Portable Electronic Vents

Improved Consistency in Testing for Water and Particulate Protection

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Having a durably rugged housing for your portable electronic device protects the internal electronics from environmental contaminants. The International Standard IEC 60529 defines specific levels of protection for enclosures with electronic voltage not exceeding 72.5 kilovolts. Different protective levels are classified based on the enclosure's ability to protect against both solid objects and water, and the standard describes tests used to verify that an enclosure meets the requirements of each level.

Electronic devices with audio components must include openings in their housings to enable sound waves to be transmitted. These openings expose the electronics to water, liquids, and particulates, so many device manufacturers cover these openings with protective vents. These vents are not independently IP-rated, but are only tested as part of the enclosure. As electronics have gotten smaller and more portable, the level of exposure to environmental contaminants has increased, which in turn increases the level of protection required by the vents.

The requirements outlined in the IEC 60529 standard do not adequately provide consistent testing of the protective vents needed for portable electronic devices. This results in two issues during the device's design that can affect the durability of its housing. First, the standard only includes tests for protective vents after the device is completely designed and assembled. Second, the testing protocols included in the standard can be broadly interpreted, resulting in inconsistent conclusions. W. L. Gore & Associates has developed four testing protocols that address these issues and mirror real-world conditions more effectively. With these protocols, we can improve the reliability of test results and the durability of the housings used in portable electronics.

Materials Testing

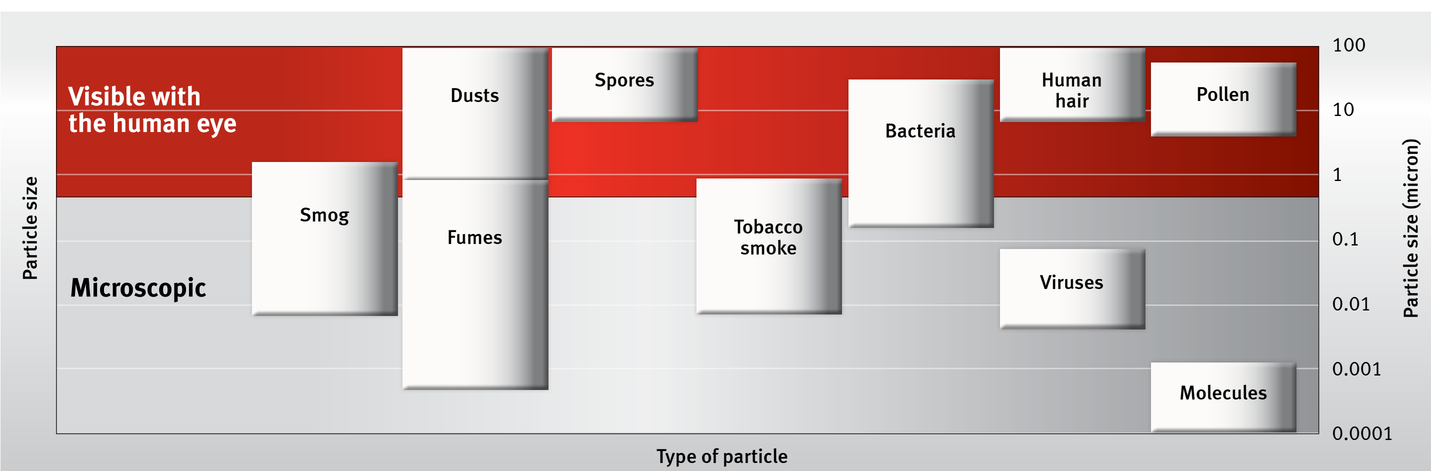
The ideal protective materials for electronic devices with audio components provide IPx4 splash protection and IP6x dust protection without compromising the audio quality of the transducer. Three types of materials that are generally used in vents include wovens, non-wovens and expanded polytetrafluoroethylene (ePTFE). While ePTFE is inherently water- and dust-resistant, woven and non-woven materials provide different levels of contaminant protection. Therefore, it necessary to test these materials to determine the degree of protection provided in specific applications.

The right material depends on the type of housing used for the device. For example, if the housing has open holes near the transducers, a tight non-woven material is needed for protection; however, if the housing has louvered openings, these louvers provide some level of contaminant protection, so the material can have a more open weave. While developing audio devices, engineers often want to evaluate the performance of various materials and housing designs to determine what combination is best for their specific application.

Dust Protection

Portable electronics are exposed to a variety of particles as they are used in outdoor environments. When selecting the right material for the protective vent, it is important to consider the type of particles the electronics will encounter (Figure 1).

Figure 1: Portable electronic devices are often exposed to particles visible to the human eye.

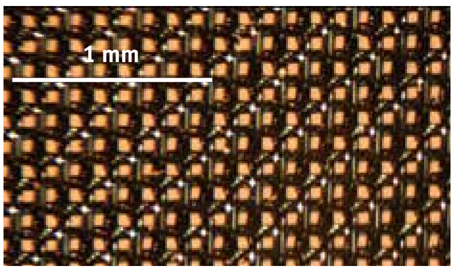


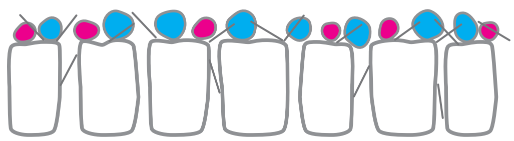
Portable Electronic Vents

Dust Protection, continued

Many manufacturers simply specify a maximum pore size. However, our testing has shown that particle shape and surface area have a more direct impact on the level of protection a material can provide than pore size does. Because the woven product has uniform pore size — as defined by the width of the open square between fibers — the woven material is able to capture only spherical particles equal to or greater than the material's defined pore size (Figure 2). In addition, captured particles sit on the surface of the woven material, which can block airflow and reduce venting capability.

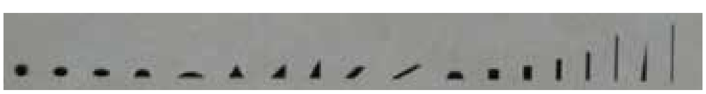
Figure 2: Woven material captures particles equal to or greater than its specified pore size.





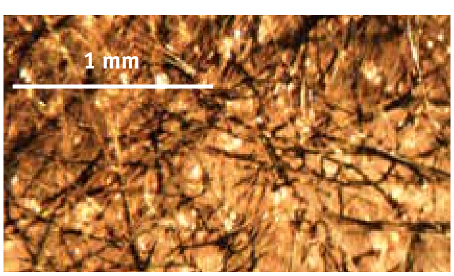
Particles such as human hair or metal fibers that have a surface area equal to or larger than the specified pore size can still pass through the woven material because of their shape (Figure 3).

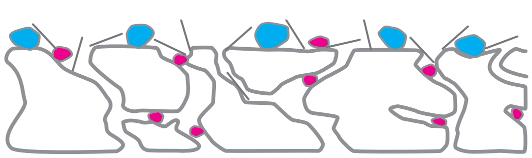
Figure 3: Particles with different shapes and sizes that are classified as 5µm pore size.



Non-woven materials are able to capture particles of various shapes and sizes because of their three-dimensional structure. They are also more likely to maintain consistent airflow because they capture particles in a torturous path not limited by a specific pore size (Figure 4).

Figure 4: Non-woven material captures particles of varying size and shape because of its tortuous path structure.





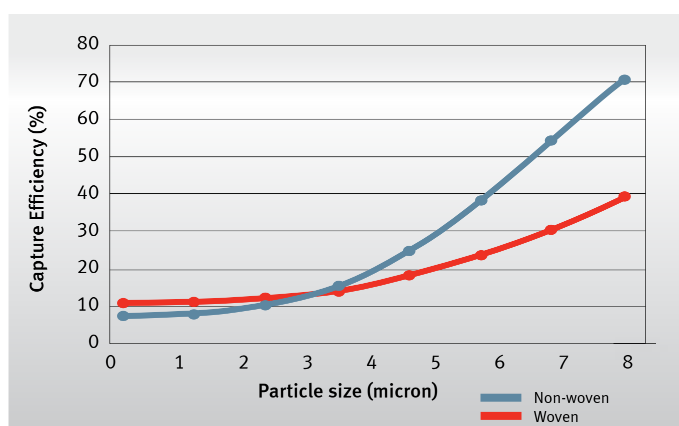
These materials can all pass the current IP test protocols, which specify particle sizes in excess of 50µm. However, the environments in which portable electronic devices are used expose the materials to particles ranging from one to ten microns. Therefore, our engineers focused on particles in this range when designing our particle testing protocol. We assessed several particle testing methods, including EU779, EU1822, IEST-RP-CC0041.3, MIL-STD- 282, and ASHRAE 52.2. ASHRAE 52.2 test protocol, ***Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size***, was selected because it most closely simulated the environment and applications in which portable electronic devices are used. The other tests focus on submicron particle testing, and their flow rates are not realistic for the environmental conditions in which portable electronic devices are used. We worked with an independent laboratory to modify the ASHRAE 52.2 test protocol by

- changing from a horizontal to a vertical pipe orientation to help improve air flow,
- reducing flow rate to 10 cubic feet per minute to simulate ambient conditions,
- redesigning for flat sheet media rather than the pleated cartridges used in many filtration systems, and
- setting a particle size of 1–10µm.

We pump potassium chloride particles at the specified flow rate toward the test sample and use particle counters upstream and downstream to measure how many particles actually pass through the material.

Using the modified ASHRAE 52.2 test method, we can evaluate a material's ability to capture particles of different sizes at different flow rates. For example, we tested two materials with similar airflow and acoustic resistance properties — one woven and one non-woven (Figure 5). The non-woven material's capture efficiency rate improved as particle size increased, with almost twice the efficiency at 8.5µm, when compared to the woven material's efficiency.

Figure 5: Modified ASHRAE 52.2 test results for woven and non-woven materials

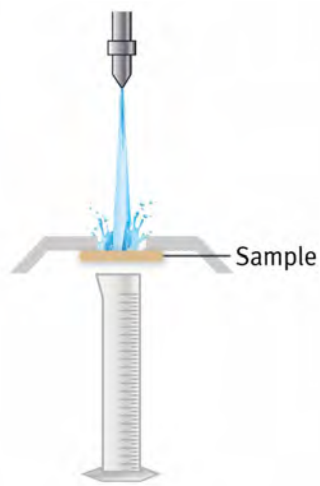


Water Protection

To enable our engineers to provide guidance on housing design for IPx4-rated portable electronic devices, Gore has developed a test protocol to categorize spray-resistant products consistently. This protocol allows design engineers to evaluate various alternatives before they complete the design and construction of the device. The test assesses both the amount of time required for water to penetrate a specific material and the amount and speed at which water passes through the material during the test. Gore performs the test as follows:

1. Using a water nozzle with 0.5mm diameter, position the nozzle 200mm above the material sample to be tested (Figure 6).
2. Select a back pressure of 10 psi and a flow rate of 70 ml per minute.
3. Spray water for one minute.
4. Collect and measure the water in the cylinder beneath the sample.

Figure 6: Test setup for spray-resistant materials



By using this testing protocol, Gore has found a significant variation in the amount of water that spray-resistant materials allow to enter a housing. In a recent test, seventy milliliters (70 ml)) passed through a completely unprotected opening during the test. An open non-woven material allowed 9 ml of water to pass through, whereas a woven material of equivalent acoustic resistance allowed 14 ml of water to pass through.

IPx4 Protocol for Splash Protection

The IEC 60929 standard includes two test protocols for assessing spray protection — the wand protocol and the showerhead protocol. W. L. Gore & Associates prefers the showerhead protocol because it is more rigorous, representing real-world applications.

The construction of the showerhead (geometry, hole size, hole position and flow rate) and the duration of the test are clearly specified in the standard. However, some of the specifications are quite broad, so they can be interpreted in a variety of ways. In addition, some test criteria such as showerhead movement are not specified at all. These broad specifications can directly influence test results, especially for acoustic devices with openings near the transducers that enable sound transmission. Gore has added specific parameters within the standard's showerhead protocol to ensure consistent results in all applications:

- **Position of the Device Relative to the Showerhead** — Acoustic devices tend to have openings near the transducers, which are clearly the most at risk for water penetration. Within the broad specifications of the IEC standard, the device can be positioned so that these vulnerable openings are not exposed to any real water challenge. For example, positioning a housing with a 3mm opening facing the showerhead resulted in 25ml of water ingress after the showerhead test was performed. However, positioning the same housing so that the opening was on either side rather than facing the showerhead resulted in less than 1ml of water ingress after the same showerhead test. Gore always places the face of the enclosure that contains the opening directly below the center of the showerhead before the test begins. This placement reproduces the most challenging conditions the device will encounter in real-world environments.
- **Distance to Sample** — The distance between the center of the showerhead and the surface of the enclosure is described very clearly in the standard. However, the standard allows a range of distances from 300mm to 500mm, which results in a significant disparity between the velocity and aggressiveness of the spray as it comes into contact with the device. At the beginning of its IPx4 tests, Gore positions the showerhead 300mm from the opening that is being tested. By using the same distance in every test, our engineers are able to compare results from different tests done at different times, knowing that the circumstances of all the tests were identical.
- **Showerhead Movement** — The IEC standard does not specify whether the showerhead should be moving or remain stationary at a specific angle. Depending on the position of the showerhead and the opening being tested, a stationary showerhead could prevent any water from contacting the opening. Moving the showerhead continuously during the test increases the likelihood of water directly splashing onto the openings and better replicates real-world conditions. Therefore, Gore has enhanced its IPx4 testing protocol to include a showerhead that moves 40° left and 40° right of its vertical starting position (Figure 7). At the beginning of the test, the opening being tested is positioned directly beneath the showerhead. Using the water pressure, flow rate, etc., specified in the standard, the showerhead moves between five positions that are 20° apart. The showerhead remains at each position for one minute before moving to the next position.

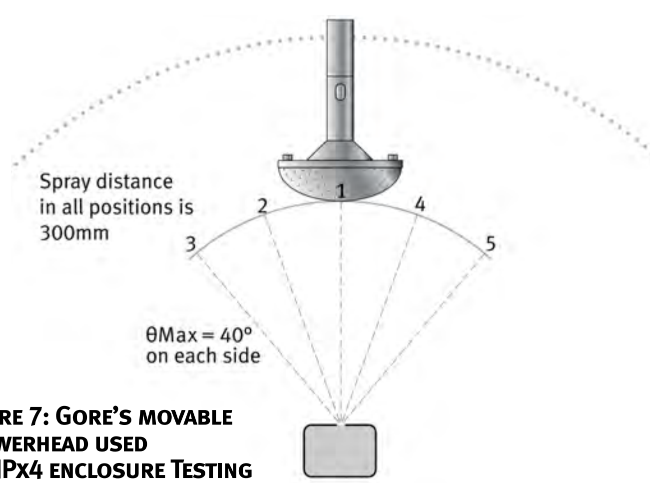


Figure 7: Gore's movable showerhead used for IPx4 enclosure Testing

- **Water Temperature** — The IEC standard specifies using water that is within 5°C of the device temperature. In acoustic devices, the openings around the transducers are also used to maintain equalized pressure within the housing. In areas where water tends to pool, temperature changes can cause vacuum to occur inside the housing. If the water temperature varies more than 5°C from the device temperature, the vacuum that is created can easily be strong enough to pull the pooled water into the device, causing failure. Our engineers have seen situations in which a variation in the water temperature has caused the same amount of pressure to build up as if the device was submerged in water that is eight inches deep. This type of pressure on the device changes the purpose of the test from spray protection to submersion conditions. To prevent potential issues with vacuums during the IPx4 test, Gore stringently follows the standard's recommendation to maintain the water temperature equal to ±5°C of the device temperature.
- **Passing Criteria** — Even when the IPx4 test is performed consistently, the result still needs to be interpreted. The standard's protocol only states that the device must continue to function after the test is performed, but it does not provide a definition of "function." This can lead to very subjective results in acoustic devices. Does a device pass as long as it can be turned on and off, or does it have to perform every feature successfully? For example, one lab may pass a device as long as the electronics do not short out, yet another lab may fail a device with only a slight reduction of acoustic performance. Gore works with the customer or lab's definition of pass/fail when testing their device.

  Also, the passing criteria require that the device be completely designed and assembled. Using the test protocols in the IEC standard, an engineer developing a new product cannot determine if the housing provides adequate protection for internal components that are not yet present. For development testing, Gore compiles mass measurement data using a glass container with a cap containing the protective vent being tested. The glass container is weighed before the test. After the test, the cap is removed, the outside of the container is dried, and it is then re-weighed. Results are given in mass gained, and Gore defines "pass" as less than one gram of water at room temperature. This test protocol enables design engineers to evaluate potential housing solutions during the development process rather than only after the device is completely assembled.

New Protocol for Shallow Immersion Protection

IEC Standard 60529 includes the testing protocols for enclosures designed to meet IPx7 specifications. These protocols require full submersion in one meter of water for 30 minutes, which equals 1.5 psi of water pressure on the device and its protective covers. However, this protocol does not address several situations:

- a device dropped in shallow water briefly, which creates additional pressure as the device hits the water
- a device intended to provide water protection not classified as IPx7 immersion resistant

To address these issues, Gore has developed a test protocol for shallow immersion. This protocol represents a scenario such as a phone being dropped into shallow water like a puddle or a basin. It takes into account the pressure exerted onto a device being dropped from 25 inches above the water's surface (the typical drop height). To ensure that the opening is rigorously challenged, we drop the device so that the openings face the water. The water is three inches deep to replicate the typical depth of a basin or puddle. The device is held in the water for five seconds, and then removed. It is then evaluated based on the pass/fail criteria set forth in the standard.

When evaluating an enclosure during research and development, we use the water-weight measurement protocol (see discussion on "Passing Criteria").

Conclusion

One of Gore's core values is to ensure that our products are engineered to meet or exceed the needs for our customers' specific applications, a concept we refer to as "fitness for use." Although IEC Standard 60529 provides testing protocols for electronic housings, these protocols are not sufficiently comprehensive to test housings for audio components. The IEC protocols can be broadly interpreted regarding test setup, which can lead to inconsistent results.

To align with our core value, we have developed testing protocols to ensure consistent results when testing the water and particle protection performance of electronic device housings. These protocols enable our application engineers to collaborate with our customers while designing audio components and ensure that the venting materials provide the appropriate protection without compromising sound quality.

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