GORE

Protective Vents

White Paper

How to Extend the Service Life of LED Outdoor Lighting

*By Gary Chan and Henning von Lepel**

LED luminaires in outdoor use need to be protected from harsh environmental conditions. The most significant stress factor for the sealings of luminaire housings are pressure differences caused by everyday temperature changes. In order to protect the sensitive electronics inside, pressure variations have to be equalized while preventing water and dust to enter the housing. The most effective solution is a "smart venting element" with a membrane that protects electronic housings against contamination and fluids and provides air exchange and pressure equalization at the same time.

For both commercial and residential applications standard neon tubes and energy-saving lamps are increasingly replaced by LED (light-emitting diodes) luminaires. The advantages of LED lightings are numerous:

- They are fully RoHS-compliant (Restriction of Hazardous Substances).
- They provide up to 85 percent energy savings in comparison to conventional lamps.
- They can generate as much as 50,000 hours of light.
- They are one of the most environmentally friendly and reliable solutions for outdoor lighting applications.

However, the service life of a LED is subject to the reliability of the electronic components and power supply drivers, which altogether make up the lighting system itself. This poses a major challenge on LED systems for outdoor use. The housings of the LED luminaires must be able to withstand the harsh environmental conditions. To achieve this goal, the housing of an LED lamp is sealed against the ingress of water and contaminants. However, changes in outdoor temperature cause the air pressure within the housing to fluctuate constantly, which in turn puts either positive or negative pressure on the seals and compromises their functionality. Over time, seals begin to allow water and contaminants to enter the housing, which can lead to corrosion, shorts, and potential failure of the electronics. In addition, condensation on the inside of the luminaire can impact the quality of its light.

Causes for Pressure Differentials

Temperature Fluctuations
Changes in outdoor temperature are one of the most common causes of pressure differentials. These changes can be sudden, for instance a strong thunderstorm on a hot summer day, or more gradual over the course of the day or of the year. Either way, they put significant stress on the seals. What is more, direct sunlight can often cause the air inside the LED luminaire to rapidly heat up, with the resulting higher pressure putting positive pressure on the seals. As temperatures drop again at night, the internal air contracts and creates a gentle vacuum, which draws the seals inward. A quick drop in temperature can create a vacuum of up to 150 mbar inside the luminaire, while a 30 °C change in temperature creates approximately 10 percent of volumetric flow of air in or out in a non-hermetically sealed enclosure.

Typical Calculation
Pressure differential in a housing with 5 liters of free air volume caused by a temperature drop from 65 °C to 15 °C in 11 minutes.

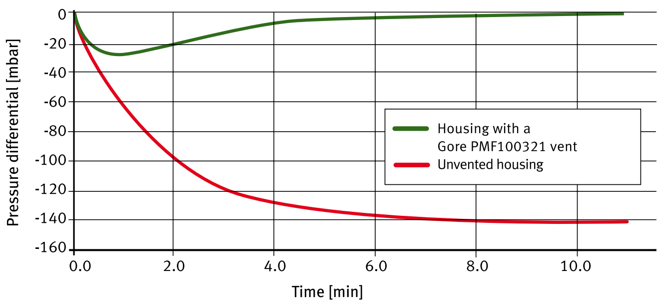

Figure: Typical calculation of pressure differentials in a housing

Temperature Changes within LED Luminaires
Although LEDs do not get as hot as incandescent lamps, switching a luminaire on and off nonetheless results in significant temperature fluctuations. These are at their strongest immediately after switching, which means that switching luminaires on and off repeatedly puts not only the electronics but also the seals under considerable strain.

Altitude Changes
When LED luminaires are shipped by air from their manufacturing sites, the lamps will be subject to major changes in altitude, even several times when the shipment involves intermediate stops. This means LED luminaires are exposed to the difference in pressure between a little over 1,000 mbar at ground level and 800 to 850 mbar in the aircraft.

Thermal Shock
A thermal shock occurs when a hot LED luminaire is sprayed with cold water from a garden hose, for instance, or when a cold luminaire is washed with hot water. It can also arise when a luminaire encounters snowfall.

Important Consideration: Hydrogen Sulfide

Not only constant pressure is important for a long service life of an LED luminaire. Hydrogen sulfide is given off especially by inexpensive EPDM seals produced using sulfur vulcanization where not all the sulfur atoms were one-hundred per cent cross-linked. Sulfur vulcanized nitrile butadiene rubber (NBR) or other components containing sulfur can also give off hydrogen sulfide. This substance corrosion in luminaire components such as silver-plated leadframes, which could impact electrical contacts with the wire bond or die bond.

Challenge: Equalizing Pressure

For maintaining constant pressure inside a luminaire it is crucial to allow air to flow freely in and out of the luminaire. The challenge is to block water and contaminants in doing so. Most types of seals to achieve this goal have multiple drawbacks as explained below:

- Labyrinth seals are completely permeable to particles, insects, and water.
- Rugged seals, additional bolts, thicker housings or potting compounds for hermetically sealing the device require the use of non-permeable materials and is relatively expensive. Moreover, it makes the device heavier, extremely difficult to open under negative pressure and repair almost impossible.
- Felt elements and sintered vents address the pressure differentials, but they can become blocked by water and contaminants.
- A mechanical valve is a one-way solution from inside to outside, which means it cannot prevent a vacuum.

Solution: "Breathing" Luminaire Housings

Gore has developed a solution: a vent made of expanded polytetrafluoroethylene (ePTFE). A two-way breathable membrane continuously equalizes pressure inside the luminaire housing while also preventing the ingress of water and contaminants. Equalizing pressure using an ePTFE vent reduces the potential for moisture vapor to condense on lenses and reflectors, and increases the service life of seals. The microporous membrane can be coated to provide oleophobicity. ePTFE's node-and-fibril microstructure is open enough to allow gas molecules and vapor to pass through it easily, but the openings are so small that liquid and other particulates are repelled. Also, hydrogen sulphide is expelled this way.

Proper pressure equalization and water tightness have been demonstrated by thorough testing to compare two commercially available LED luminaires, one conventionally sealed unit and one with an ePTFE vent. Although the on/off cycle of both luminaires caused temperatures to rise and fall, the amount of pressure placed on the seals is significantly different. In the sealed luminaire, the pressure spiked by 6.2 mbar when the light was switched on and dipped -6.9 mbar when switched off. However, the vented luminaire showed a change of only ±0.69 mbar.

Impact of pressure on vented and unvented housings.

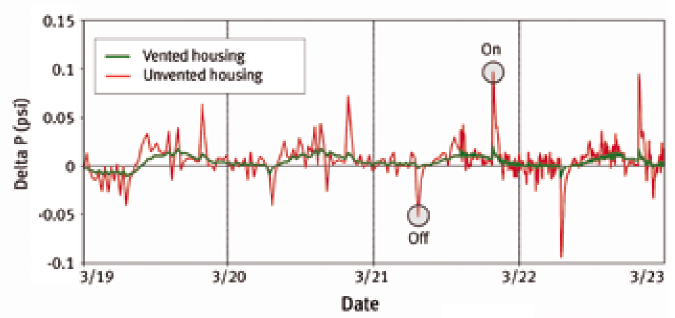

Figure: Impact of pressure on vented and unvented housings.

Comparing the relative humidity inside the LED luminaires after a standard IPX5 water ingress test demonstrates the significance of pressure differentials. The relative humidity in the sealed luminaire was significantly higher than in the vented luminaire. Over the course of ten days, the relative humidity in the sealed luminaire almost always remained at around 100 percent.

Relative humidity in vented and unvented housings.

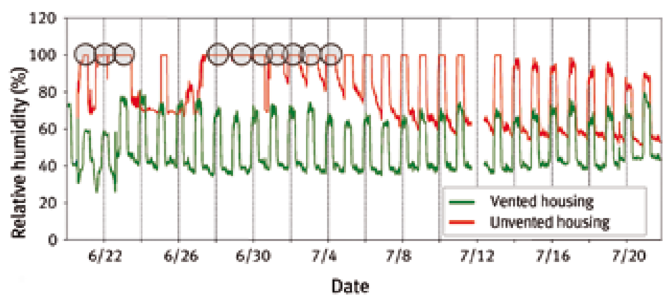

Figure: The unvented housing shows relative humidity of 100%, indicating condensation.

This indicated condensation inside the luminaire caused by water entering during the test. Although the relative humidity in the vented luminaire rose immediately after the shock test, it decreased again relatively quickly and there was no evidence of condensation.

Figure:
Luminaire with condensation

Protective Vents

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Comparison Test Proves Long-Term Protection

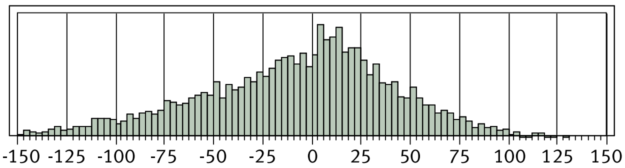
A further test, conducted outdoors over a period of five years south of Munich, demonstrated the longer service life of vented enclosures. Five units were tested: two with no vents, one with a side vent, one with a top vent, and one with two vents (one on each side). The testing showed that the pressure differential in the unvented units ranged from -150 mbar in both to 131 and 147 mbar respectively.

A significant amount of condensation was also detected. In the vented units, the maximum pressure measurements fell to ±40 mbar with a top vent, ±30 mbar with a side vent, and just ±4 mbar with both vents. This is an impressive demonstration of how effective these venting systems are at equalizing pressure. In addition, no condensation was detected, and neither was the ingress of water or dust. Further testing showed that the vents were fully functional even after five years of outdoor operation.

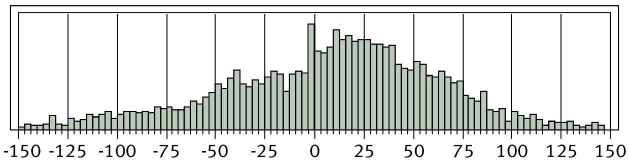
Long-term study of pressure differentials in electronics housings

Over a period of five years, pressure differentials were recorded in five housings.

✗ High pressure differentials in the unvented housings.

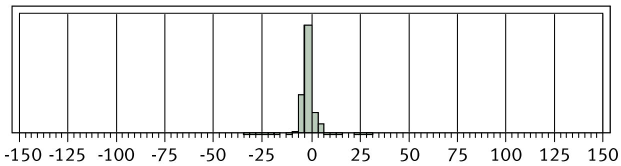


-150 mbar ‹ **Enclosure # 1** [No Vent] ‹ 131 mbar

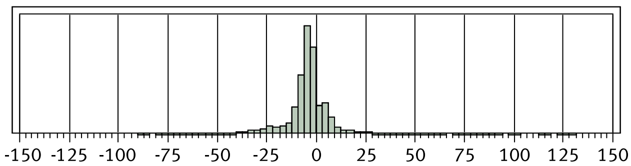


-149 mbar ‹ **Enclosure # 2** [No Vent] ‹ 147 mbar

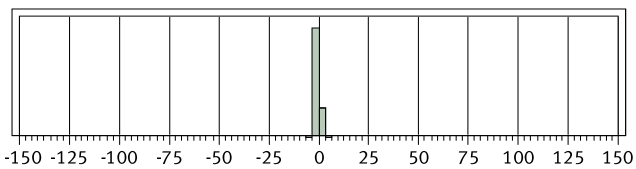
✓ Conditions on the interior almost exactly match the environment in the housings featuring GORE® Protective Vents.



-30 mbar ‹ **Enclosure # 3** [One Vent: Side] ‹ 30 mbar



-40 mbar ‹ **Enclosure # 4** [One Vent: Top] ‹ 41 mbar



-4 mbar ‹ **Enclosure # 5** [Two vents: One per Side] ‹ 4 mbar

Figure: Long-term study of pressure differentials in electronics housings

Figure: Long-term study of pressure differentials in electronics housings

Roundup: Venting Solutions Extend the Service Life of Outdoor LED Luminaires

Pressure differentials compromise housing seals. Not taking this into account when designing LED luminaires can reduce the service life of LEDs, power supply drivers and other electronics. The ingress of water through damaged seals also leads to condensation on lenses and reflectors that can decrease light efficiency and the aesthetic quality of the luminaire. As demonstrated through the IPX5 test, integrating an ePTFE vent into the housing equalizes pressure by allowing continuous airflow in both directions and preventing the ingress of water. What's more, the vent reduces condensation because moisture vapor is able to escape from the luminaire before condensing.

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Long-term study

You will find more information on this topic in the long-term study "Life Time Study of GORE® Protective Vents installed in Enclosures in Outdoor Environments", which you can download from **www.gore.com/5-year-study**.

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About W. L. Gore & Associates

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 fail.

For almost thirty years, Gore has delivered venting solutions for a variety of applications working in rugged environments throughout the world — applications for heavy-duty equipment and the automotive industry; electronic housings for the solar, lighting, security and telecommunication market; mobile electronic devices; 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. In Europe, Gore started its first business operations only a few years after the Enterprise's founding in 1958.

Learn more at gore.com/protectivevents.

Please Contact Gore to Learn About the Right GORE® Protective Vent for Your Unique Application

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