Protective Vents

Temperature Cycling Tests to Evaluate Product Life

Daisy Gu, Applications Engineer

New technologies are increasing the amount and complexity of electronics used in solar energy equipment such as junction boxes, power optimizers, inverters, tracking systems, and combiner boxes. Much of this equipment is installed in areas where it can be exposed to harsh weather conditions. For example, the high winds and blowing rain in a rapidly approaching storm can easily compromise the internal electronics of this equipment if they are not protected adequately. Therefore, manufacturers house the electronics in rugged, sealed enclosures that are expected to last for 25 years or more.

As a storm approaches — or even during the 24-hour cycle of day and night — ambient temperature and pressure changes can create significant pressure differentials inside the enclosure. To equalize the pressure, the enclosure attempts to draw air inside, which puts stress on the protective seals. Over time, the seals can become compromised, creating leak paths for contaminants.

These environmental challenges have led the industry to incorporate ventilation into the modules. Ventilation allows air to flow into and out of the module to equalize pressure; however, electronics in solar technology continue to become more sophisticated, which makes them more sensitive to potential contamination. Therefore, the vent must also protect against water and particulate contamination. W. L. Gore & Associates performed temperature cycling testing to evaluate the performance of GORE® Protective Vents in empty enclosures as well as enclosures with power input.

Test Method

Gore purchased four identical junction boxes that were made of Underwriters Laboratory (UL) rated plastic and contained a DC power supply. These boxes provided ingress protection (IP) rated for IP66. With an internal volume of 193 milliliters (ml), each box had approximately 175 ml of free-space air. Gore's engineering team installed an MSR145 Miniature Signal Data Recorder in each box to record the internal temperature, pressure, and relative humidity. They also recorded the ambient temperature, pressure, and relative humidity with another MSR145.

The Gore team welded GORE® Protective Vents made entirely of ePTFE membrane onto two of the four junction boxes to record the impact of pressure differentials. The team then sealed the junction boxes with a robust glue to ensure they had no leak paths before putting them into the climate chamber. The power was turned on in two of the boxes before the test started, and it remained on for the testing.

Gore set up the test following the more rigorous Underwriters' Laboratory test UL1703 (Figure 1). Temperature, pressure, and relative humidity were recorded for 48 cycles over 10 days using the MSR145 software.

Figure 1: Testing Protocols

Specification	Value
Low temperature	-40°C
High temperature	90°C
Maximum temperature change during dwell	65°C/hour
Dwell time	30 minutes
Number of cycles	48

Test Results

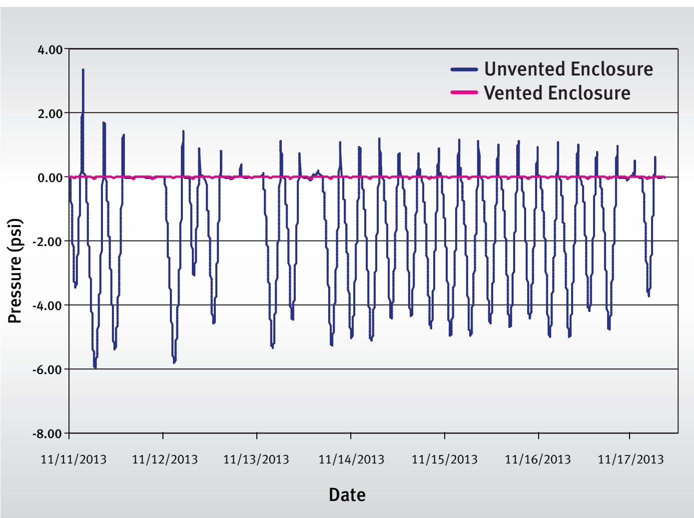
The junction boxes were removed from the test chamber, and the differential pressure and relative humidity of the vented and unvented junction boxes were evaluated. In addition, the dew point was used to evaluate the potential for condensation in the vented and unvented junction boxes.

Differential Pressure

To ensure that the enclosures were completely sealed, Gore evaluated the differential pressure using the two junction boxes without power.

The differential pressure inside the unvented junction box reached a high of 3.8 psi (0.26 bar) and a low of -6.0 psi (-0.41 bar) at the beginning of the test (Figure 2). As the test continued, the pressure range in the unvented box gradually decreased; after six days of temperature cycling it reached 0.0 psi. This gradual decline in pressure differential indicated that the seals could not withstand the high pressure and eventually failed, creating a leak path for air — and possibly water and contaminants — to move in and out of the junction box. On the other hand, the junction box with the GORE® Protective Vent maintained constant pressure of approximately 0.0 psi because the vent allowed air to flow freely in and out.

Figure 2: Differential Pressure

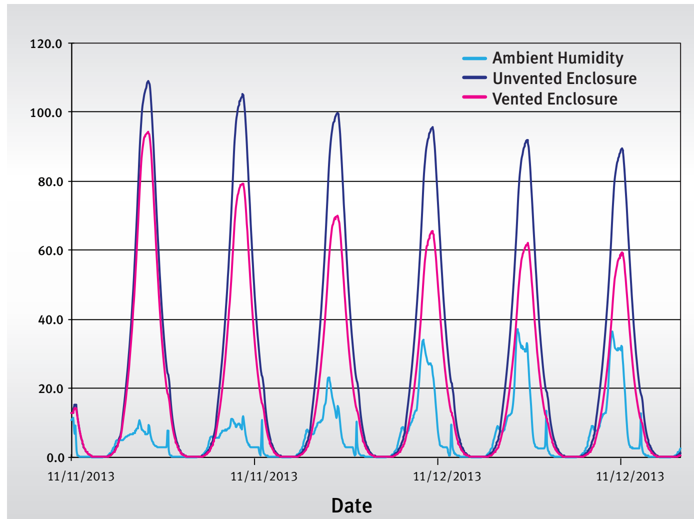


Absolute Humidity

Gore evaluated the absolute humidity values of the two junction boxes with power. The absolute humidity inside the unvented junction box remained higher than the absolute humidity of the junction box with the GORE® Protective Vent (Figure 3). Moisture vapor inside the unvented box did begin to escape slowly after several cycles because of a leak path around the seal. The leak path was created when the seal failed after extended pressure differentials.

The humidity in the junction box with Gore's vent remained low. The vent enabled moisture vapor to escape from the junction box, so the absolute humidity decreased rapidly with each cycle. At the same time, the ambient humidity increased because the moisture vapor inside the vented box was escaping.

Figure 3: Absolute Humidity



Dew Point

The dew point is the temperature at which water vapor in the air condenses into liquid. The internal dew point can be calculated using the actual temperature and relative humidity inside the junction box. When the ambient temperature is lower than the internal dew point, condensation occurs. Likewise, when the ambient temperature is higher than the internal dew point, condensation does not occur. As the gap between ambient temperature and internal dew point widens, the potential for condensation lessens. Because the relative humidity inside the junction boxes was consistently above 50 percent, Gore used the simplified calculation for finding the dew point (Figure 4).

Figure 4: Dew Point Calculation[1]

Internal Dew Point = $T - [(100 - RH)/\alpha]$

Where **T = internal temperature in °C**

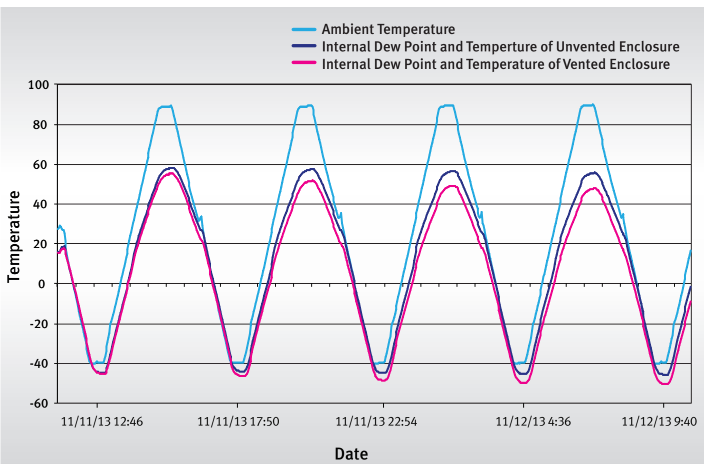
RH = relative humidity in percent

α = constant of 5

[1] Lawrence, Mark G., 2005: *The relationship between relative humidity and the dewpoint temperature in moist air: A simple conversion and applications.* Bull. Amer. Meteor. Soc., 86, 225-233. doi: http;//dx.doi.org/10.1175/BAMS-86-2-225. Reference found at http://iridl.ldeo.columbia.edu/dochelp/QA/Basic/dewpoint.html.

To mirror the internal conditions of solar equipment more effectively, Gore evaluated the dew point using data from the junction boxes in which the DC power supplies were running. The dew point of the unvented junction box remained almost the same throughout the temperature cycling. However, the dew point in the junction box with the GORE® Protective Vent was consistently lower than the dew point in the unvented box and continued to decline during the temperature cycling. In addition, the gap between the ambient temperature and the dew point in the vented box widened (Figure 5). Consequently, the use of the vent reduced the potential for condensation to occur.

Figure 5: Difference Between Ambient Temperature and Dew Point



Conclusion

W. L. Gore & Associates' testing of four IP66-rated junction boxes with DC power supplies proved the importance of ventilating solar energy equipment. Whether caused by climate changes, day/night cycles, or internal power sources, fluctuations in temperature can create performance issues that compromise the service life and durability of electronics. Pressure differentials that result from rapid temperature changes create stress on enclosure seals. Over time, these pressure differentials can cause the seals to fail and provide leak paths for contaminants such as water, dirt, and dust. Ventilation also helps reduce condensation – a major cause of corrosion – by increasing the gap between the internal dew point and the ambient temperature.

As shown in this testing, GORE® Protective Vents can help lengthen service life by equalizing pressure to ensure the integrity of enclosure seals. At the same time, these vents provide a proven barrier that blocks ingress of liquids and contaminants, while minimizing condensation by diffusing water vapor more effectively.

GORE

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Gore is a technology-driven company focused on discovery and product innovation. Well known for waterproof, breathable GORE-TEX® fabric, the company's portfolio includes everything from high-performance fabrics and implantable medical devices to industrial manufacturing components and aerospace electronics. Gore products have remained at the forefront of creative solutions because they are engineered specifically for challenging applications requiring durable performance where other products might fail.

For almost thirty years, Gore has delivered venting solutions for a variety of applications installed in rugged environments throughout the world — applications such as solar, lighting, security, telecommunication, and other electronic systems; automotive and heavy-duty vehicles; and chemical and agricultural packaging. Engineered with the latest materials and technology, Gore's vents are backed by years of research and testing to help extend product life and enhance reliable performance — all to ensure that these venting products can meet the challenging environments and application demands of today's technology.

Headquartered in the United States, Gore employs approximately 10,000 associates in 30 countries worldwide.

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International Contacts

Australia	+61 2 9473 6800	Scandinavia	+46 31 706 7800
Benelux	+49 89 4612 2211	Singapore	+65 6733 2882
China	+86 21 5172 8299	South Africa	+27 11 894 2248
France	+33 1 5695 6565	South America	+55 11 5502 7800
Germany	+49 89 4612 2211	Spain	+34 93 480 6900
India	+91 22 6768 7000	Taiwan	+886 2 2173 7799
Italy	+39 045 6209 240	Turkey	+90 216 3935749
Japan	+81 3 6746 2572	United Kingdom	+44 1506 460123
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W. L. Gore & Associates, Inc.
401 Airport Road • Elkton, MD 21921 • USA
Phone: +1 410 506 7812 (USA) • Toll-free: +1 800 523 4673 (USA)
Fax: +1 410 506 8749 • Email: protectivevents@wlgore.com

gore.com/protectivevents

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