Protective Vents

Reliability Testing of GORE® Protective Vents in LED Luminaires

Much of the lighting for both commercial and residential applications is being upgraded to light-emitting diodes (LED). LED lights are fully RoHS-compliant and can provide up to 85 percent energy savings. These lights can generate as much as 100,000 hours of light and are one of the most environmentally friendly and reliable solutions for outdoor lighting applications.

Outdoor lighting systems are designed with sealed housings to protect against environmental contaminants. This sealed construction prevents the heat from escaping. Atmospheric conditions such as temperature shifts and relative humidity also present challenges to the reliability of outdoor lighting luminaires. Changes in ambient temperatures can lead to significant pressure differentials. Over time, pressure on the enclosure seals can cause them to fail and allow contamination and/or water to breach the enclosure. This shortens the life of the luminaire by damaging the wiring, leads and other electronics of the power supply driver and the LEDs. The moisture also reduces light efficiency and can cause condensation to form on the lenses and reflectors.

Equalizing the luminaire's internal pressure increases its reliability and durability. The challenge is to allow air to flow freely in and out of the luminaire without allowing water or contaminants to enter. GORE® Protective Vents allow constant airflow while preventing water and particle ingress. To evaluate the impact of these vents on the long-term reliability of LED lighting luminaires, W. L. Gore & Associates installed two lighting luminaires outdoors and monitored the internal temperature, humidity and pressure of both luminaires for a period of one year.

TEST DESIGN

To ensure validity of the testing, Gore purchased two commercially available LED street lights (Figure 1) for installation in an exterior testing area in Elkton, Maryland. The luminaires are engineered to last for 20 years and comply with IEC60529 Ingress Protection standard IP66. These lighting systems have a middle chamber for the power supply and driver and two outer chambers that contain LED lights with reflectors and refractors. Open ports were designed between the middle chamber and the two outer chambers to allow wires to pass between the three chambers. These open ports also allowed air to flow through. In addition, a photosensor was positioned on top of each luminaire to automatically turn the power on and off based on available ambient light.

Temperature and pressure probes were installed in the middle chamber of both lights, and the data recorder was set to measure temperature, humidity and pressure every ten minutes. Silicone was used to plug the GORE® Protective Vent to seal one of the luminaires (Figure 2).

LEAK PATH ISSUE

From the onset of the testing, pressure inside the sealed luminaire spiked as soon as it was turned on, but it immediately began to decrease. Because this rapid decrease was consistent from the beginning, the engineering team determined that it was most likely inherent in the luminaire design rather than failure of a gasket. However, this type of leak is typical of the impact of pressure differentials over time.

FIGURE 1: LUMINAIRE WITH GORE® PROTECTIVE VENT

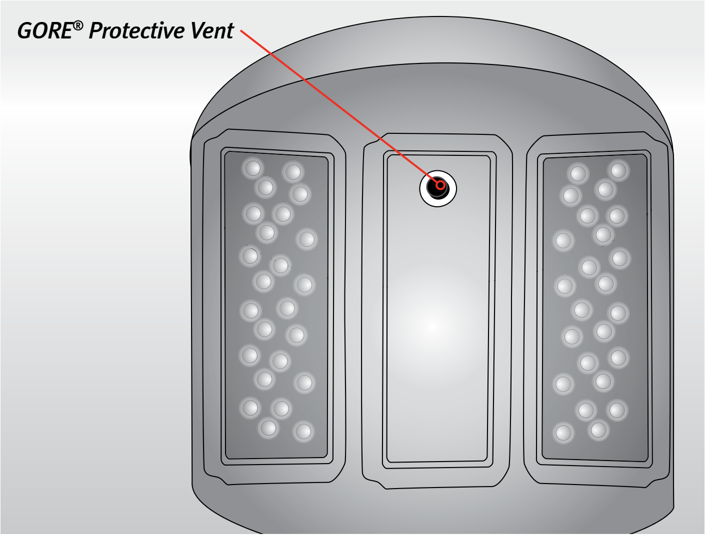
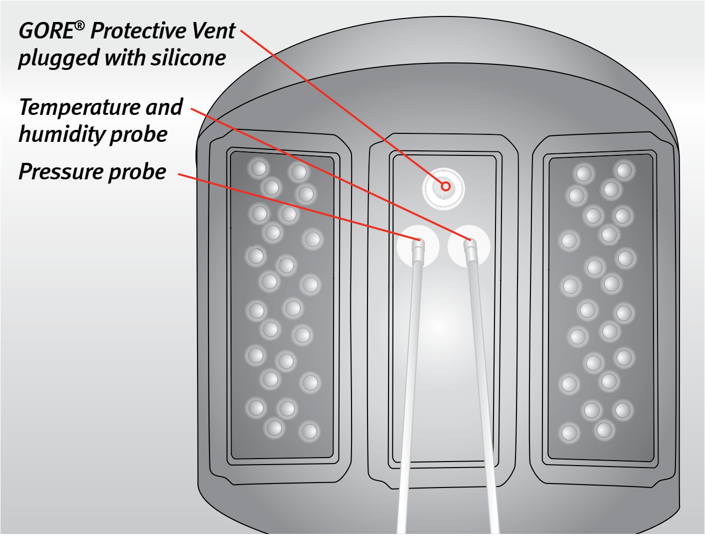
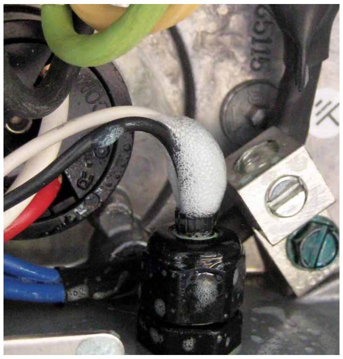


FIGURE 2: LUMINAIRE WITH PLUGGED VENT



The leak path was located in the wire fitting between the power supply module and the electrical compartment (Figure 3). Specifically, the leak occurred between the rubber tube and the nonwoven material that surround the wires in both luminaires.

Figure 3: Leak Path in Wire Connector

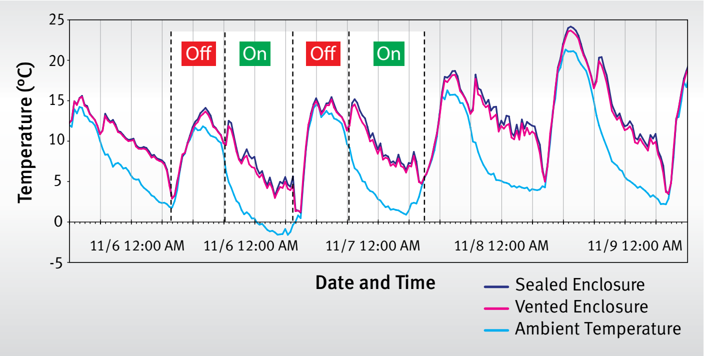


Internal Temperatures

Daily and seasonal temperature shifts can cause the air within the luminaire to contract and expand, which can lead to significant pressure differentials. In addition, temperature changes between on and off cycles of the lights increase the severity of the pressure differentials.

The internal temperatures fluctuated inside both luminaires (Figure 4). For example, on November 7, 2011, the ambient temperature ranged from 1°C to 16°C. On this day, the internal temperature of the sealed luminaire ranged from 5°C to 19°C, while the range for the vented luminaire was 5°C to 18°C.

Figure 4: Temperature Cycles

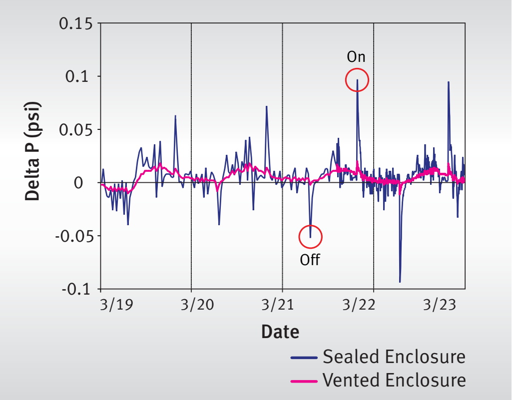


Pressure Differentials

Pressure differentials are driven by changes in the internal temperature. As the internal temperature rises, the internal air expands, putting positive pressure on the O-ring seals and other housing components. As the internal temperature drops, the internal air contracts and creates a vacuum, again putting pressure on the O-ring seals and other housing components.

As a result, the pressure inside the luminaires followed the on/off cycle of the lights (Figure 5). In the sealed luminaire, the pressure spiked as much as 0.09 pounds per square inch (psi) when the light was turned on, and it dipped approximately –0.1 psi when turned off. The pressure differentials would have been much greater if the luminaire did not have the leak path. The pressure differentials in the vented luminaire were minimal as it turned on and off, showing only a ±0.01 psi change due to the lower resistance IP67-rated GORE® Protective Vent.

Figure 5: Pressure Differentials

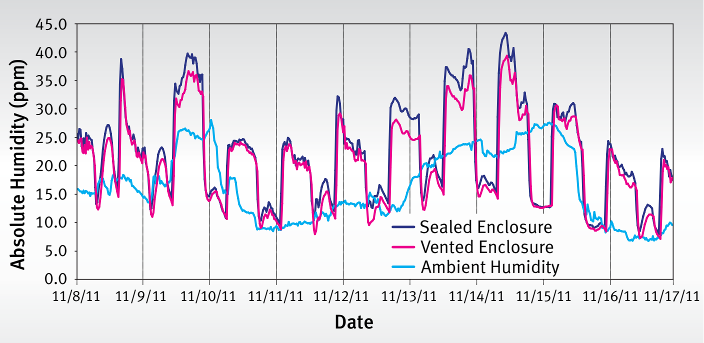


Humidity

The humidity indicates the amount of water vapor inside the luminaires. Absolute humidity indicates the weight of water per volume of air, measured in parts per million (ppm); and the relative humidity indicates the percentage of water with respect to saturation at a given temperature. The significance of evaluating humidity relates to the potential for condensation that can compromise electronics and decrease the effectiveness of the LEDs. Three factors affected the internal humidity (Figure 6):

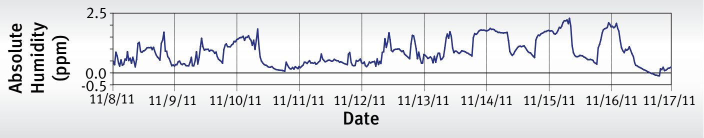
- The humidity inside both luminaires tended to follow the external humidity independently of the lighting cycle because vapor was able to enter both luminaires either through the vent or the leak path.
- The permeable plastic material used in the lens of each luminaire allowed moisture to pass through the lens.
- The materials used in printed circuit boards (PCBs) inherently absorb moisture. The heat generated when the lights were on caused the PCB moisture to desorb, increasing the amount of moisture vapor in the luminaire. When the lights went off, the PCBs absorbed the moisture again. Therefore, the humidity level measured by the probe dramatically increased when the lights turned on and decreased when the lights were off.

Figure 6: Internal Humidity Relative to Ambient Humidity



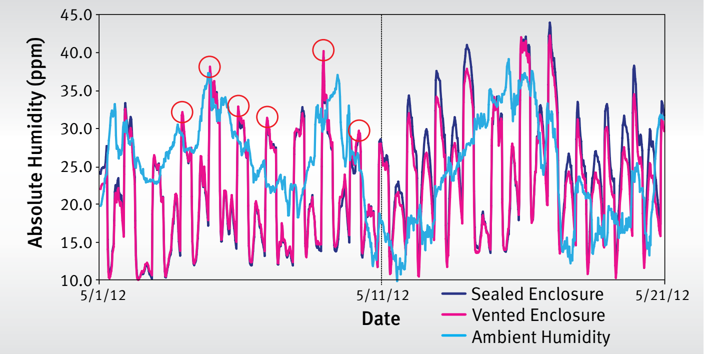
Throughout the test period, the sealed luminaire's absolute humidity was almost always higher than the humidity in the vented luminaire (Figure 7). This positive difference indicates that the vented luminaire was drier, which translates to better long-term performance due to less exposure to moisture.

FIGURE 7: DIFFERENCE OF INTERNAL HUMIDITY IN SEALED AND VENTED LUMINAIRES



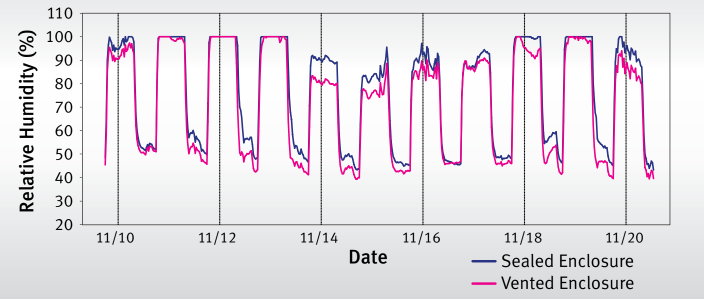
On rare occasions when the external humidity was higher than the internal humidity, such as in May 2012 (Figure 8), the absolute humidity in the sealed luminaire was lower than that in the vented one. However, the difference was nominal, probably due to the desiccant effect of the printed circuit boards.

FIGURE 8: EFFECT OF HIGHER EXTERNAL HUMIDITY



The difference between the absolute humidity and the relative humidity of the two luminaires was small. When the humidity values were sufficiently high, both luminaires reached 100 percent relative humidity, which resulted in condensation inside the luminaires (Figure 9). However, the vented luminaire generally recovered more quickly, indicating that it allowed moisture vapor to escape through the vent.

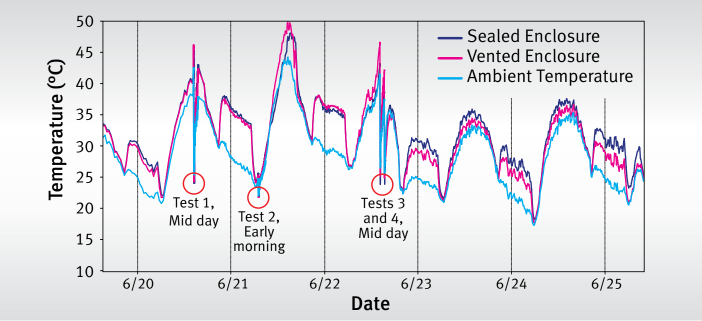
FIGURE 9: CONDENSATION EVENTS INSIDE THE LUMINAIRES



THERMAL SHOCK TESTING

To test the housings' waterproof protection in real-world conditions, thermal shock testing under wet conditions was conducted. The test was designed to exceed IP65. An IP65 nozzle was used at a distance of 2.5 to 3 meters for 3 minutes, with a water flow of 21 liters/minute. IEC60529 specifies that the testing should be conducted in a lab with the water temperature ±5°C of the test equipment to minimize changes to the housings' internal pressure; however, using outdoor conditions are more realistic to what the equipment experiences in operation. Therefore, the tests were done when the outdoor and water temperatures would provide a realistic but high level of thermal shock. The test was repeated four times between June 20 and June 22, 2012, when the ambient temperatures reached almost 38°C. The luminaires' internal temperatures ranged from 25°C to 41°C, and the water temperature was 24°C except for the second test, which was 22°C to be within 5°C of the internal temperature. This resulted in maximum temperature changes of more than 16°C (Figure 10). The third and fourth tests were done back-to-back to simulate more rugged environmental conditions, such as during routine cleaning.

FIGURE 10: TEMPERATURE CHANGES DURING SHOCK TESTING

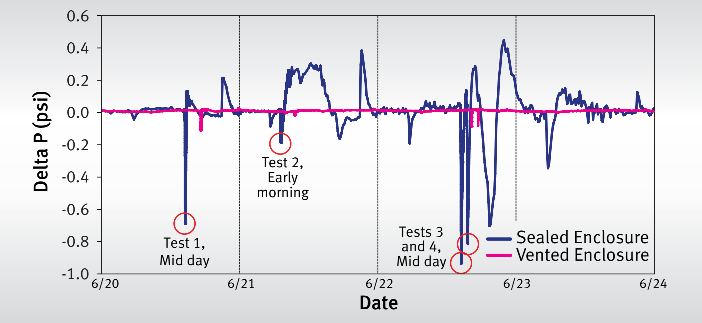


Pressure Results: Evaluating the pressure during the shock tests determined the housing's ability to equalize pressure in rapidly changing environmental conditions. During all tests, the vented luminaire maintained equalized pressure inside the enclosure while preventing water entry (Figure 11).

The sealed luminaire experienced significant pressure differentials up to 0.95 psi, with changes exceeding ten times those caused by the leak path at the wire fittings (Figure 11). Because the second test was performed with a water temperature within 5°C of the luminaires' internal temperature, the thermal shock was minimal (less than 0.2 psi change in pressure). The third and fourth test results were consistent with the results of the first test.

During these tests, the sealed luminaire's leak path was partially sealed by water due to a vacuum. As the luminaire's internal temperature increased during the day, the housing could not sufficiently equalize pressure through the leak path; therefore, internal pressure significantly increased, reaching approximately 0.4 psi after the second, third and fourth tests (Figure 11). Because the sealed enclosure could not use the blocked leak path to equalize pressure, the thermal shock test created an internal vacuum and caused water to enter the sealed enclosure.

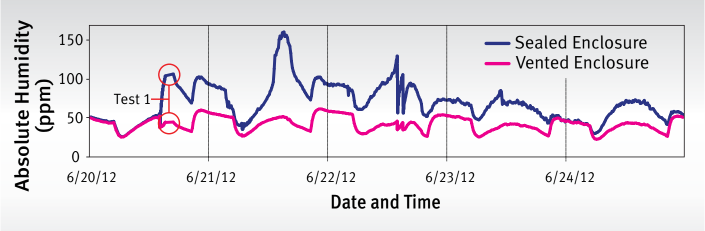
FIGURE 11: PRESSURE DIFFERENTIALS DURING SHOCK TESTS 1 AND 2



Protective Vents

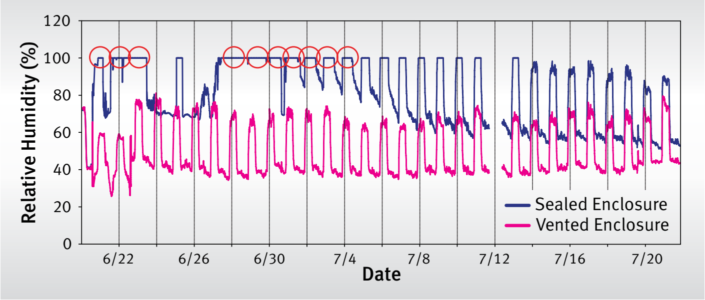
Humidity Results: Evaluating the absolute humidity inside both housings determined their ability to protect against water ingress. As previously shown (Figure 6), the absolute humidity inside both luminaires remained lower than 45 ppm; however, when exposed to a water-spray thermal shock, the absolute humidity in the sealed luminaire increased to 155 ppm. Although the absolute humidity in the two luminaires was similar prior to the test, the vented luminaire maintained a significantly lower humidity level than the sealed luminaire during and after the test (Figure 12).

FIGURE 12: ABSOLUTE HUMIDITY DURING SHOCK TESTS



For more than a month following the thermal shock tests, the relative humidity in the sealed luminaire remained significantly higher than the relative humidity in the vented luminaire (Figure 13). This was because the air flow and moisture diffusion rate was very low in the sealed enclosure's leak path. In addition, over the course of the first ten days, the relative humidity almost constantly remained at 100 percent in the sealed enclosure, which proved that liquid water was present throughout the entire time.

FIGURE 13: EXTENDED PERIODS OF HUMIDITY IN THE SEALED ENCLOSURE



Note: After long-term saturation, the humidity probe ceased to deliver accurate measurements, which resulted in erroneous output of approximately 70 percent instead of 100 percent relative humidity.

CONCLUSION

Testing of two identically designed LED luminaires (a sealed control unit and an unmodified vented unit) has shown that equalizing pressure in the enclosures can reduce the chance of water ingress, condensation and the amount of moisture vapor. An on-going extended life test begun in November 2011 indicated that the luminaires' on-off cycles heat and cool the circuit boards, causing them to absorb and desorb water continuously.

Because the sealed luminaire was constructed with an inherent leak path inside its wire fittings, significant differences in internal pressure between the two units were recorded only at the beginning of the on-off cycle. However, the temperature changes during the outdoor IPX5 tests were significant enough to create a vacuum inside the control unit, which resulted in water being drawn into the unit. Once inside, the liquid could not escape easily, so it remained there for more than a month. This long-term saturation could lead to corrosion, shorting of the electronic components and condensation on the lenses — affecting aesthetics, reducing durability and lighting effectiveness and potentially causing catastrophic failure.

Constructed with a GORE® Protective Vent in the power supply chamber, the vented luminaire maintained equalized pressure during the testing. Although its internal absolute humidity did increase during the thermal shock testing due to diffusion, the level remained consistently lower than the sealed luminaire, and there was no saturation. In all tests, the GORE® Protective Vent was able to maintain equalized pressure and prevent liquid from entering the enclosure. Also, when moisture vapor entered the vented unit, the GORE® Protective Vent allowed the vapor to escape, reducing condensation events inside the luminaire. Available in a variety of sizes, forms and materials, these vents provide maximum airflow to reduce pressure differentials inside sealed enclosures in a wide range of sizes.

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Germany	49.89.4612.2211	South America	55.11.5502.7800
India	91.22.6768.7000	Spain	34.93.480.6900
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