GORE® Automotive Vents
White Paper

VENTING SOLUTIONS FOR CLEAR VISIBILITY

Reliably Protect Headlamps Against Condensation as well as Dirt and Water Ingress

Ronald Szewczyk, Senior Application Engineer for Automotive Lighting, W. L. Gore & Associates, Inc.

To perform as designed and offer drivers and integrated headlamp sensors a clear view, headlamps must offer effective, life-of-vehicle condensation clearing and protection against contaminant and water ingress. Gore's extensive on-car testing demonstrates that, due to their unique thermodynamics, Battery Electric Vehicles (BEVs) can be just as vulnerable to condensation as their warmer-running ICE counterparts. This White Paper reviews the factors that give rise to moisture and condensation within headlamps, and compares different types of vents' effectiveness at reducing condensation.

Three Moisture Sources

Moisture in headlamps comes from three main sources **(Figure 1).** The primary source, sorption (collection of moisture within and on plastic surfaces), is triggered by differences in temperature, and accounts for roughly 80% of the moisture in headlamps.

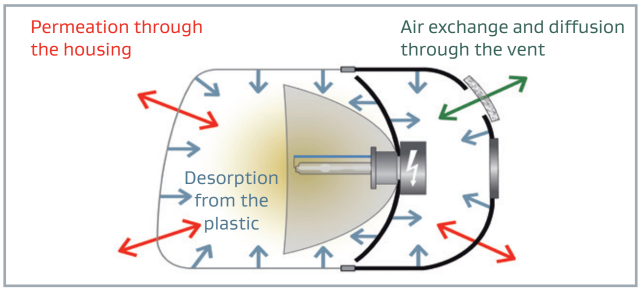

Figure 1: Three sources of moisture in vehicle headlamps

The absence of front-end internal combustion engine heating means BEV headlamps experience frequent lower-temp drive cycles. These drive cycles encourage moisture to accumulate (via sorption) within and on the headlamp interior surfaces. Exposure to an external heat source (sun load, fast charging) releases (desorbs) this moisture into the headlamp enclosure. Subsequent external cooling (rain, wind or nightfall) causes the moisture to collect and condense on the inner lens surface **(Figure 2)**.

Unlike ICE vehicles which dry out lamp plastics with each drive cycle, BEV lamp plastics continuously collect moisture with each low-temp drive cycle, which could prolong condensation clearing times.

Permeation is the second source of moisture: a process by which water vapor from the outside continuously diffuses through the plastic into the housing interior over a longer period.

The third source of moisture is the vent itself, through which moisture can get in and out of the headlamp.

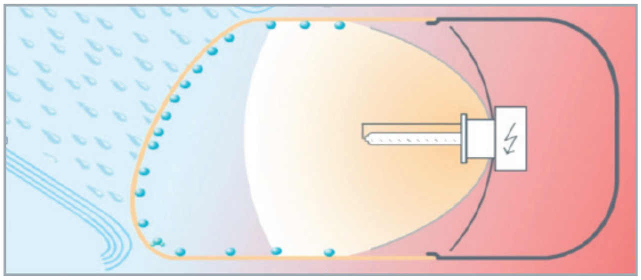

Figure 2: A cooling event after fast charging causes free moisture to collect and form condensation inside the lens.

Measuring Moisture

Although moisture levels in headlamps are frequently expressed in terms of relative humidity, specifying the dew point is actually much more useful and to the point, as it does not depend on prevailing temperatures. This will become clear in the following example, which demonstrates the correlation between dew point and temperature. In the example, moisture is measured under laboratory conditions. At 22 °C and 50 % relative humidity, the dew point is 11 °C **(Figure 3).**

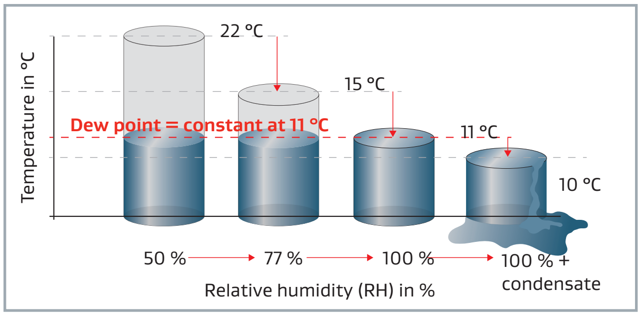

Figure 3: The water glass analogy demonstrates the correlation between temperature and humidity

Together, improving life

If the temperature falls to 15 °C, relative humidity climbs to 77 %. The dew point remains constant. At 11 °C, relative humidity reaches 100 %, meaning that the air is saturated and cannot absorb any more moisture. If the temperature drops below the dew point, condensation occurs.

Conducting Moisture Outside by Means of Convection or Diffusion

Essentially, there are two methods of removing moisture and ventilating headlamps: convection and diffusion.

Convection involves open, transverse ventilation using at least two venting tubes, which allow circulating air to conduct moisture outside **(Figure 4).** The air circulation is triggered by pressure differentials, which arise due to temperature changes (Scenario 1: when the headlamp is switched on, the warmed air exits) or due to the vehicle's motion (Scenario 2: ambient air is drawn in through the lower opening and flows out again through the upper opening). Disadvantages of convective venting, especially for high-value LED lamps, include: Convection works only when the vehicle is in motion or the headlamp is switched on; and contaminants (fine dust, particulates, insects) are drawn into the headlamp along with the suctioned air. Also, multiple integrated components (e.g., sensors) in the lamp and in the surrounding BEV "frunk" area can prevent adequate air circulation around headlamps.

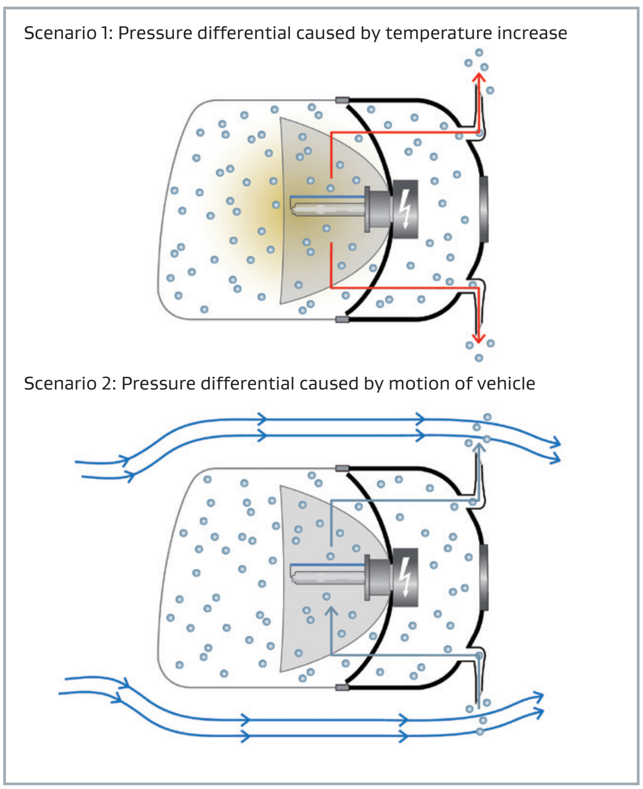

Figure 4: Temperature rise and vehicle motion lead to air exchange in headlamp

A more effective means of removing moisture from headlamps is diffusion. This physical process causes water vapor to move from regions of high concentration to regions of low concentration. The following law of diffusion describes this movement: **$v_D = -D * A * dc/dx$,** whereby v_D is the diffusion rate and D is the diffusion constant. Accordingly, in order to increase the diffusion rate, you must increase either the exchange surface A and/or the concentration gradient dc/dx. Here, dc represents the concentration difference (dc = c1 - c2), and dx is the distance between the concentrations. The influence of exchange surface A on the diffusion rate is illustrated in **Figure 5.**

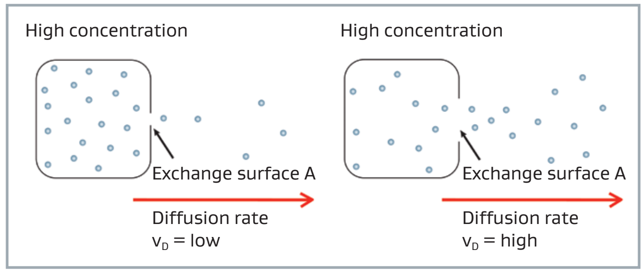

Figure 5: The larger the exchange surface, the higher the diffusion rate

In addition, the diffusion rate increases when the concentration gradient dc/dx is as high as possible **(Figure 6).** This happens when the following conditions between the inside and the outside of the headlamp are met:

- the concentration difference dc is as big as possible
- the distance dx is as small as possible.

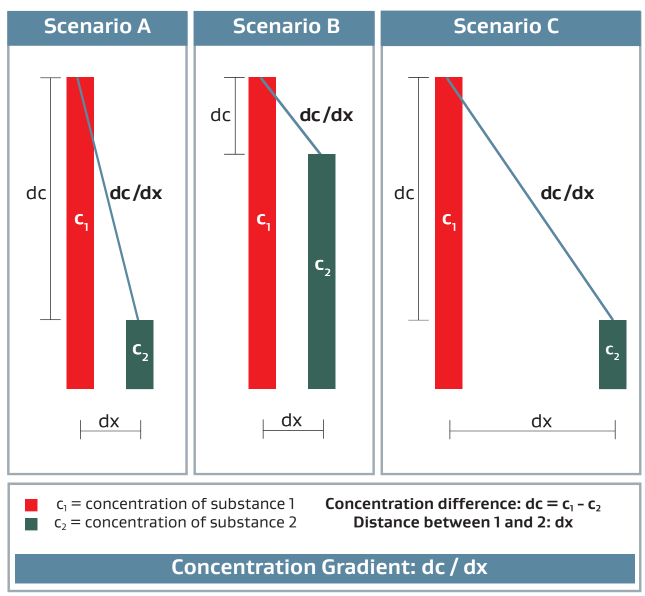

Figure 6: The diffusion rate increases as the concentration gradient rises

Cap Vents Versus Venting Membrane

There are two practical options for facilitating diffusion: cap vents and venting membranes. As **Figure 7** shows, a venting membrane adhered to the headlamp housing (i.e., an adhesive vent) enables better condensation reduction. The exchange surface A of an adhesive vent is typically larger than that of a cap vent, which has a positive effect on the diffusion rate. In addition, adhesive vents have an average thickness of approximately 0.3 mm, whereas cap vents are often about 20 mm in length. As a consequence, the distance (dx) that the moist air has to overcome is significantly higher with cap vents and leads to poorer condensation reduction. Furthermore, dust, dirt, and deposits can clog up the venting path in cap vents, further obstructing ventilation.

The Larger the Ventilation Surface, the Higher the Diffusion Performance

The easiest way to demonstrate the performance of venting components in relation to moisture transfer is to carry out a Moisture Vapor Transmission Rate (MVTR) test **(Figure 8).** This involves filling a vessel with 100 ml of water, sealing it airtight, and fitting it with a venting product. The container is weighed daily for two weeks under laboratory conditions (23 °C, 50 % rH) in order to measure the volume of water that has diffused every day. Measurements show that approx. 700 mg of liquid can diffuse through the GORE® Automotive Vent AVS 120 in one day.

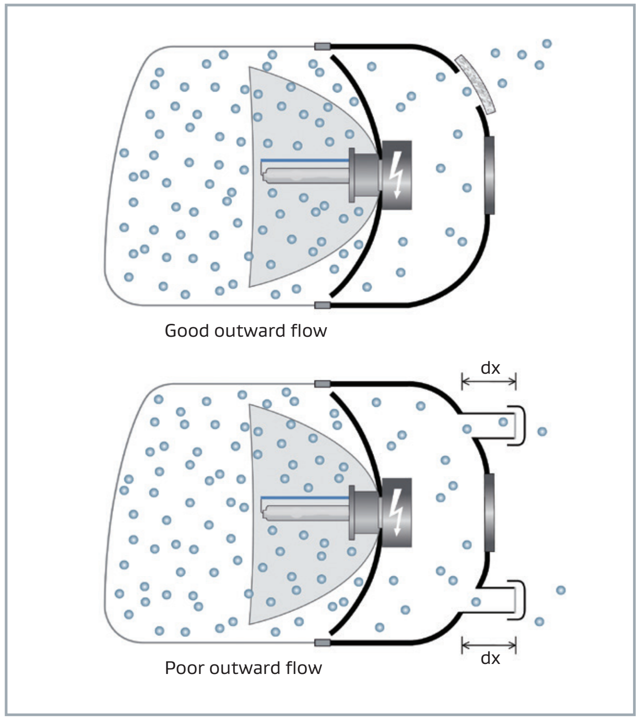

Figure 7: Venting membranes offer escaping air the shortest path and the least resistance

This offers a significant performance advantage over all other venting methods tested. A similar MVTR test, conducted over 28 days, showed that **AVS 120 diffused 10x more moisture than a cap vent with high-airflow membrane, and an open tube with sponge filter.**

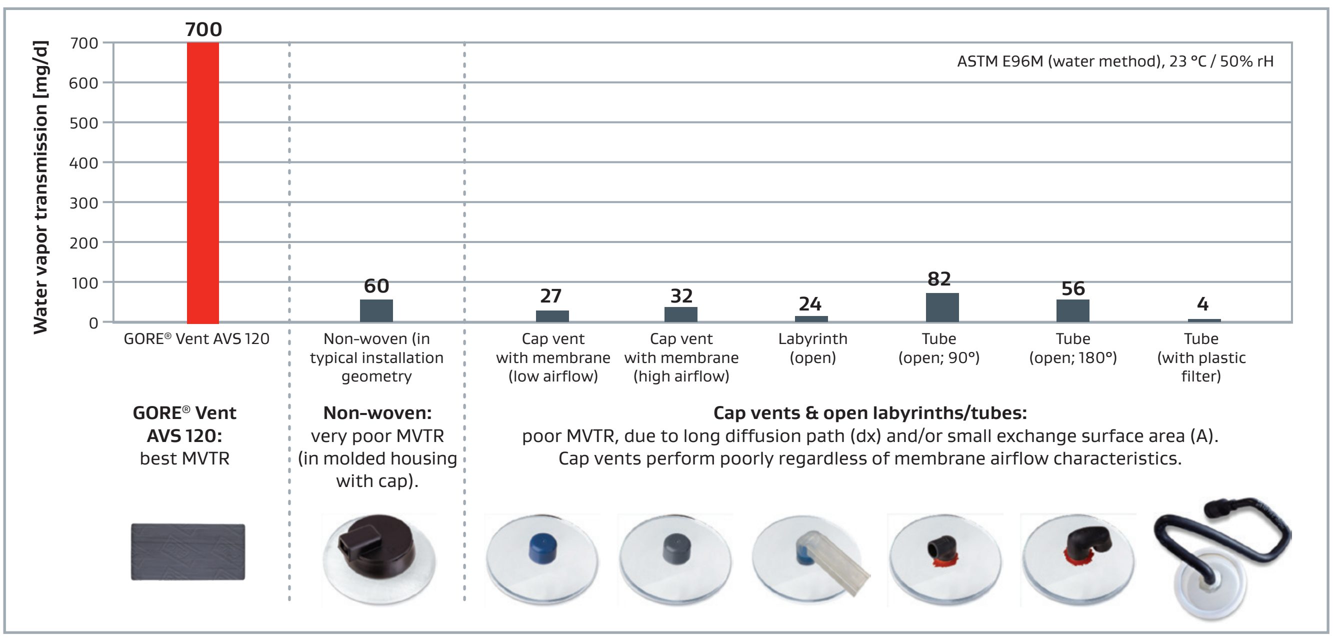

Figure 8: The MVTR test demonstrates the outstanding diffusion performance of GORE® Automotive Vents

A comparison of two GORE® Automotive Vents that use the same membrane material further demonstrates the importance of exchange surface A. GORE® Vent AVS 120 (exchange surface 398 mm^2) transports 700 mg of moisture per day, while the much smaller GORE Vent AVS 5 (exchange surface 62 mm^2) transports 132 mg. However, even the smaller AVS 5 has an MVTR that is double that of most tube vents or cap vents **(Figure 9).** This makes the AVS 5 particularly well-suited for use in smaller housings, such as those used in rear or accessory lighting applications.

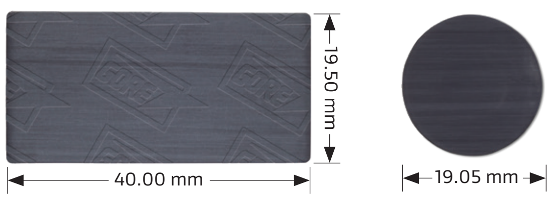

Figure 9: Compared to the MVTR of most cap and tube vents, AVS 120 is ~ 10x higher, and even the much smaller AVS 5 is twice as high.

GORE Automotive Vents outperform other venting methods due to their documented superior diffusive performance, which can enable faster condensation clearing times, as well as their life-of-vehicle ingress protection and pressure equalization.

- Tube vents are limited by convection: they reduce condensation only while the vehicle is in motion, and they do not provide effective ingress protection.
- Cap vents offer effective ingress protection, but provide only limited diffusion, which leads to poor condensation reduction.

GORE Automotive Vents, on the other hand, provide effective ingress protection and condensation reduction for the life of the vehicle.

Proven Performance and Value

GORE Automotive Vents deliver proven product performance for all your exterior lighting needs, as well as your electronic, powertrain, battery and acoustic venting applications. And Gore offers more ways to bring you value:

- Innovation-focused material and technology initiatives, including a science-based carbon-footprint reduction commitment.
- Global tech service and support based on decades of application expertise, international industry certifications andregulatory compliance (e.g., REACH).
- The stability of Gore's global supply chain, and our ability to rapidly scale production capacity.

Contact Us

Ask how we could help with your headlamp condensation issue, or ask about the data from our on-car studies of BEV headlamp thermodynamics.

INTERNATIONAL CONTACTS

Australia +61 2 9473 6800
China +86 21 5172 8299
EMEA +49 89 4612 2211
India +91 22 6768 7000
Japan +81 3 6746 2570
Korea +82 2 393 3411
Mexico +52 81 8288 1281
Singapore +65 6733 2882
South America +55 11 5502 7800
Taiwan +886 2 2173 7799
USA +1 410 506 7812

W. L. Gore & Associates, Inc.
401 Airport Road, Elkton, MD 21922
T +1 800 523 4673 **F** +1 410 506 8749 **E** automotive.us@wlgore.com
gore.com/autovents

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