

Measuring Water Vapor Transmission Rates (WVTR) of 3M™ Ultra Barrier Solar Films

Background

Through various tests, 3M™ Ultra Barrier Solar Films have demonstrated a Water Vapor Transmission Rate (WVTR) of less than 5×10^{-4} g/m²/day at 23°C. However, validating WVTR measurements below 10^{-3} g/m²/day is difficult and/or time consuming due to limitations on currently available measurement equipment and techniques. The best determinant to ensure that the WVTR performance is adequate is to test the actual film in a solar module construction via 85°C/85% RH Damp Heat testing. Multiple solar modules utilizing 3M™ Ultra Barrier Film 9L have far exceeded the 1,000 hours testing requirement outlined in IEC 61646. 3M is evaluating alternative methods to support high volume production testing of WVTR. These methods may be available by June 2012.

Current 3M WVTR test protocol for 3M Ultra Barrier Solar Films production product release

- Individual production lots of 3M Ultra Barrier Solar Films are screened for WVTR using a MOCON® Permatran® 700 at 50°C and 100%RH. The test is allowed to run until the standard deviation of the last five readings is less than 0.0025. Individual lots are evaluated for pass/fail at the machine detection limit of 0.007 g/m²/day.
- 3M Ultra Barrier Solar Film has been demonstrated to show an Arrhenius relationship with regard to its WVTR performance. Thus, the WVTR approximately doubles for every 10°C increase in temperature.
- Applying such an Arrhenius relation, 0.007 g/m²/day at 50°C is approximately 0.0011 g/m²/day at 23°C.
- All released 3M Ultra Barrier Solar Films have been sampled and tested below the detection limit for MOCON® Permatran® at 0.007 g/m²/day at 50°C and are shipped with a certificate of conformance.

Testing WVTR on 3M Ultra Barrier Solar Film 9L

If validation of receivables is desired using MOCON® instruments, the following procedures are recommended:

- Identify and label sides of samples. The sun-facing side is the Fluoropolymer side.
- Care should be taken to properly zero the MOCON® Aquatran® or Permatran®. The Green calibration sample provided by MOCON Inc. should be used. All calibration films should be run at 37.8°C. It is critical to properly zero the Aquatran® or Permatran® before measuring 3M Ultra Barrier Solar Film. Zero is reached when the certified foil sample measurements are within 1% over a 24 hour period. That is, measurements must be within 0.0005 g/m²/day at 37.8°C.
- WVTR testing on the 3M Ultra Barrier Solar Film should be performed at 50°C and 100%RH.
- When placing the test specimen in the Permatran® 700 or Aquatran®, place the fluoropolymer side towards the moisture source.
- The test should be allowed to run until the standard deviation of the last five readings is less than 0.0025. 3M recommends repeating tests two to three times on any given sample to gain confidence in values at low detection.
- When making multiple measurements on the same sample, the sample should be thoroughly cleaned and all mounting grease removed.
- When the final WVTR is measured, the last five data points should be reported for verification. The zero calibration should also be recorded. See typical transmission rate graph below.

An alternate to MOCON® testing is to run a Calcium test as described by NREL*. This is currently the preferred method for the most accurate results; however, the time to run the test may be considerably longer.

Results should be consistent with the following table and graph:

Water Vapor Transmission

Initial WVTR Performance of 3M Ultra Barrier Film 9L (UBF9L) by Various Methods

| Method | Detection Limit (g/m ² /day) | Temperature (°C)/RH(%) | UBF9L (g/m ² /day) |
|-------------------|---|------------------------|-------------------------------|
| MOCON® Permatran® | 0.005 | 50/100 | <0.005 |
| MOCON® Aquatran® | 0.0005 | 50/100 | <0.0005 |
| NREL Ca Test* | 10 ⁻⁶ | 45/85 | 5 ± 3 × 10 ⁻⁵ |

*See http://www1.eere.energy.gov/solar/pdfs/pvrv2010_dameron.pdf



Example of MOCON® 700 Generated Test Report

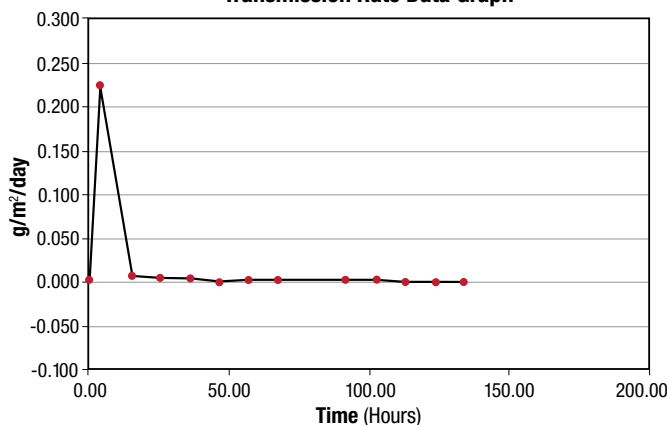
| Module Information | Typical Values |
|----------------------|-------------------------|
| Module 3, Serial | MA_01029 |
| Setup Name | Default Setup |
| Temp Setpoint/Actual | Auto: 50.0/50.0°C |
| Barometric Pressure | Manual: 760.00 mmHg |
| Relative Humidity | Permeant - Manual: 100% |
| Flow Rate | Auto: 9.98 SCCM |
| Ambient Temperature | Auto: 26.1°C |

| Cell B Information | Typical Values |
|--------------------|----------------------------------|
| Sample Type | Film: 50 cm ² , 1 mil |
| Test Mode | Continuous |
| Control Parameters | Infinite |
| Exam Minutes | 60 |
| Individual Zero | Use Last: 7.0120E-3 |
| Conditioning | 1 Hour |
| Cycles Complete | 12 |
| Current Status | Finished |
| Elapsed Time | 133:33 |

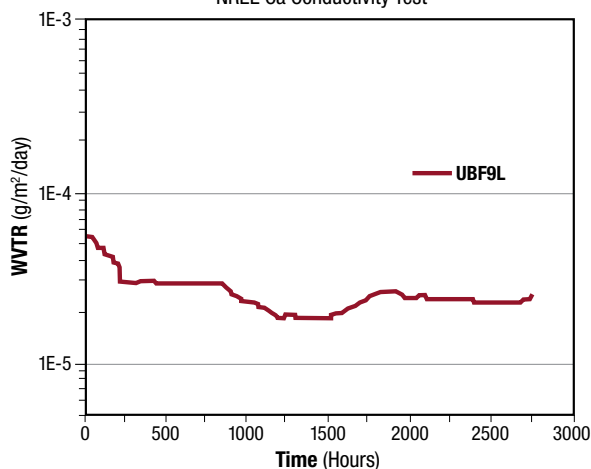
| Test Results | In Selected Units |
|-------------------|--------------------------------------|
| Transmission Rate | -4.9969E-4 g/m ² /day |
| Permeation | -4.9969E-4 g/mil/m ² /day |

| Data Points | | | |
|-------------|------------|--------|------------|
| Time | Rate/Event | Time | Rate/Event |
| 0:00 | Condition | 66:59 | 1.8942E-3 |
| 1:59 | Test | 91:33 | 1.4674E-3 |
| 3:59 | 0.221797 | 102:33 | 6.3738E-4 |
| 14:59 | 6.9414E-3 | 112:33 | -4.9411E-4 |
| 24:59 | 3.5865E-3 | 123:33 | 4.1895E-4 |
| 35:59 | 4.2983E-3 | 133:33 | -4.9969E-4 |
| 45:59 | -3.4134E-4 | 136:03 | Complete |
| 56:59 | 1.1538E-3 | 136:04 | Finished |

Transmission Rate Data Graph



WVTR at 45°C/85% RH for 3M™ Ultra Barrier Solar Film 9L NREL Ca Conductivity Test



Michael Kempe, Arrelaine Dameron, and Matthew Reese, "NREL Electrical Ca WVTR Test", manuscript in preparation, 2011.

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