



Measuring the specular reflectance of ReflecTech film on a parabolic trough concentrating solar collector.

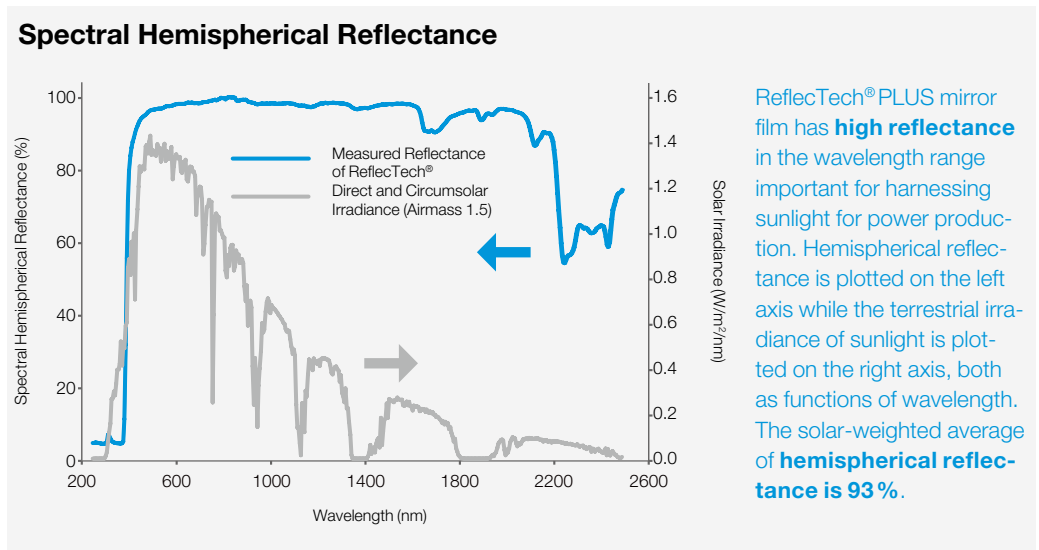
“ReflecTech polymer film is a viable alternate to glass mirrors, offers comparable performance and durability, and is not susceptible to breakage as are glass mirrors.”

Sargent & Lundy, LLC

Product Information

Construction

ReflecTech[®] PLUS mirror film uses pure silver to provide high specular reflectance and multiple layers of polymer films to protect against extreme outdoor environments including ultra-violet (UV) radiation and moisture. ReflecTech[®] PLUS mirror film has a pressure sensitive adhesive for application to aluminum sheet and a peel-off release liner that covers the adhesive until application. A tough, transparent coating protects the film against abrasion.



ReflecTech[®] PLUS Mirror Film Attributes:

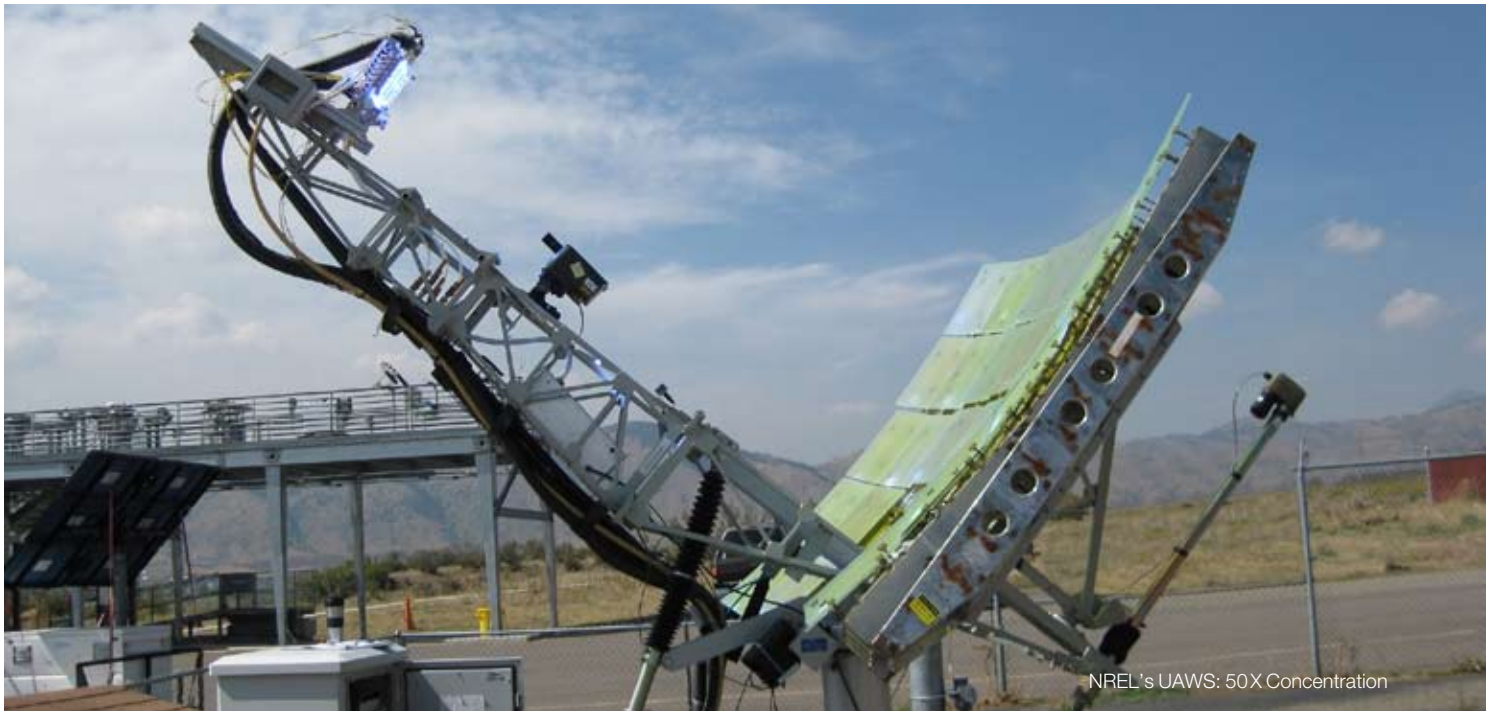
- **High Reflectance**
- **Outdoor Weatherable**
- **Ultra Lightweight**
- **Abrasion Resistant**
- **Commercially Proven**
- **Low Cost**
- **Self Adhesive**

ReflecTech[®] PLUS mirror film was developed in partnership with the U.S. National Renewable Energy Laboratory (NREL). (US Patents 6,989,924 and 7,612,937)



Excellent Outdoor Weatherability

ReflecTech[®] PLUS mirror film recently surpassed the 30 year milestone in a long term durability test conducted with NREL's Ultra-Accelerated Weathering System (UAWS).



NREL's UAWS: 50X Concentration

Abrasion Resistant Coating

ReflecTech®PLUS has an abrasion resistant coating that protects the reflector surface.

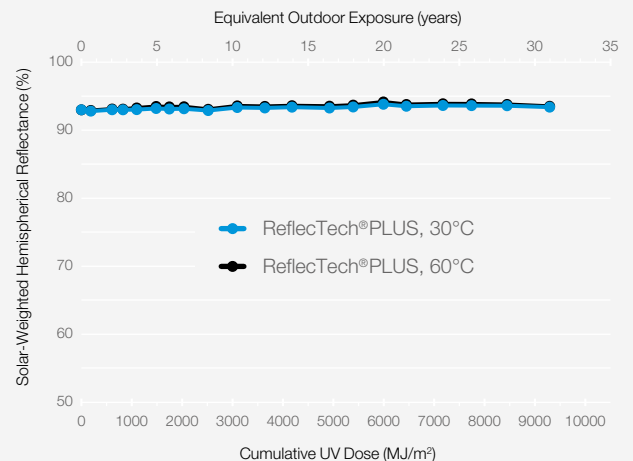
ReflecTech, Inc., Red Spot Paint & Varnish Company, Inc., and the National Renewable Energy Laboratory (NREL) collaborated on the development of this tough, transparent coating. ReflecTech®PLUS is recommended when reflectors are washed using scrub brushes, or other contact cleaning methods that are typical of those used in solar fields. Details of the development process are documented in a paper⁽¹⁾ presented at the Solar PACES conference in 2010.

Durability Testing

Testing Summary

Samples of ReflecTech®PLUS were tested under accelerated conditions, in terms of both weathering and contact cleaning. Weathering is simulated by exposure to concentrated ultraviolet (UV) radiation and elevated temperature and humidity. Specular reflectance after exposure was measured to determine performance under the various accelerated stress conditions including abrasion, and outstanding resistance to UV radiation, temperature, humidity, and abrasion was demonstrated.

Optical Durability



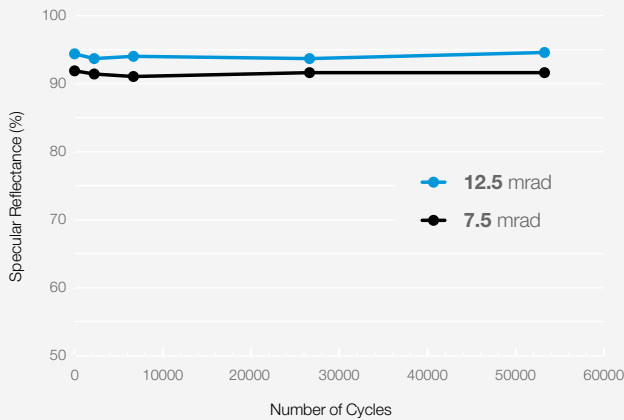
UAWS Exposure at 30°C and 60°C

After receiving the equivalent cumulative UV dose of over 30 years of outdoor exposure, no degradation and no loss in reflectance were measured in samples of ReflecTech®PLUS.

Accelerated Weathering

Samples of ReflecTech®PLUS have undergone durability testing using the Ultra-Accelerated Weathering System (UAWS) at the U.S. National Renewable Energy Laboratory (NREL). UAWS is the most accelerated method to determine the long-term durability of a material to outdoor UV exposure. The UV portion of natural sunlight is concentrated 50X while sample exposure temperatures are maintained at 30°C and 60°C to accelerate degradation mechanisms.⁽²⁾

Abrasion Resistance



Scrub Test

Abrasion resistance of ReflecTech®PLUS in terms of scrub brush cycles. Specular reflectance was measured at 660 nm, and $\theta = 7.5$ and 12.5 mrad half acceptance angles.

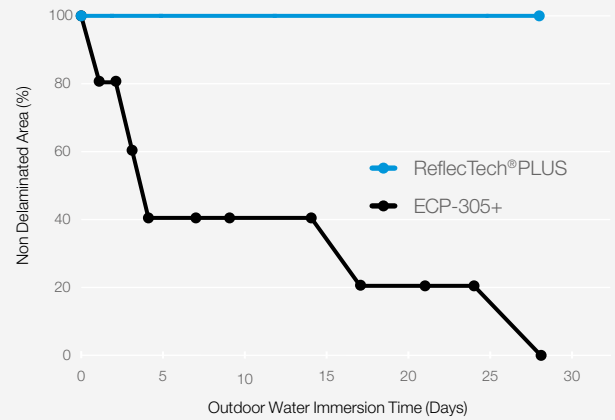
Abrasion Resistance – Scrub Test

To simulate the most aggressive solar field mirror cleaning process, ASTM D2486⁽⁹⁾ was performed with a BYK Model PB5005 wet abrasion scrub tester. This test uses linearly articulated scrub brushes cycled in a back-and-forth motion 37 times per minute across the surface of ReflecTech®PLUS. The figure illustrates that no loss in specular reflectance occurred after over 50,000 back-and-forth scrub brush cycles, simulating more than 50 years of scrub cleaning.



Brushes used in scrub test to simulate aggressive cleaning of ReflecTech®PLUS.

Resistance to Moisture Induced Delamination



Water Immersion Tests

ReflecTech®PLUS mirror film demonstrated complete resistance to delamination during an extended water immersion test, conducted at NREL. In this graph, ReflecTech®PLUS is compared to ECP 305+, a mirror film that was removed from the market by its manufacturer due to its propensity to delaminate when exposed to moisture.

Resistance to Moisture

Samples of ReflecTech®PLUS laminated to aluminum panels were immersed in deionized water for 30 days. There was no sign of delamination at any layer interface. The cross hatch tape peel test was also performed after immersion, and there was no loss of adhesion.

Other Standard Tests ⁽⁹⁾

- UV | Temperature | Moisture Test (ASTM G 155): 2X UV | 30°C & 60°C | 5% & 60% Relative Humidity: 12,000 hours – **pass**
- Outdoor Test (ASTM G90) 5X sunlight & hourly water spray: 7,500 hours – **pass**
- Water Resistance Test (ASTM D870) 60 days of immersion – **pass**
- Cyclic Condensation (ASTM D4587): 100% relative humidity | 30°C & 60°C: 100 cycles – **pass**
- Taber Abrasion (ASTM D4060) | 30 cycles before and after weathering – **pass**
- Adhesion of Coating (ASTM D3359) | Cross hatch tape peel test before and after weathering – **pass**
- Bending Test (ASTM D522) @ 25 mm radius and above – **pass**
- Hail Test (ASTM E822) front and back, 1" diameter – **pass**
- Falling Sand Abrasion (ASTM D968) | 2 liters of 120 grit sand – **pass**

References:

- (1) Gary Jorgensen, Randy Gee, and Michael DiGrazia, "Development and Testing of Abrasion Resistant Hard Coats for Polymer Film Reflectors", Solar PACES, 2010.
- (2) H. K. Hardcastle, G. J. Jorgensen, and C. E. Bingham, "Ultra-Accelerated Weathering System I: Design and Functional Considerations", *Natural and Artificial Ageing of Polymers – 4th European Weathering Symposium*; Reichert, T., Ed. Publication No. 11, Gesellschaft fur Umweltsimulation: Germany, 2009.
- (3) American Society of Testing and Materials (ASTM) Annual Book of Standards, ASTM International, West Conshohocken, PA, www.astm.org.

Technical Data

ReflecTech® PLUS mirror film

Performance Characteristics

Specular Reflectance ⁽⁴⁾	94 %	At 25 mrad, 660 nm
Solar-Weighted Hemispherical Reflectance ⁽⁵⁾	93 %	ASTM E 891

(4) Measured on Devices & Services 15R Specular Reflectometer

(5) Integrated over direct normal air mass 1.5 solar spectrum.

Product/Physical Characteristics

Nominal Thickness (mm)	0.1		
Coefficient of Thermal Expansion (cm/cm/°C)	5.5x10-5		ASTM E831
	Machine Direction	Transverse Direction	
Tensile Strength (MPa)	61	64	ASTM D882
Elongation at Break (%)	88	72	ASTM D882
Yield Strength at 2 % Offset (MPa)	40	36	ASTM D882
Yield Elongation at 2 % Offset (%)	4.7	4.6	ASTM D882
Modulus (MPa)	1430	1566	ASTM D882

Application Characteristics

Adhesion to Aluminum ⁽⁶⁾		
180° Peel Strength (N/25 mm)	10.0	ASTM D903

(6) Adhesion depends on the cleanliness and nature of the surface. The indicated values are for reference only.

Storage and Operation

Shelf Life ⁽⁷⁾	1 year	
Maximum Operating Temperature	60°C	(140°F)
Cleaning	Standard wet brush cleaning or pressure wash with de-mineralized water	

(7) Store in clean and dry environment at a temperature of 38°C (100°F) or less.

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