, WVP values at five different mean relative humidity (RH) levels (i.e., 25%, 35%, 45%, 85%, 95%) were determined according to ASTM *Standard* E96/E96M-05. Three specimens were tested and averaged for each RH.

WVP After UV and Heat Aging. Nine specimens were tested according to ASTM *Standard* E96/E96M-05. Three specimens in accordance with procedure A (25% mean RH), another three specimens in accordance with procedure B (75% mean RH) and the last three in accordance with procedure B (85% mean RH).

Air Permeance. Three specimens were tested according to the procedure in Bomberg and Kumaran (1985). The same specimens were used for both water vapor permeability and air permeability tests.

Tensile Strength. The tensile strength was determined on specimens 200 mm long by 25 mm wide in the machine direction, according to the ASTM *Standard* D882, with an initial jaw separation of 100 mm. Five specimens were tested and the results averaged.

Test Specimens

Smart Vapor Retarder (SVR). Test specimens were prepared from SVR samples that were randomly collected by a third party. Four packages (P-1, P-2, P-3, and P-4) of folded and rolled SVR were delivered to the laboratory. They were each 100 ft long and 2 mil thick, as marked on the package, but had different widths (P-1: 12 ft, 4 in.; P-2: 10 ft, 4 in.; P-3: 9 ft, 4 in.; P-4: 8 ft, 4 in.). Four rectangular (full width and 18 in. long) pieces from four different packages were cut and six specimens were prepared for original (i.e., before accelerated aging) water vapor permeability and air permeability tests from different locations, as shown in Figure 2. The tensile test specimens were cut out from the rest of the SVR sheets after taking samples for water vapor and air permeability tests. The test specimens for the other tests were prepared from the subsequent pieces cut out from different rolls, as follows:

- 48 h UV exposure—Package 4 (P-4)
- 48 h UV + 168 h at 90 °C exposure—Package 3 (P-3)
- 48 h UV + 336 h @ 90 °C exposure—Package 1 (P-1)
- 72 h UV exposure—Package 4 (P-4)
- 72 h UV + 168 h at 90 °C exposure—Package 2 (P-2)
- 72 h UV + 336 h at 90 °C exposure—Package 1 (P-1)

6-mil Poly. The 6-mil poly specimens, complying with CGSB *Standard* 51.34-M86-CAN/CGSB AMD 1, were randomly cut from a roll that had been recently used in a construction project.

EXPERIMENTAL RESULTS AND DISCUSSION

Water Vapor Permeance

The water vapor transmission characteristics of the original (i.e., before accelerated aging exposure) SVR specimens

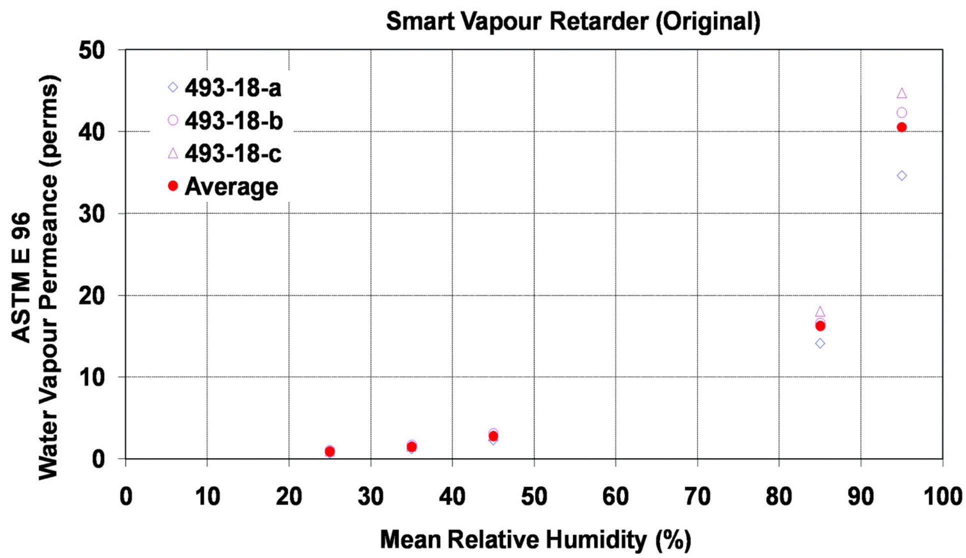


Figure 3 *Water vapor permeance of original SVR specimens.*

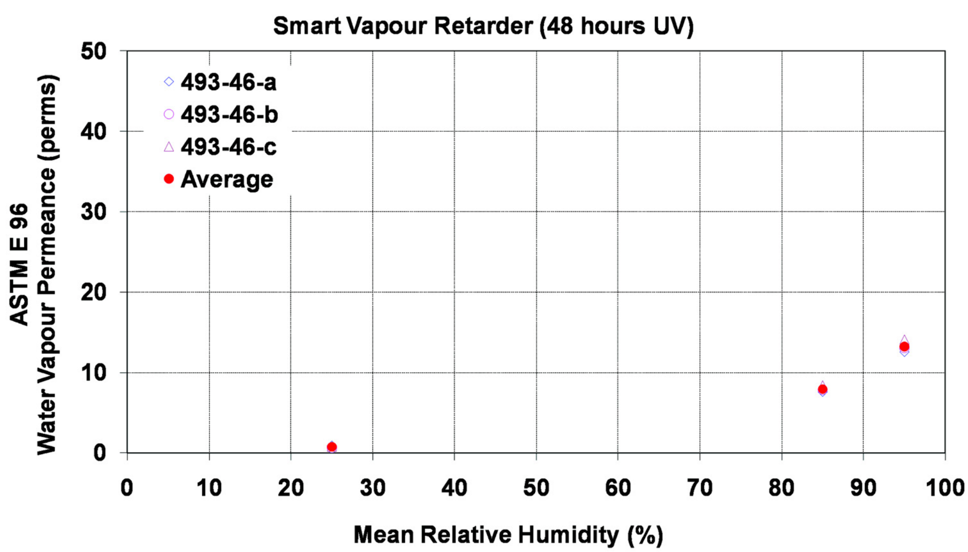
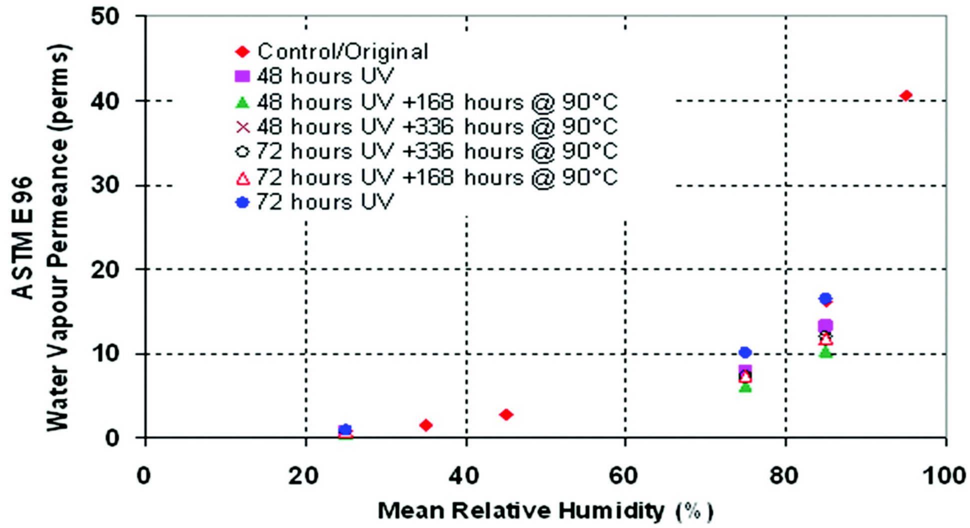


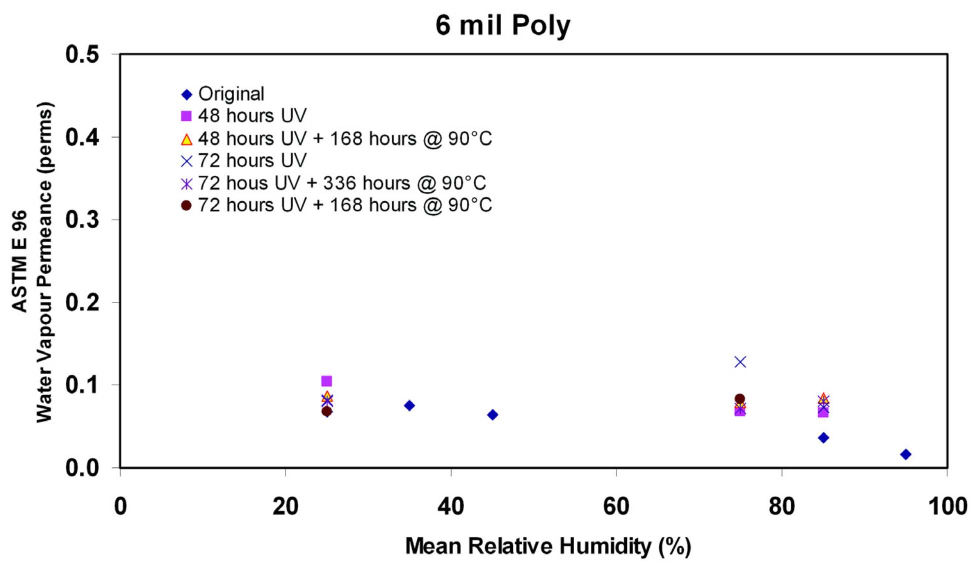
Figure 4 *Water vapor permeance of 48 h UV exposed SVR specimens.*

are shown in Figure 3, and the typical water vapor transmission characteristics of the SVR specimens after accelerated aging tests are shown in Figure 4. The overall changes in water vapor permeance properties of both SVR and 6-mil poly due to accelerated aging tests are indicated in Figures 5a and 5b (take note of change in vertical axis scale). It is very evident from these results that changes in water vapor permeance values of SVR due to accelerated exposure tests were more than 15% and resulted in the reduction of water vapor permeance, possibly because of changes in microstructure (annealing). This reduction of water vapor permeance in SVR (Figure 5a) appeared to be relatively greater at higher relative humidity (RH). The water vapor permeance of original (i.e., before accelerated aging tests) 6-mil poly (Figure 5b), on the other hand, was much lower (less than 0.1 perm) compared to SVR (0.9 to 50 perm), and after accelerated aging tests the water vapor permeance of 6-mil poly increased to marginally higher values (maximum ≈0.13 perm).

In general, the SVR specimens became more resistant to water vapor transmission (i.e., lower water vapor permeance) after accelerated aging exposure tests. However, water vapor permeance values still increased with the increase of relative humidity. Comparison of the results obtained from the 48 and 72 h UV exposure tests on SVR also indicates that prolonged exposure to UV and heat aging did not reduce the water vapor permeance of the SVR further. On the contrary, the water



(A)



(B)

Figure 5 *(A) Water vapor permeance of original and exposed SVR specimens. (B) Water vapor permeance of original and exposed 6-mil poly specimens.*

vapor permeance after 72 h UV exposure was slightly higher than the same after 48 h.

Air Permeance

The air permeance characteristics of the SVR specimens before and after accelerated exposure tests are shown in Table 2a and the same for 6-mil poly are shown in Table 2b. The SVR specimens were found to be very airtight (i.e., no measurable quantity of air passing through it) in most of the measurements. However, combined 72 hours UV and heat aging resulted in measurable air transmission through the SVR specimens. In addition, combined 48 hours UV and 336 hours heat aging also shattered one SVR specimen. In a similar vein, 6-mil poly also showed aging sensitivity to UV and UV-heat exposure (Table 2b). These observations clearly indicate that UV exposure during construction for both SVR and 6-mil poly needs to be kept to a minimum.

Tensile Strength

The results from the tensile tests on SVR and 6-mil poly specimens are shown in Tables 3a and 3b. Initially with 48 h UV and 48 h UV + 168 h heat exposure, the tensile strength of SVR specimens increased to about a maximum of 15%. Thereafter, due to further heat and/or UV exposure, the tensile strength of SVR specimens reduced considerably (more than 40%). However, compared to tensile test results obtained from 6-mil poly (Table 3b) under similar conditions, it is evident that the mechanical response of SVR, with a higher tensile

Table 2a. Air Permeance of SVR

Membrane	Lab Book	Permeance, $mL(75\ Pa)^{-1}\ m^{-2}\ 15\ s^{-1}$			
		Sample ID			
		A	B	C	Average
Original	493-18	0	0	0	0
48 h UV	493-46	0	0	0	0
48 h UV, 168 h at 90°C	493-56	0	0	0	0
48 h UV, 336 h at 90°C	493-144	—*	0	0	0
72 h UV	493-78	0	0	0	0
72 h UV, 336 h at 90°C	493-100	320.7	6.8	142.7	156.7
72 h UV, 168 h at 90°C	493-122	1241.7	21.8	0	421.2

*NOTE: Specimen had shattered and could not be tested.

Table 2b. Air Permeance of 6-mil Poly

Membrane	Lab Book	Permeance, $mL(75\ Pa)^{-1}\ m^{-2}\ 15\ s^{-1})$			
		Sample ID			
		A	B	C	Average
Original	493-1	0	0	0	0
48 h UV	493-35	0	0	0	0
48 h UV, 168 h at 90°C	493-67	0	0	0	0
72 h UV	493-89	0	0	3.1	1.04
72 h UV, 336 h at 90°C	493-111	8355[1]	0[2]	0	2783.46
72 h UV, 168 h at 90°C	493-133	0[2]	0	0	0

NOTES: 1. Specimen had small rip in it leading to high air permeability.
2. There was leakage through the specimen, but could not be measured.

load-bearing capacity than 6-mil poly, can provide the accelerated weathering performance of traditional 6-mil poly membranes for resistance to wind pressure.

SUMMARY OF OBSERVATIONS

In this study, the possible aging or durability assessment of innovative proprietary 2 mil (50 μm) thick smart vapor retarder (SVR), to be used as vapor/air barrier in exterior building envelope constructions but not exposed directly to outdoor conditions, has been carried out using a purpose-designed accelerated aging test protocol, and compared with the performance of a more traditional vapor barrier 6-mil (150 μm) poly.

The accelerated aging tests show that SVR material, designed as an interior vapor/air barrier, is sensitive to extreme environmental exposure conditions not applicable for indoor uses: ultraviolet (UV) light and elevated temperature.

The mechanical, water vapor permeance, and air permeance properties do change under controlled and prolonged laboratory simulated extreme exposure conditions.

In the aged SVR material, compared to the original specimens, the relative humidity (RH) dependency of the water vapor permeance at higher RH levels appears to be less evident.

However, overall accelerated weathering performance of SVR is found to be equivalent or better compared to traditional 6-mil poly to function as a dual vapor and air barrier.

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Table 3a. SVR Tensile Tests Data

SVR Specimen ID	Aging Conditions, h		Thickness, mm	Max. Load, N		Load/Width. kN/m		Tensile Strength, MPa	
	UV	Heat (90°C)		MD*	XD†	MD*	XD†	MD*	XD†
Original	—	—	0.06	64 ± 2	65 ± 1	2.58 ± 0.08	2.58 ± 0.02	43 ± 1	43 ± 0
V1	48	—	0.05	71 ± 1	66 ± 2	2.85 ± 0.05	2.63 ± 0.07	57 ± 1	53 ± 1
V4	48	168	0.05	73 ± 9	76 ± 1	2.92 ± 0.37	3.02 ± 0.03	58 ± 7	60 ± 1
V12	48	336	0.05	39 ± 6	37 ± 5	1.56 ± 0.26	1.47 ± 0.20	31 ± 5	29 ± 4
V6	72	—	0.05	42 ± 3	41 ± 1	1.69 ± 0.11	1.64 ± 0.03	34 ± 2	33 ± 1
V8	72	168	0.05	49 ± 12	42 ± 5	1.97 ± 0.50	1.66 ± 0.21	39 ± 10	33 ± 4
V10	72	336	0.05	47 ± 4	42 ± 5	1.86 ± 0.17	1.71 ± 0.22	37 ± 3	34 ± 4

*MD: machine direction; †XD: cross direction.

Table 3b. 6-mil Poly Tensile Tests Data

6-mil Poly Specimen ID	Aging Conditions, h		Thickness, mm	Max Load, N		Load/Width, kN/m		Tensile Strength, MPa	
	UV	Oven (90°C)		MD	XD	MD	XD	MD	XD
Original	—	—	0.16	59 ± 1	50 ± 0	2.36 ± 0.05	1.99 ± 0.01	14.8 ± 0.3	12.4 ± 0.1
P1	48	—	0.14	43 ± 1	36 ± 1	1.71 ± 0.03	1.44 ± 0.02	12.2 ± 0.2	10.3 ± 0.2
P4	48	168	0.14	34 ± 2	33 ± 1	1.36 ± 0.08	1.32 ± 0.04	9.70 ± 0.6	9.4 ± 0.3
P10	48	336	0.11	25 ± 4	32 ± 2	1.00 ± 0.15	1.27 ± 0.10	9.06 ± 1.0	11.5 ± 0.9
P5	72	—	0.10	32 ± 1	27 ± 0	1.30 ± 0.04	1.09 ± 0.01	13.0 ± 0.4	10.9 ± 0.1
P7	72	168	0.10	29 ± 1	31 ± 0	1.16 ± 0.04	1.24 ± 0.01	11.6 ± 0.4	12.5 ± 0.1
P9	72	336	0.10	31 ± 1	32 ± 2	1.23 ± 0.03	1.29 ± 0.10	12.3 ± 0.3	12.9 ± 1.0

NOTE: All 6-mil poly samples aged in the oven broke normally (the control, P1, and P5 did not break before the travel limit of the machine was reached).

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