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DIMENSIONAL STABILITY AND REFLECTIVITY OF FIELD EXPOSED THERMOPLASTIC POLYOLEFIN (TPO) ROOF MEMBRANES

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National Research Council Canada | Conseil national de recherches Canada

Canada

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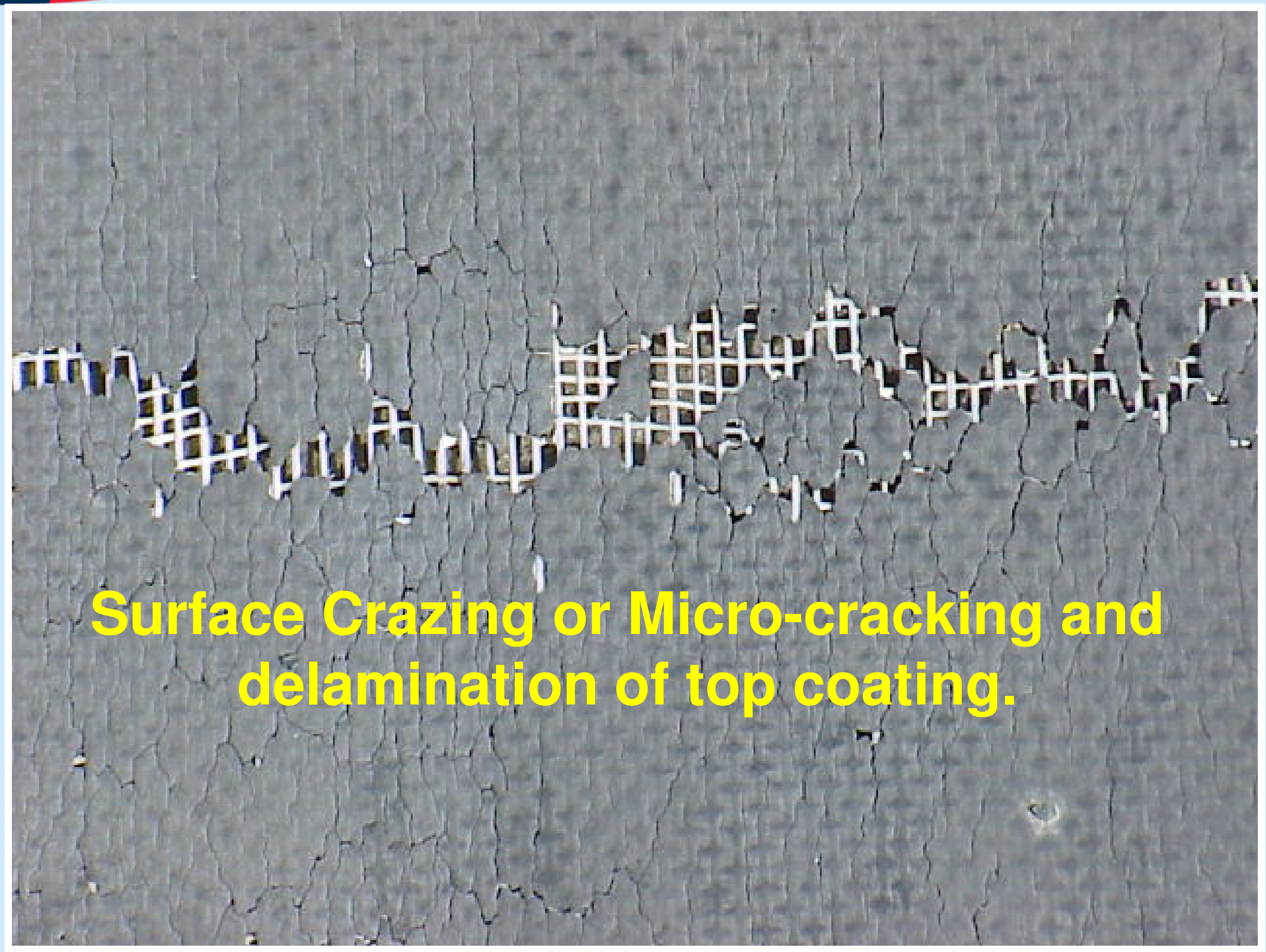
WSRCA's TPO Task Group

- Christian Madsen, WSRCA President, and the Last 10 WSRCA Presidents.
- KC Barnhardt, WSRCA Former President, Task Group Co-Chairman
- Arlene Lawson, WSRCA Executive Director
- Randy Ober, Carlisle SynTec
- Dwayne Wacenske, Firestone Building Products
- Mark Sansing, American Roofing & Metal Co., San Antonio, Texas
- Tim Gardner, Snyder Roofing, Seattle, Washington
- Misty Stoddard & Curt Miller, Rainproof Roofing, Anchorage. Alaska
- Mark Sansing, American Roofing & Metal Co., San Antonio, Texas
- Dennis Conway & Ray Snow, Commercial Roofers, Inc., Las Vegas, NV
- Tim Gardner & Kyle King, Snyder Roofing, Seattle, Washington
- Ana H. Delgado, Ralph M. Paroli, National Research Council of Canada
- Stephen Elliot, Michael Ludwig, Bill Collins, Darrell Hunt, Ernie Rosenow, Andy Leonard, and Jim Carlson of BET&R

Issues Reported by Contractors

Montana TPO Roof

Montana TPO Roof



Early Generation TPO Roof in Oregon

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Same Early Generation TPO Roof in Oregon

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There can be no progress if people have no faith in tomorrow

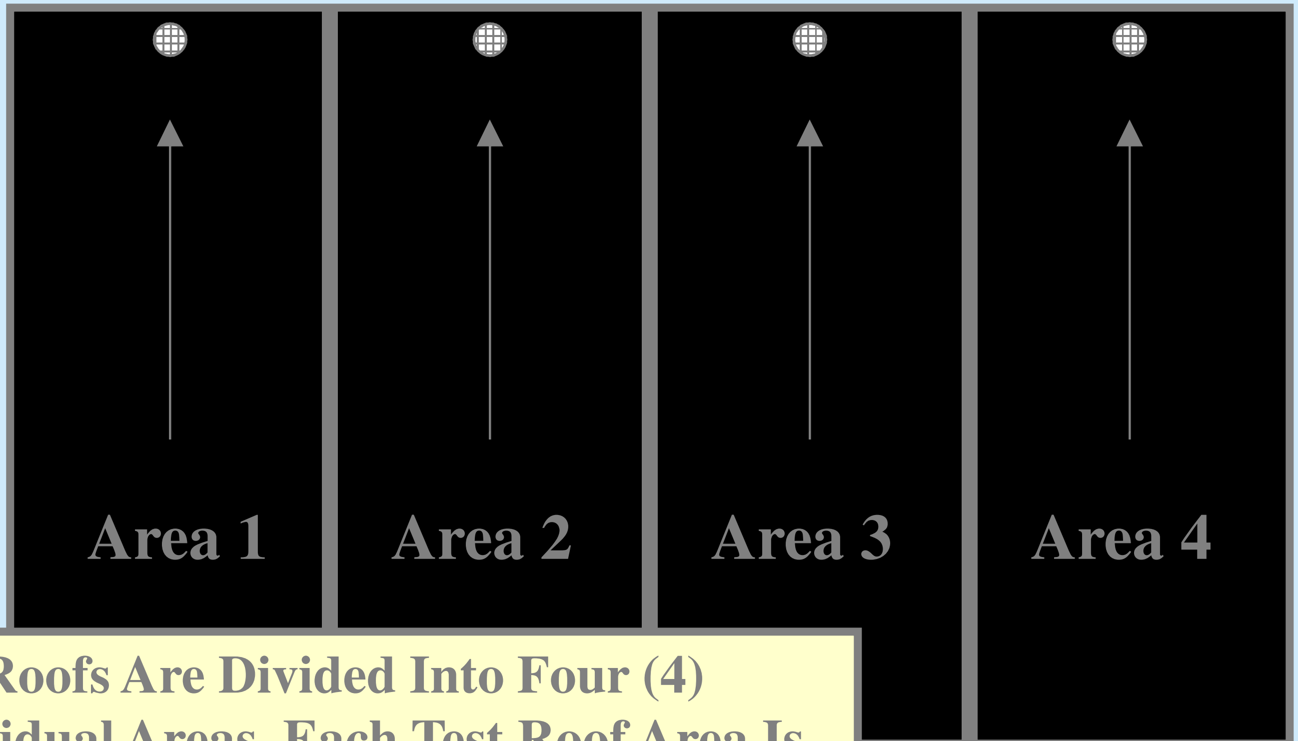
President John F. Kennedy

Program Goal

To provide pertinent technical and performance information to the North American roofing industry at large, regarding 60-mil (1.5 mm) TPO roof membrane (over polyiso) attributes, their performance properties and resistance to degradation due to the effects of weathering

Inception: 2000

General Installation and Exposure Information



The Roofs Are Divided Into Four (4) Individual Areas. Each Test Roof Area Is Separated by a Roof Area Divider and Must Drain Individually

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Overview of Properties tested

Mechanical Properties

- Thickness, Sheet Overall
- Thickness of Coating Over Scrim
- Linear Dimensional Change
- Water Absorption
- Tensile Properties
- Seam Strength
- Surface Characteristics (Thickness, Reflectivity)

Chemical Properties

- Dynamic mechanical analysis (DMA)
- Thermogravimetry (TG/DTG)
- Fourier transform infrared spectroscopy (FTIR)

Anchorage, Alaska
Cold and Damp

Las Vegas, Nevada
Hot and Dry

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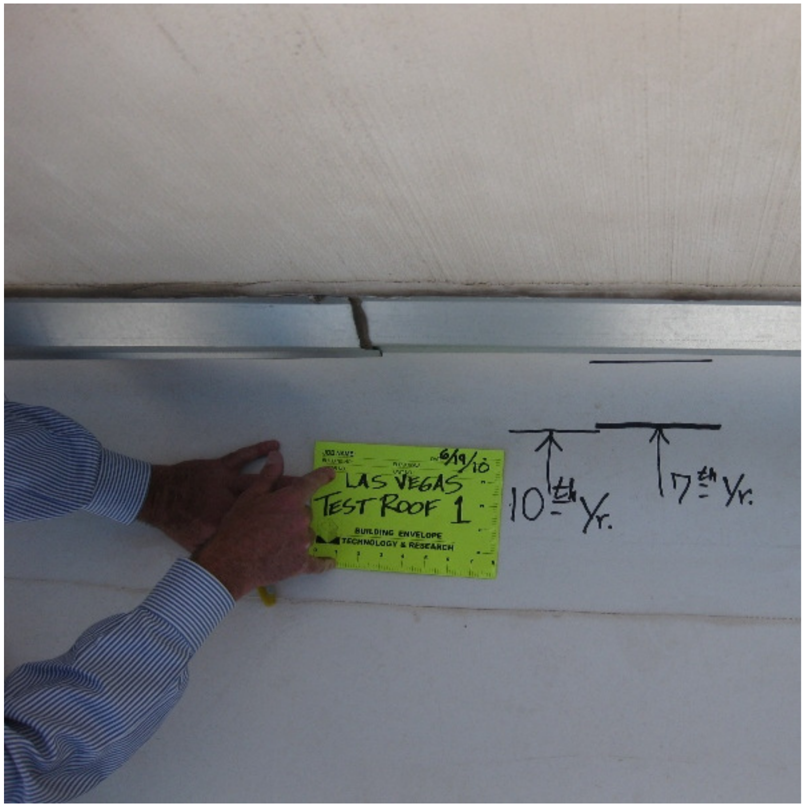
Seattle, Washington
Moderate and Wet/Dry

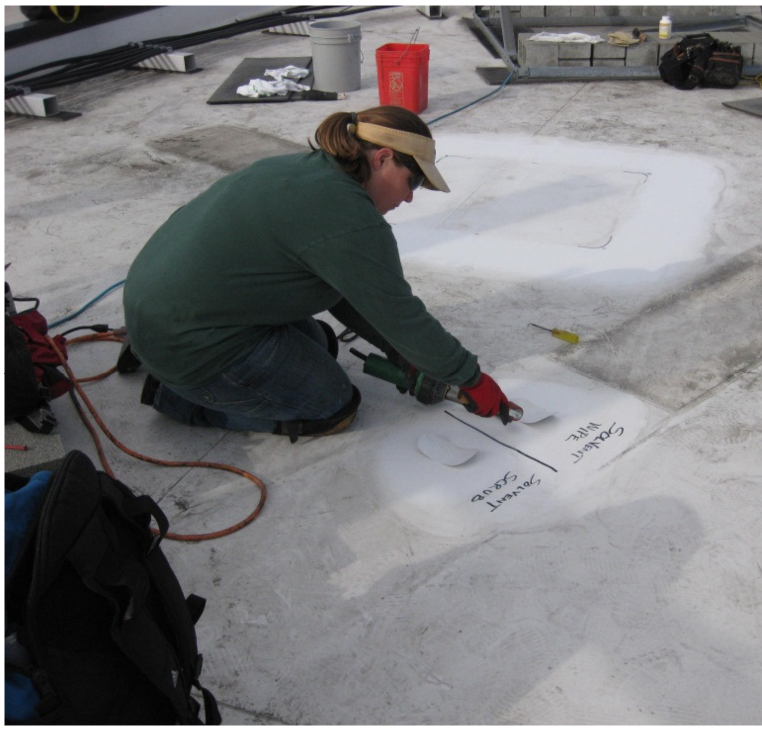
San Antonio, Texas
Hot and Humid

Las Vegas– Roof Area 2



A slight increase in tightening was observed at year ten in multiple locations.

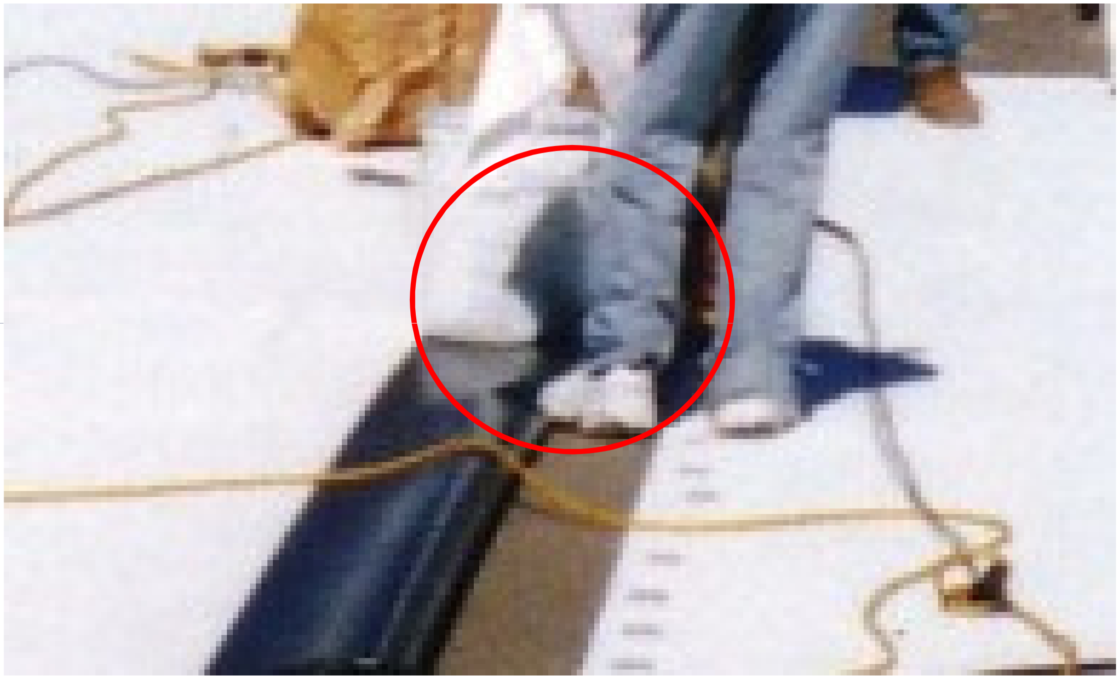
Anchorage – Roof Area 4
Weldability



Test patches were welded on the existing membrane, then field peel tests were performed.

Las Vegas – Roof Area 1

Effect of Hard Creases



A photo from original installation of the TPO membrane in 2000. Note how the bucket and roofer's foot are hard-creasing the membrane.

Las Vegas – Roof Area 2
Effect of Hard Creases

A side lap seam where creasing during installation and sun/heat load have led to cracking of the creases (2011)

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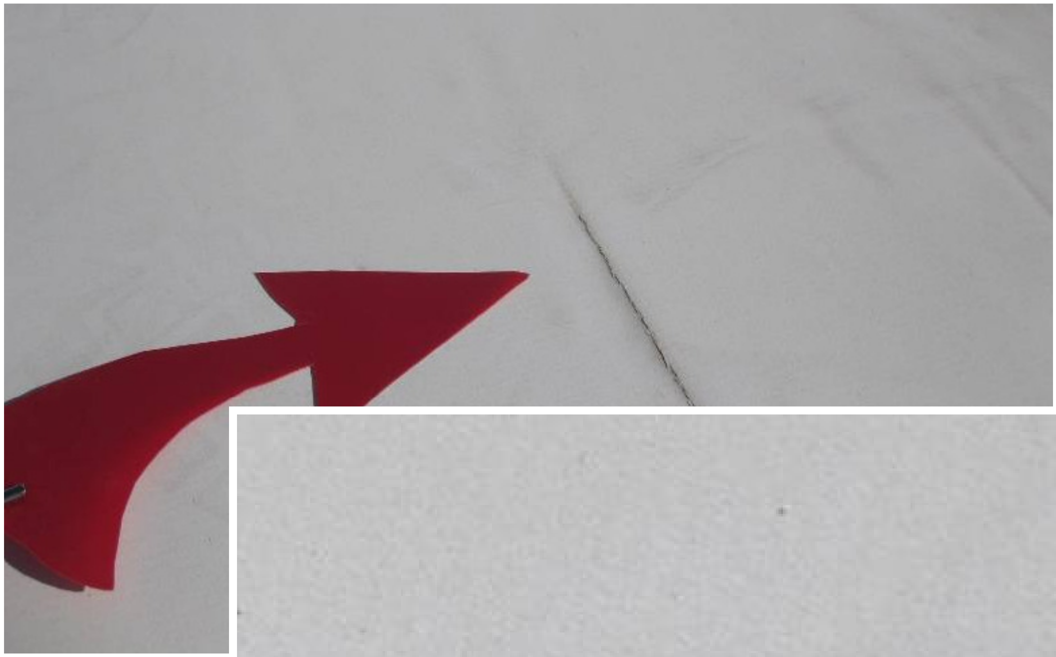
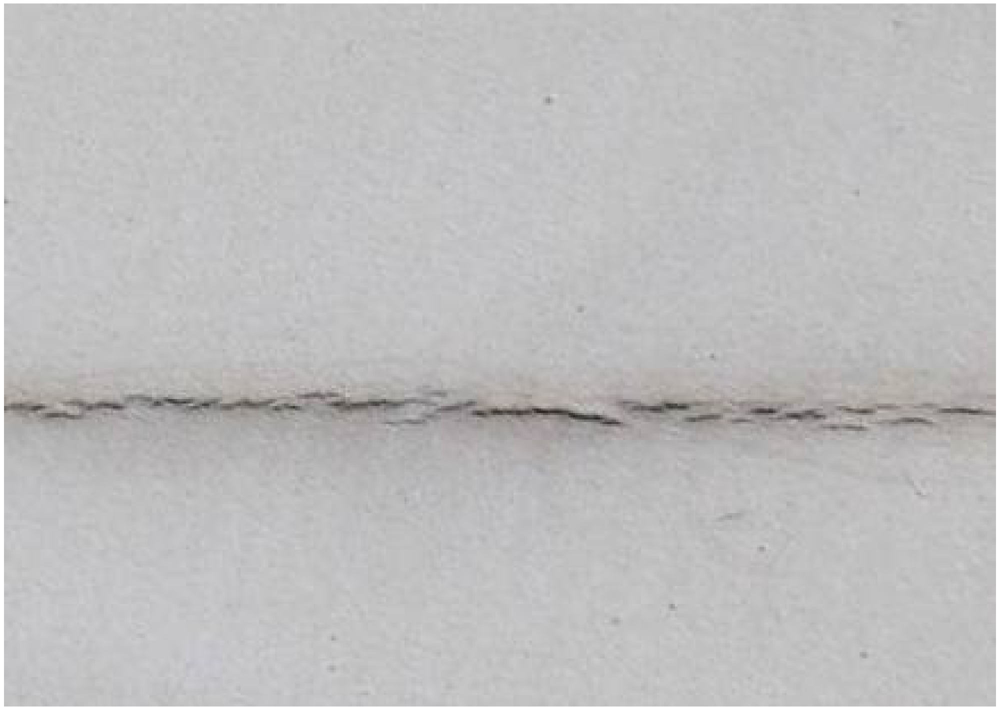
Las Vegas – Roof Area 2
Effect of Hard Creases





A close-up view of an isolated "crease crack"

Dimensional Stability

- **Change in length or width of membrane due to exposure to elevated temperatures or membrane relaxation**
  - Can affect waterproofing integrity
  - Expansion can cause wrinkling
  - Shrinkage can lead to tearing or cracking

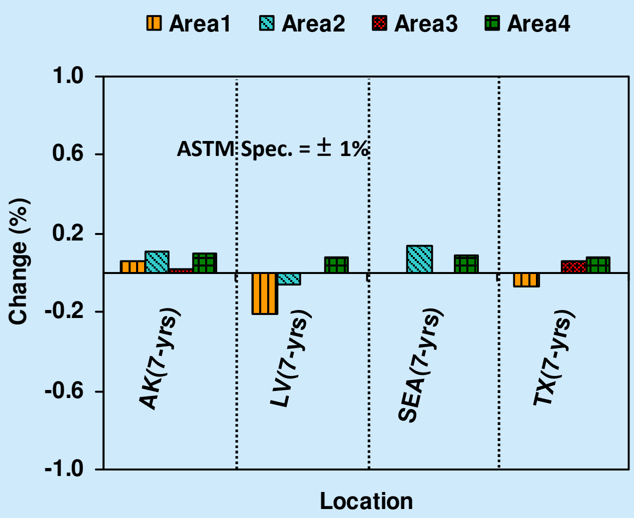
Linear Dimensional Change

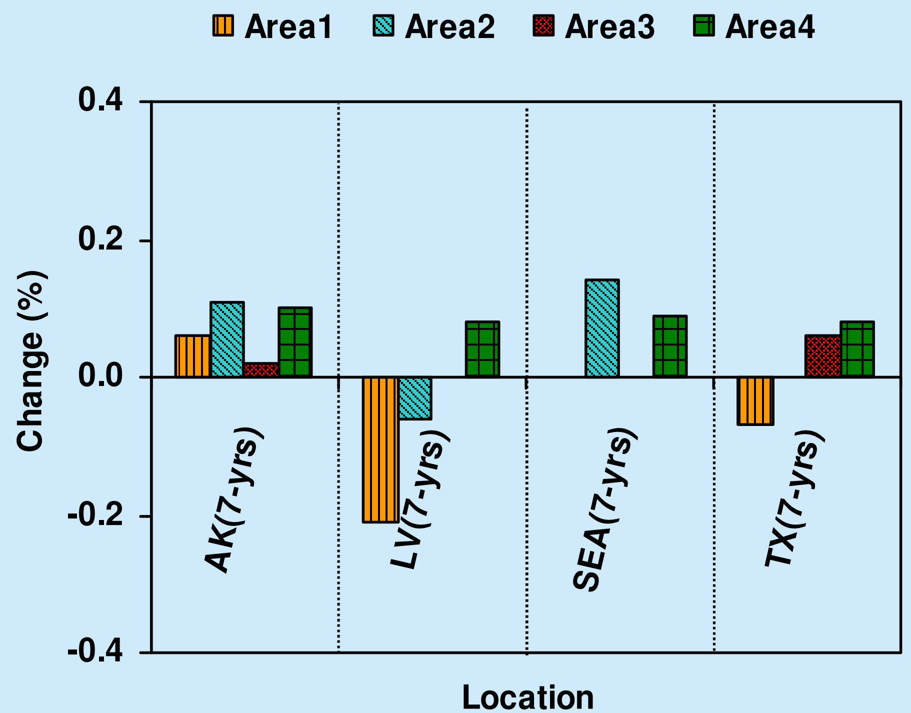
- Measured based on ASTM D1204-02
- Samples were removed from the oven and reconditioned in the laboratory at 23 ± 2°C (73 ± 4°F) and 50 ± 5% RH for at least 1 h.
- The linear dimensional change is the change in dimension as a percent of the original dimension.

$$\text{Dimensional Change} = (D_f - D_o)/D_o \times 100\%$$

A positive linear dimensional change indicates expansion while a negative value denotes shrinkage.

Linear Dimensional Change (MD)





Why is Reflectivity important?

- Solar reflectance is a key characteristic of a roof membrane in terms of mitigating the urban heat island effect and helping reduce energy demands during warmer months

- New, white TPO membranes usually have a reflective value greater than 80%, which exceeds the U.S. Environmental Protection Agency's ENERGY STAR performance levels set at 65% when new and 50% after three years exposure.

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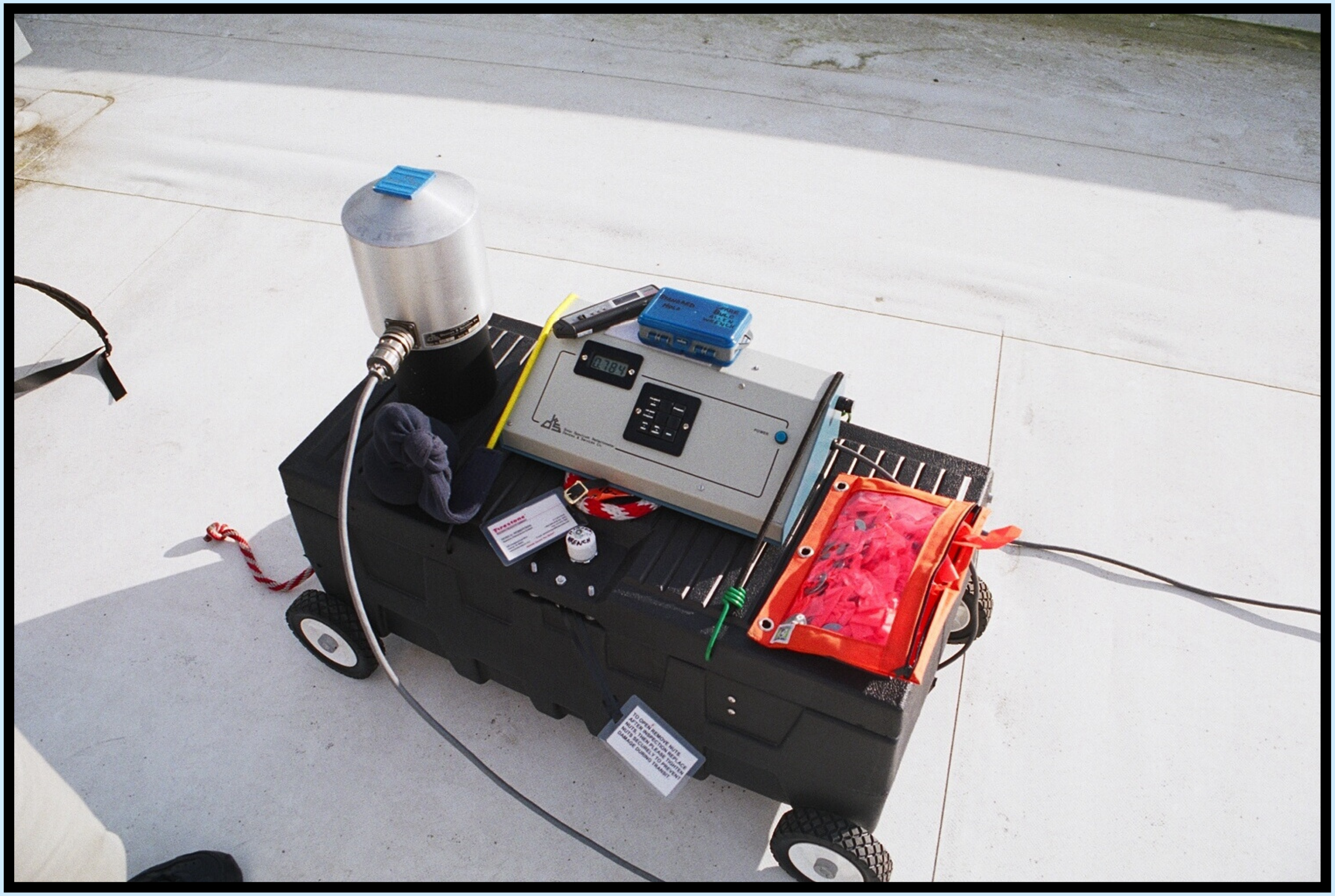
Reflectivity Testing in the Field



Reflectivity Testing

Reflectivity Testing

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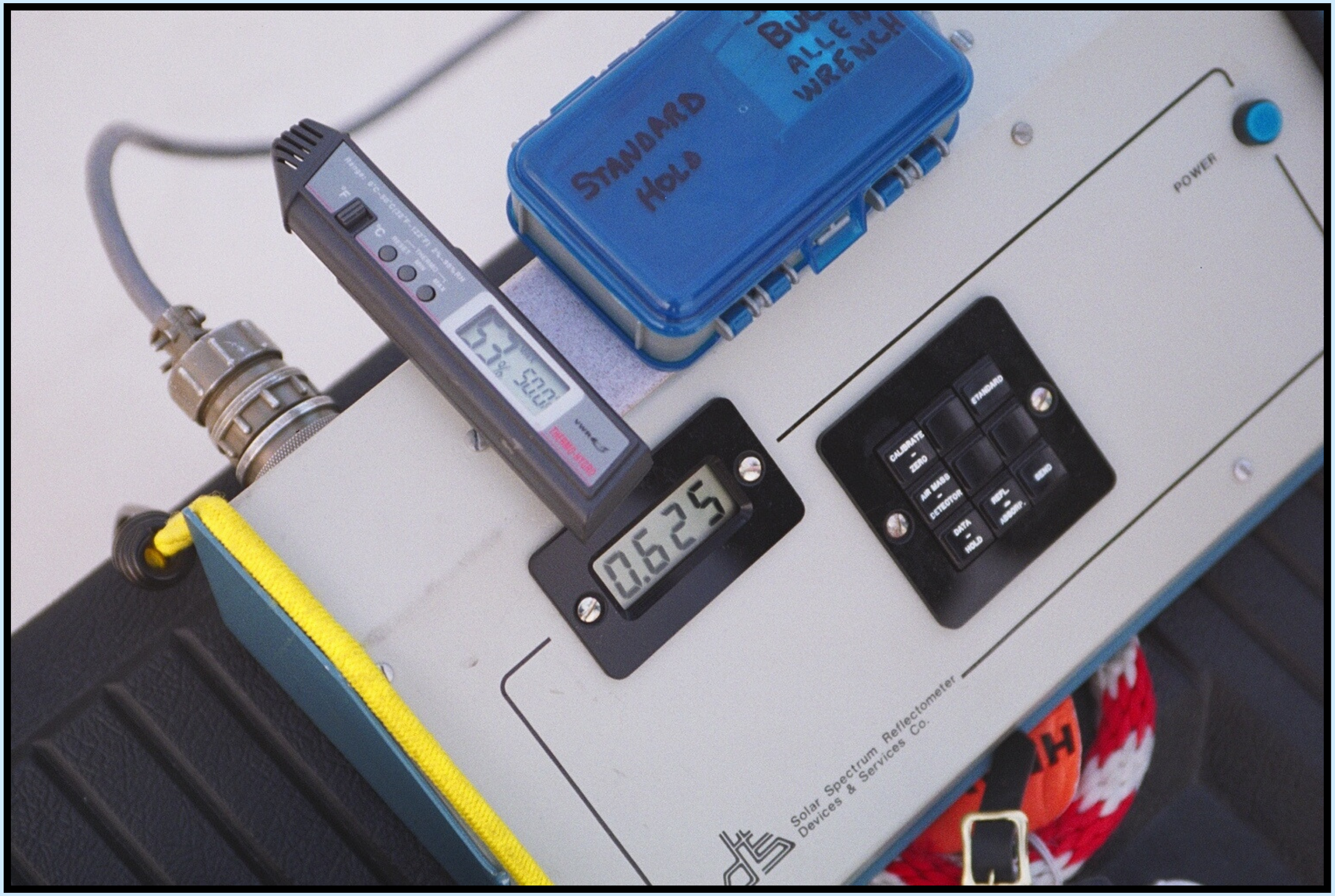
Reflectivity Testing

Reflectivity Testing

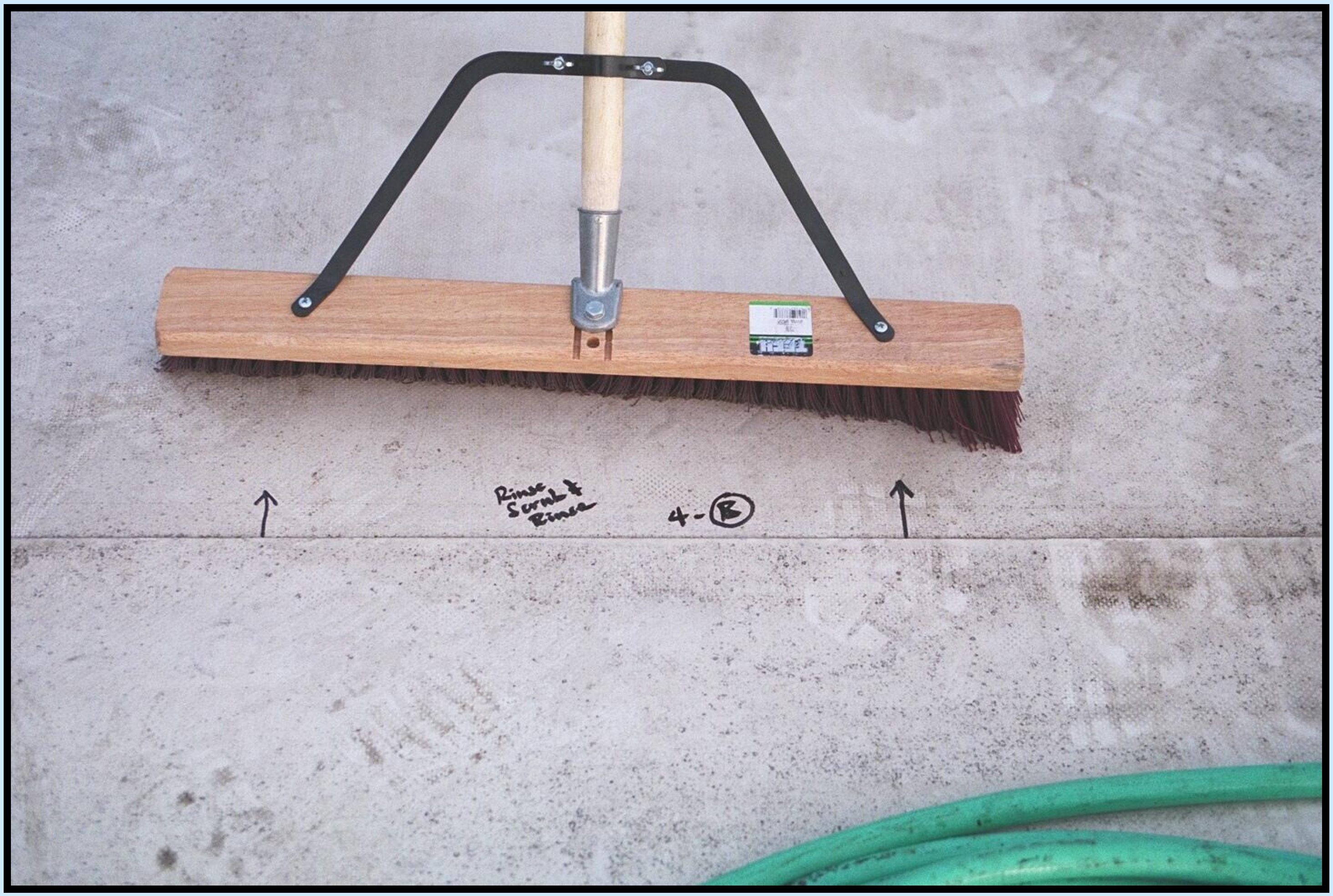
Reflectivity Testing at Cleaned Area

Reflectivity Test Reading



Pressure Washing

Scrubbing to Clean Surface



Scrubbing to Clean

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Reflectivity Testing Cleaned Areas

Solar Reflectivity Testing

WSRCA TPO WEATHERING FARM

AGE OF ROOF	TEST COMPARISONS FROM REGIONAL LOCATIONS																AVERAGE
	Anchorage, Alaska				Las Vegas, Nevada				San Antonio, Texas				Seattle, Washington				
	ROOF AREA				ROOF AREA				ROOF AREA				ROOF REA				
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
New	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Average: 0.826				Average: 0.826				Average: 0.826				Average: 0.826				0.826
7-Month	-	-	-	-	-	-	-	-	-	-	-	-	0.670	0.657	0.676	0.668	
	Average: -				Average: -				Average: -				Average:* 0.668				0.668
3-4 Year	0.720	0.595	0.603	0.626	0.693	0.721	0.654	0.701	0.000	0.000	0.000	0.000	0.683	0.605	0.618	0.656	
	Average: 0.636				Average: 0.692				Average: 0.000				Average: 0.641				0.656
	Elapsed Change: - 0.190				Elapsed Change: - 0.125				Elapsed Change: - -				Elapsed Change: - 0.186				0.170

AGE OF ROOF	CLEANED ROOF AREA TEST COMPARISONS FROM REGIONAL LOCATIONS																AVERAGE
	Anchorage, Alaska				Las Vegas, Nevada				San Antonio, Texas				Seattle, Washington				
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
New	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Average: 0.826				Average: 0.826				Average: 0.826				Average: 0.826				0.826
3-4 Year	0.774	0.680	0.681	0.723	0.746	0.761	0.742	0.783	0.000	0.000	0.000	0.000	0.713	0.628	0.669	0.732	
	Average: 0.715				Average: 0.758				Average: 0.000				Average: 0.686				0.719
	Elapsed Change: - 0.112				Elapsed Change: - 0.068				Elapsed Change: -				Elapsed Change: - 0.141				0.107

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Reflectivity Testing

WSRCA TPO WEATHERING FARM

PROJECT: LAS VEGAS, NEVADA	**DATE:** 6/3/2004
SURFACE TYPE: WHITE TPO	**AGE OF SURFACE:** Approx. 48 MONTHS
ROOF AREA: 4	**REFLECTANCE OPERATOR:** Ross Robertson
PURPOSE: REFLECTIVITY / REFLECTANCE TESTING	**METER READER AND**
INSTRUMENT: D & S Model SSR-ER (Version 5.0)	**DATA ASSEMBLY:** Ernie Rosenow
ON-SITE CALIBRATION: START 0.787, END 0.787; **INDUSTRY STANDARD CALIBRATION:** NBS A92 = 0.787	**TEMPERATURE & HUMIDITY:** 129 F at 3%

REFLECTIVITY TESTS ON EXISTING/UNCLEANED TPO ROOF MEMBRANES

TEST ZONE	EXISTING/EXPOSED ROOF AREA TEST LOCATIONS					AVERAGE
	A	B	C	D	E	
1	0.707	0.712	0.711	0.705	0.671	0.701
2	0.680	0.669	0.672	0.689	0.696	0.681
3	0.714	0.709	0.699	0.713	0.707	0.708
4	0.704	0.696	0.703	0.688	0.678	0.694
5	0.692	0.700	0.679	0.686	0.699	0.691
6	0.705	0.702	0.707	0.700	0.714	0.706
7	0.694	0.724	0.710	0.709	0.708	0.709
8	0.719	0.710	0.718	0.709	0.705	0.712
9	0.716	0.713	0.709	0.707	0.712	0.711
10	0.689	0.697	0.701	0.688	0.680	0.691
TOTAL ROOF AREA 4 AVERAGE:						**0.701**

ROOF AREA	COMPARISON OF ENTIRE ROOF AREA AVERAGE
1	0.693
2	0.721
3	0.654
4	0.701
ENTIRE ROOF AREA REFLECTIVITY AVERAGE	**0.692**

REFLECTIVITY TESTS ON CLEANED TPO ROOF MEMBRANES

ON-SITE CALIBRATION: START 0.758, END 0.787; **TEMPERATURE & HUMIDITY** 132 F at 2%

TEST ZONE	CLEANED TEST LOCATIONS					AVERAGE
	A	B	C	D	E	
4A*	0.768	0.774	0.765	0.761	0.755	0.765
4B^	0.804	0.795	0.808	0.800	0.804	0.802
AVERAGE:						**0.783**

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Reflectivity Laboratory Measurements

Experimental procedure

- **Unexposed, three, seven and ten years samples from the WSRCA research project were selected for reflectivity measurements**
- **Five specimens 3 cm x 4 cm (1.2 in x 1.6 in) in size were cut from each of the 'as received' (0-, 3- and 7-yrs) samples. Due to time limitation, only two specimens from each of the ten years samples were cut and tested.**

Reflectivity
Laboratory Measurements

- A Cary 5E UV-VIS-NIR spectrophotometer equipped with a diffuse reflectance accessory and the Cary WinUV Scan software was used to measure the reflectivity of specimens
- The top ply surface of the specimen before and after cleaning was measured in the 2500–300 nm range
- The specimen surface was cleaned by wiping the surface with a damped kimwipes and allowed to dry for at least 20 minutes before re-scanning.

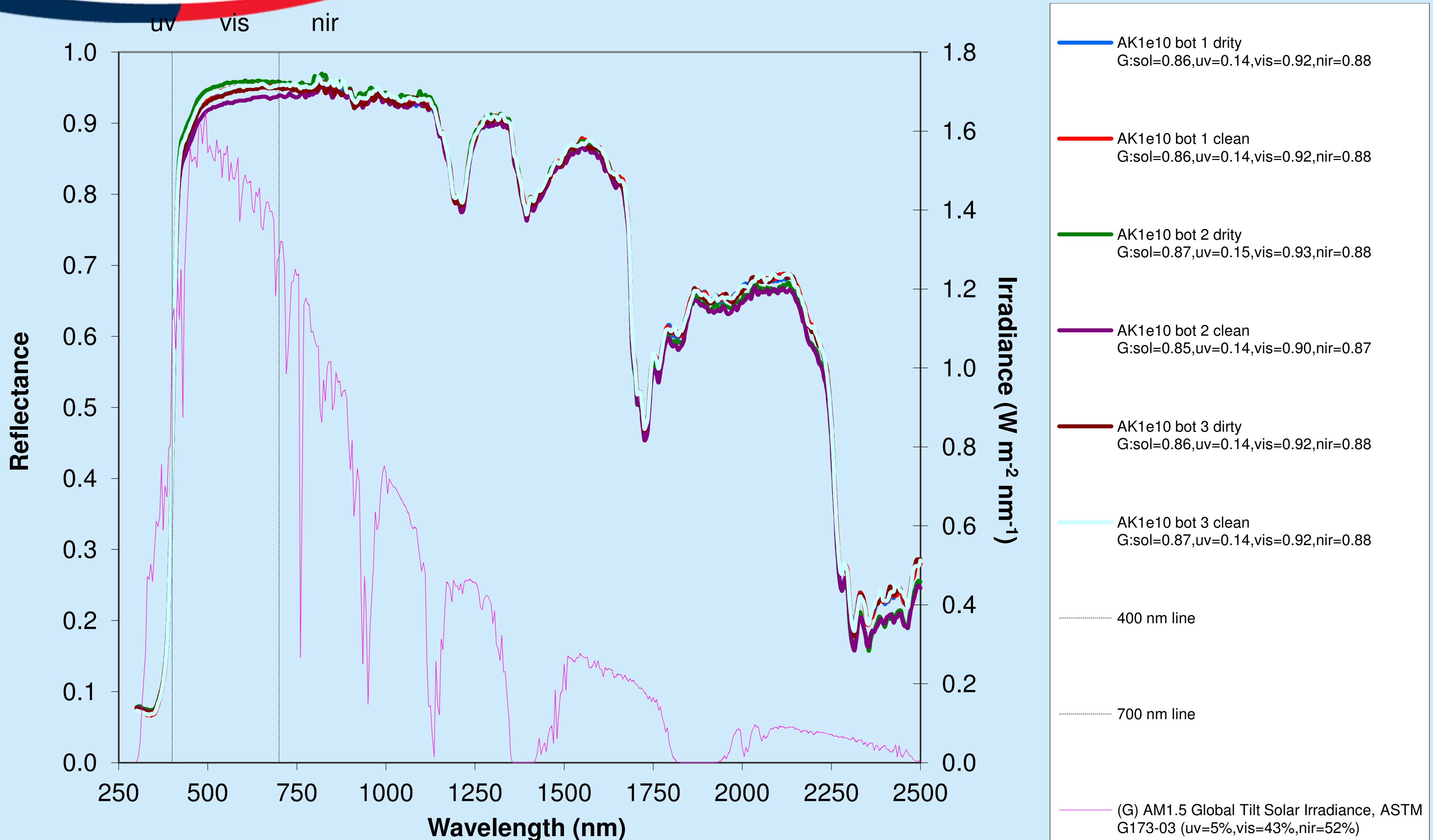
Reflectivity Calculations

- The *E903 Tool Simplified0011 integrator*[a], which is the newest version of the *Spectral Integrator Workshop*[b] was used as calculating tool

[a] *E903 Solar Reflectance, Coded by Ronnen Levinson, Lawrence Berkeley Laboratory. Revised 2008-03-02 to remove display of direct-normal ("collimated") solar reflectance*

[b] *Courtesy of Dr. Hashemn Akbari and Dr. Ronnen Levinson, Heat Island Group, Lawrence Berkeley National Laboratory, USA*

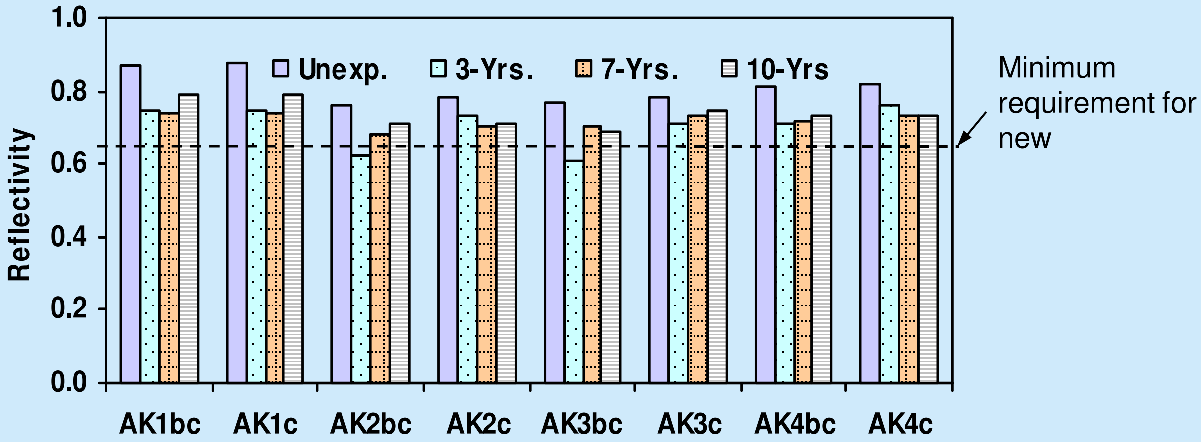
Typical Reflectance Graphs from Integrator

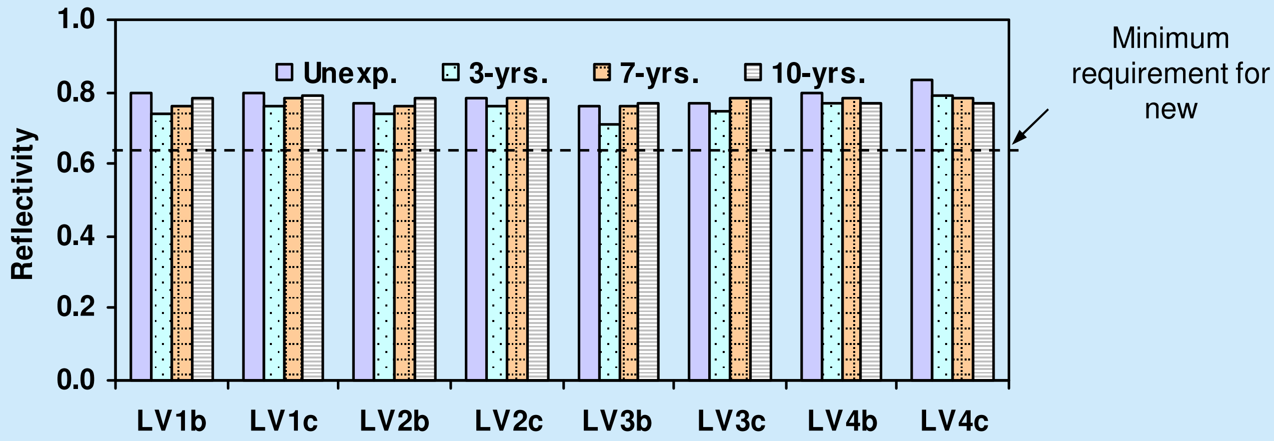


sol=300-2500 nm; uv=300-400 nm; vis=400-700nm; nir=700-2500 nm

Laboratory Reflectivity

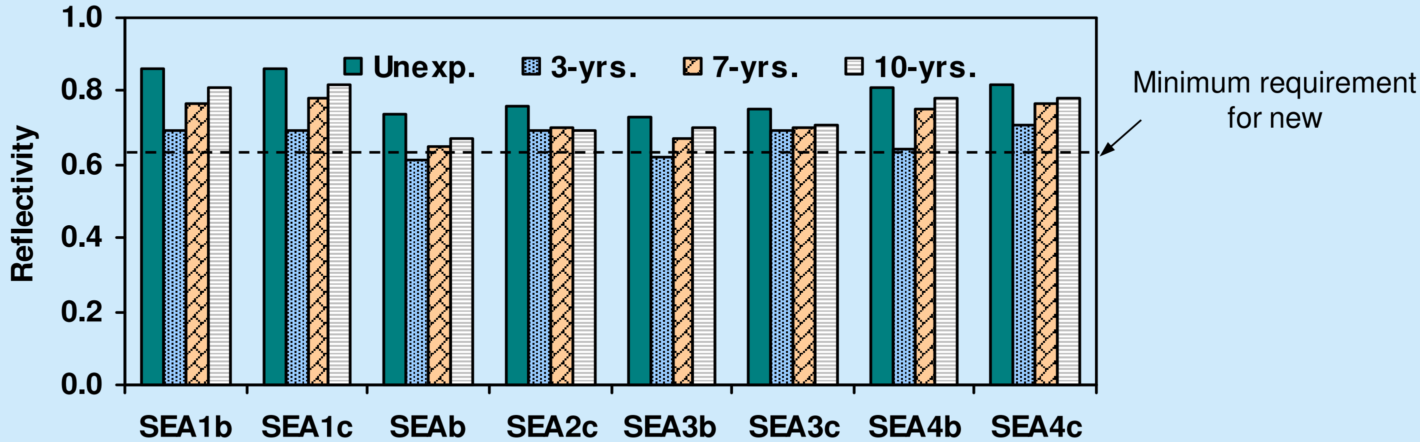
b = before cleaning   c = clean

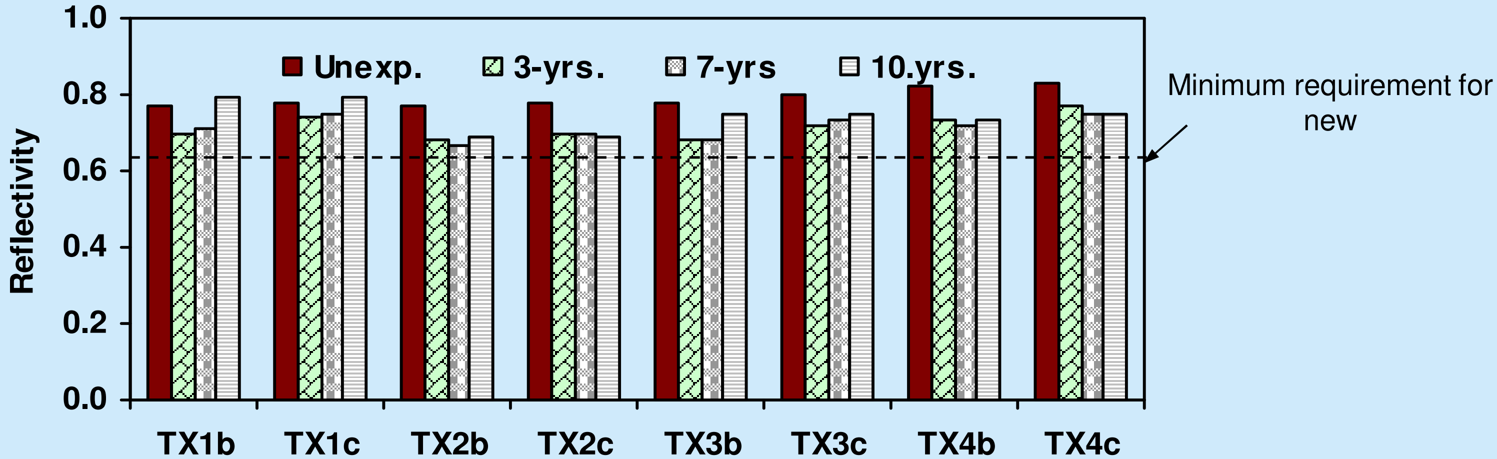




Laboratory Reflectivity

b = before cleaning **c = clean**





Conclusions

- The linear dimensional change of all seven years samples was within the maximum allowable limit of ±1% as specified in ASTM D6878 for new membranes.
- After the small changes observed in the first year of exposure, the linear dimensional stability in MD and XD remained almost unchanged up to seven years of service in the field.
- In general, the reflectivity of the roof membranes increased by less than 10% after cleaning, regardless of the cleaning method with the exception of the Texas field values, which show an increase up to 16% after cleaning.

Reflectivity

- Reflectivity values for the new samples measured in the laboratory are, in general, similar to those measured in the field.
- Values for exposed samples show larger differences.
  - Alaska and Las Vegas, the difference between lab and field values range from 0 to 8% and increases to 15% for the Texas samples
- The reflectivity values for the 3- and 7-year samples before cleaning (2nd time) range from 61% to 87% and from 69% to 88% after cleaning with a damped cloth.
- Higher reflectivity values after cleaning. Values after cleaning are above the 50% ENERGY STAR™ specified limit for exposed membranes

General Conclusions

- **Climate plays a large role in the service life of all roof systems, including TPO materials.**
- **In general, all four test areas in all four climatic regions are doing well, with the exception of one area at the Las Vegas site.**
  - Alaska: cold, harsh climate, roof covered with snow for weeks.
  - Las Vegas: hot, dry, and extremely sunny climate.
  - San Antonio: hot, humid, and sunny climate with hail.
  - Seattle: cool and rainy, predominantly cloudy climate.

Las Vegas – Roof Area 2

Conclusions (continued)

- The widespread rumored TPO craze-cracking, reported by some to be happening on many aging TPO roofs **was not experienced with these 60-mil, white TPO roof research and testing project**.

- Crease-cracking was experienced on one roof area in one isolated location in San Antonio at year 7, and in numerous locations on one roof area in Las Vegas at year 10.

  – Those cracks were initiated by creasing of the roof membrane during installation – a practice that was discouraged by the Task Group 5 years ago

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Conclusions (continued)

- Micro-cracking adjacent to the outer seam edge was observed at year ten on the Las Vegas roof area that also experienced crease-cracking.
- Some hand-welded T-joint covers, corner boots, and other hand-welded seam edges experienced some disbonding. But, no robotic-welded seams disbonded during this 10+ year study.
- The disbonded hand welds and the crazed or cracked membranes were all repairable, and all membranes are serviceable today.
- No widespread-catastrophic problems were observed. In general, these “3rd generation” white 60-mil TPO membranes are performing successfully.

Recommendations

- When specifying TPO roof membranes, consider using white, 60 mil (minimum). In hot, sunny, or high-altitude sunny regions, WSRCA also strongly suggests thicker membranes be considered.

- WSRCA strongly urges ASTM and other standards-setting organizations to develop rating classifications, which could include Types (e.g., Type I, Type II, etc.) and/or grades (e.g., 1, 2, 3, or Commodity-Grade, Commercial-Grade, Premium-Grade, etc.) for all roof system categories, including all single-ply membranes.

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Recommendations
(continued)

- As with all roof systems, WSRCA recommends inspecting TPO roofs on a yearly (minimum) basis.
- Just like regular service extends the life of your car – regular roof inspections, maintenance, and repairs – extend the life of all roof systems.
- Regular roof inspection, maintenance, and repair is essential for the longevity of the roof system.
- Every roof system is different, thus different repair techniques may be required. To thoroughly address TPO repair techniques, WSRCA developed the *TPO Maintenance and Repair Guidelines*.

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TPO ROOF MEMBRANE
REPAIR AND MAINTENANCE GUIDELINES

Western States Roofing Contractors Association
Serving the Roofing & Waterproofing Industry of the Western United States

First Edition -- 2011
Supplement to the 2011 WSRCA TPO Roofing Research and Testing Program 10th-Year Report

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In Memory of Terry Simmons

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Thank you!