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The Unknown Problem with Airtight Enclosures

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In today's world, sophisticated electronics are used in all types of outdoor equipment in just about every application — telecommunications infrastructure equipment, solar energy systems, outdoor lighting systems, just to name a few. This translates to electronics being exposed to the environment's harsh conditions.

A rugged environment is any environment that can potentially damage electronics. This can be outdoors, where the product is exposed to changing weather patterns, whether it's a sudden thunderstorm or the more subtle shifts between a hot day and cold night. It can also be an environment where there's risk of exposure to harsh chemicals, surfactants or liquids such as those used in high-pressure sprays to clean equipment. It can even include the environment inside the manufacturing facility or the internal environment of the device itself, generating a significant level of heat during operation. In most cases, electronics are designed to be deployed all over the world, so any or all of these situations may be applicable to the design.

To protect the electronics, most engineers design sealed enclosures with robust housing materials, durable seals, and strong bolts to ensure a tight seal. The enclosure is effectively air-tight and waterproof, particularly if it must past Ingress Protection (IP) or National Electrical Manufacturers Association (NEMA) standards. However, once the enclosure is installed in the field, it may begin to show evidence of water and particulates inside the housing. Using watertight enclosures does not necessarily guarantee long-lasting protection and reliable performance because pressure differentials, which over time can cause leak paths, have not been addressed.

Why do Airtight Housings Leak?

Failures often occur because the airtight seals prevent the device's ability to equalize pressure. As the external pressure fluctuates, the enclosure tries to equalize the internal pressure by drawing in air from the outside. If the housing is completely airtight, pressure builds up inside in the form of a positive or negative buildup. Positive buildup causes the housing to bloat, while negative buildup creates a vacuum. Either type of buildup leads to stress on the seals, joints or gaskets, which in turn compromises and damages their effectiveness. The compromised seals begin to allow water and contaminants to enter the housing, which can ultimately lead to electronic failure.

For example, at Gore, our engineers recently worked with a global manufacturer of wireless routers that were specifically designed to withstand extreme environmental conditions. However, after several months in the field, the housings began to leak, and the water caused corrosion and performance-related issues with the electronics. The engineering team determined that the leakage was due to failure of the enclosure's seals. They considered using more rugged seals to eliminate the water intrusion problem, but they soon realized that this would only prolong the time before the seals failed again.

What Causes Pressure Differentials?

Temperature changes are the most common cause of failures due to pressure. The temperature change can be internal, external or both. The electronics inside the housing generate a significant amount of heat, which can result in problems if the heat cannot dissipate. Externally, temperature changes can be dramatic, as experienced throughout the course of a typical day or during a sudden thunderstorm. The graph in Figure 1 shows that the temperature can differ by approximately 50°F over the course of an average day in the desert.

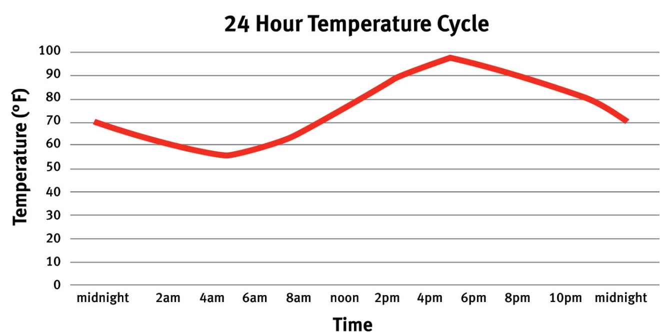

Figure 1. Temperature Cycle for 24-hour Period

A recent customer of Gore designs smart antennas for fleet management systems. The antennas are mounted on the exterior of commercial vehicles, exposing them to severe weather conditions as the trucks move across the country. The antenna is housed in an ASA thermoplastic enclosure with IP67-rated gaskets. The customer's engineering team found that sudden temperature drops caused a vacuum inside the housing and put stress on the seals. The seals eventually failed and allowed moisture inside, which damaged the electronics (Figure 2). They needed a way to equalize the pressure inside the housing without allowing water and particulates to enter.

Altitude changes are another common cause of sudden pressure differentials. Because most shipping containers are not pressurized, transporting products around the world creates many opportunities for them to encounter significant pressure differentials. If the altitude changes are not compensated for, the resulting vacuum makes it very difficult, if not impossible, to open the container. A customer was developing a mobile tool chest to meet military specifications that required the chest to open as soon as it hit the ground after being dropped from an aircraft. The tools inside also needed to be protected from water, dirt and sand, so the customer used O-ring gaskets that provided excellent seals. As shown in Figure 3, the pressure on seals could increase from about 2 psi (137.9 mbar) when dropped from the aircraft to almost 16 psi (1,103.2 mbar) in the short period it took to reach the ground. If not equalized, this rapid pressure change would prevent the sealed case from opening.

Figure 2. Failed Seal in a GPS System

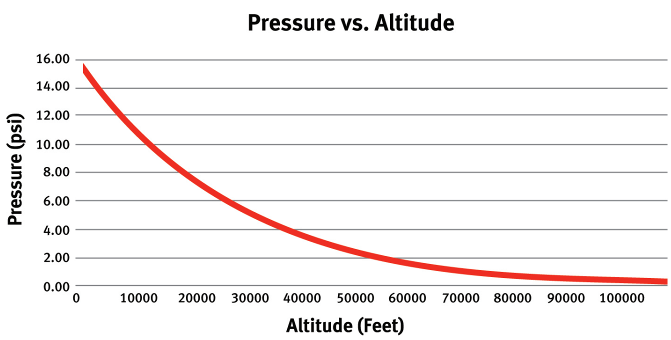

Figure 3. Altitude Changes Increase Pressure

Although electronic devices such as those used in solar energy systems are permanently installed and do not have to deal with altitude changes, they are often exposed to high-pressure sprays to clean the panels. These sprays can generate pressure drops greater than 2.0 psi (137.9 mbar) inside the electronic housings, which can cause even the most robust seals to fail over time.

Design engineers usually think of openings as the weak points, so they install gaskets to improve the seals; however, other areas like those around screw heads, indicator lights and wire conduits are also sources of potential leaks. Figure 4 shows a schematic of the various seal locations and connection points where water and contaminants can enter a tower-mounted amplifier when a vacuum occurs.

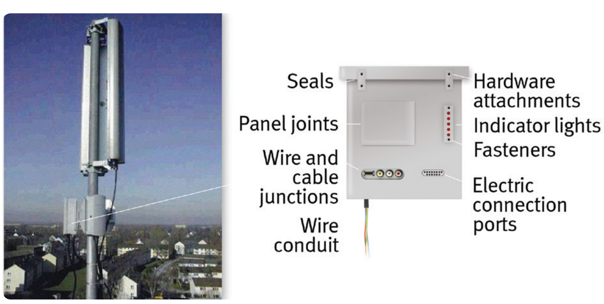

Figure 4. Potential Leak Points of Tower-Mounted Amplifier

How do we Protect Against Pressure Differentials?

The stress placed on seals and connection points is due to pressure differentials that occur again and again over time. This repeated expanding and contracting causes seals to fail. Drilling a hole in the housing or creating a hole with a torturous path eliminates the pressure differential, but this open system concept allows contaminants, including dust, dirt, water and even insects, to enter the enclosure and compromise the electronics.

Many engineers consider hermetically sealing the enclosure as the most secure method to protect electronics. However, hermetic seals require that only non-permeable materials are used in the dive, which means no plastic components. Then the device is welded shut, preventing the electronics from being accessed for maintenance. This option is usually unrealistic for most industrial devices today because they would be extremely heavy and very expensive. Another option is the use of potting compound. However, like hermetically sealing, it is not always feasible because it eliminates the ability to service the electronics, it is expensive, and specialized equipment must be added to the manufacturing process.

Other common options include larger, more robust seals, stronger gaskets or more nuts and bolts. These solutions will remedy the immediate leakage and contamination issues, but they are short-term and may ultimately fail because the fundamental problem of pressure differentials has not been addressed. The device is simply more airtight and more expensive to manufacture without having a solution for the root cause.

Equalizing Pressure without Compromising Performance

Vents made of expanded polytetrafluoroethylene (ePTFE) allow continuous pressure equalization while still maintaining an environmental seal. Expanded PTFE is a unique, microporous membrane that is inherently waterproof. Its unique node-and-fibril microstructure is open enough to allow gas molecules and vapors to pass through it easily, but the openings are so small that liquid and other particulates are repelled.

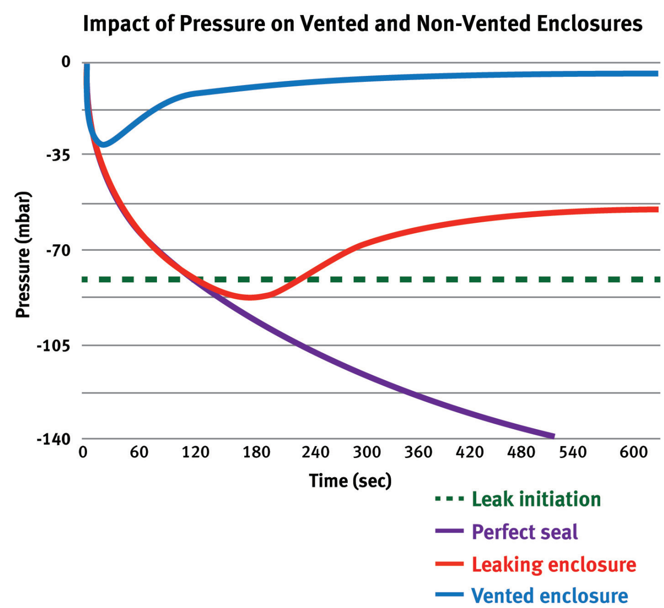

Figure 5. Impact of –70 mbar of pressure (-1.02 psi) on vented and non-vented enclosures

Figure 5 compares the different options for protective housings. The dotted line at -75 mbar (-1.09 psi) is the point at which a sufficiently strong vacuum is created to cause a leak in a sealed enclosure. The dark blue line represents a hermetically sealed metal enclosure, which is able to maintain the seal despite the pressure differentials. The red line represents a typical metal or plastic enclosure with IP67-rated gaskets. This enclosure initially withstands vacuum pressures up to about –70 mbar (-1.02 psi); however, when this pressure is exceeded, the seals are compromised and leaks begin to occur. Finally, the light blue line represents a vented enclosure, which quickly dissipates the pressure differentials, preventing the pressure in the enclosure from exceeding -35 mbar (-0.51 psi), thereby minimizing the stress on the enclosure's seals.

The unique structure of ePTFE improves the reliability of your electronic devices by continuously equalizing pressure, thus eliminating the issue of pressure differentials. Vents made of ePTFE reduce manufacturing costs because they require fewer bolts and/or thinner housings, gaskets and o-rings. Because the seals are not continuously being stressed by pressure, they require less maintenance and repairs, improving the long-term reliability of the product.

One interesting application our team worked on was a surfboard. The board's most common construction is expanded polystyrene (EPS) with a thin epoxy skin. And naturally, it needs to be sealed with air inside so it can float. When designers first switched from wood to EPS, bubbles and delamination would occur on the surface. As the board sat on the hot sand in the sun, the EPS would get hot and expand, causing the epoxy skin to delaminate. The designers tried to solve this problem by installing open plugs that needed to be shut before the board was taken into the ocean; however, the surfers usually forgot to close the plug, which allowed water, salt and sand to get inside the board. An engineer who loved to surf saw the problem as similar to any sealed enclosure. He needed to equalize the pressure so the EPS would not expand, and he contacted our engineering team to help with the problem.

Selecting the Right Vent

Product reliability is crucial to the success of any product. Vents come in a variety of forms, material sets, and sizes, which have different levels of airflow and durability. Selecting the right vent requires more than just choosing the right diameter. Gore has been working with ePTFE for more than 50 years and our expertise is in manipulating ePTFE's microstructure. We alter the membrane's microstructure depending on application-specific requirements such as maximum airflow, IP rating, and size of the enclosure. For example, the amount of free space inside an enclosure dictates the amount of air flowing in it. The more free space there is, the greater the vacuum when there is a pressure differential. Also, the type of IP rating specified for a device dictates the amount of pressure that the venting membrane must be able to withstand, while the severity of the surrounding environment can affect the method for mounting the vent.

To ensure that you select a vent that will perform reliably in your specific application, you should consider several factors. First, what type of experience does the vent's manufacturer have with your industry and the constraints of your application? What type of validation testing has the manufacturer done to ensure that the vent complies with your specific industry standards? Does the manufacturer have engineering support globally that can offer application testing, such as airflow, water entry pressure and climate chamber cycling, to assist with selecting the proper vent construction? Do they consult with you about the right form of the vent, including where it should be installed and how it should be mounted?

After 15 years of experience in the venting industry, Gore's application engineers have found that selecting the right vent for an application requires a high level of collaboration to ensure the best performance for a device or application. When selecting a venting device, make sure you evaluate all of the factors that will deliver the best venting performance, and that you collaborate with your product provider through the entire design and specification process.

For more than eight years, Jason Zambotti has worked with W. L. Gore & Associates' Protective Venting, most recently as the global leader of the telecommunication venting team. Zambotti consults with customers to solve some of the most challenging design issues of ruggedized telecommunications equipment. Zambotti holds a bachelors of science degree in mechanical engineering from Pennsylvania State University and is currently pursuing a masters of business administration at the University of Delaware.

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