Outgassing: The Hidden Danger

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Choosing the right connector for an application comes with a whole range of considerations, ranging from electrical characteristics to mechanical capabilities, but when it comes to extreme environments, other concerns also arise. In this article, we will explore what exactly outgassing is, why it is such a danger to components used in low-pressure environments, and the importance of testing standards designed to control outgassing.

CONNECTOR CONSIDERATIONS IN HARSH ENVIRONMENTS

While connectors are by no means the most interesting area of electronics, the role that they play is so important that, without them, modern electronics would simply not function. Everything from providing power to transferring data between two devices relies on connectors in some way, shape, or form, and because of this, the connector industry is filled with countless numbers of design styles, ranging from consumer USB ports to aerospace D-Sub connectors for high-reliability.

But while connectors may come in numerous styles and options, engineers must carefully consider the environment that their solution will be deployed in before choosing a connector. If such electrical, mechanical, and environmental factors are not considered correctly, then not only is the final design at risk of malfunctioning, but the risks of a faulty device can extend well beyond the scope (for example, a car braking system that seizes due to poor connector choice can inflict harm on both the passengers and pedestrians).

While commercial and industrial applications have their fair share of challenges during connector selection, these challenges are nothing compared to those faced at high-altitudes and in the vacuum of space, where high levels of radiation and massive temperature variations attempt to break designs apart.

WHAT IS OUTGASSING?

One of the unique challenges faced in low-pressure environments is outgassing. Outgassing is the release of gases trapped inside a material as a result of a large pressure difference between the internals of a material and the outside pressure.

During the manufacturing stage of many materials at sea level, it is possible for microscopic gas bubbles to either become trapped in a material, or for bubbles to form internally. This is especially true for molten plastics, where volatile emissions can collect and remain trapped during cooling, but this effect can also affect some metals.

The formation of these gas bubbles can also arise from chemical reactions, such as the solidification of thermoplastics, and impregnation of dopants into metals. Regardless of how these microscopic bubbles form, they do so under atmospheric pressure, meaning that the pressure inside these bubbles is also one atmosphere.

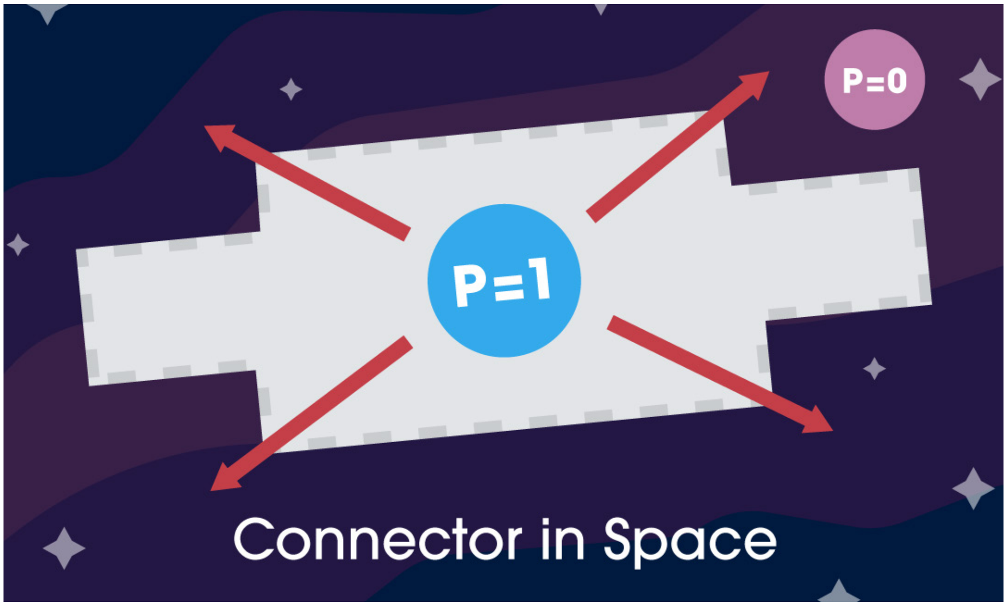
Figure 1: At sea level the pressure inside and outside the connector is 1 ATM

When at sea level, the pressure outside the material is equal to that of the outward pressure experienced by the gas bubbles, meaning that there is no net force on the gas bubble. However, the moment that material is placed into a low-pressure environment (such as a high altitude or space), the internal pressure of the gas bubble is sufficiently larger than the inward pressure, resulting in these microscopic bubbles of gas to find their way to the surface of the material and escape.

WHY IS OUTGASSING SO PROBLEMATIC?

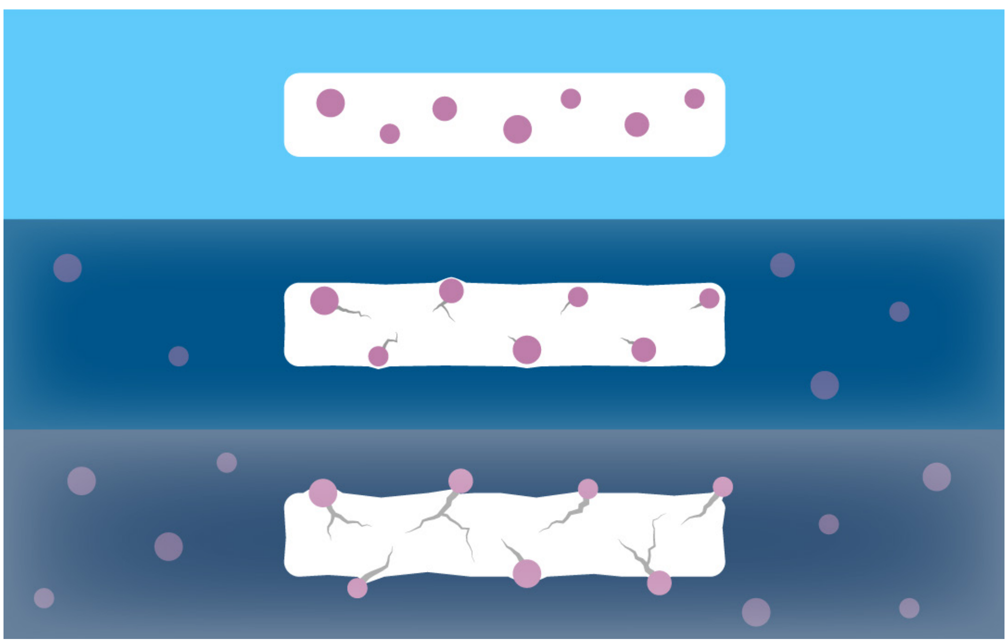
The amount of gas that is released from materials when in a low-pressure environment is miniscule, almost impossible to accurately measure, and yet, it can ruin multibillion dollar space missions. But why is this the case?

Figure 2: The vacuum of space can create a pressure differential between connector and environment.



The first major challenge that outgassing introduces is creepage. Simply put, as these gas bubbles force their way out of a connector, small cracks and fissures can form, which in turn reduces the mechanical strength of that connector. However, as space-based applications also commonly experience wide temperature variations (due to direct sunlight and exposure to space), these fissures can rapidly increase in size, which only hastens the rate of degradation of that connector.

Figure 3: Gas bubbles in a material can migrate causing fractures and damage to the connector.



Another major challenge introduced by outgassing is damage to sensors. When exposed to a vacuum, it is far easier for the trace amounts of gas diffusing from connectors to coat other parts in a thin film, which is exactly how physical vapour deposition works in the semiconductor industry. If these thin films can coat sensitive equipment (such as CCDs and gas sensors), it is possible for their functionality to be permanently affected.

These challenges may seem like an overreaction at first, but there have been numerous cases of outgassing causing issues with space systems. For example, the Cassini spacecraft, which was responsible for sending a probe to Saturn's moon Titan, experienced outgassing of some onboard parts, which coated a navigational camera and induced significant flaring.

This challenge was also faced by the Stardust space probe that was responsible for collecting samples from a passing comet. In response to these incidences, NASA introduced a new testing standard, SP-R-002A, which specifically outlines what materials to choose and how to test them.

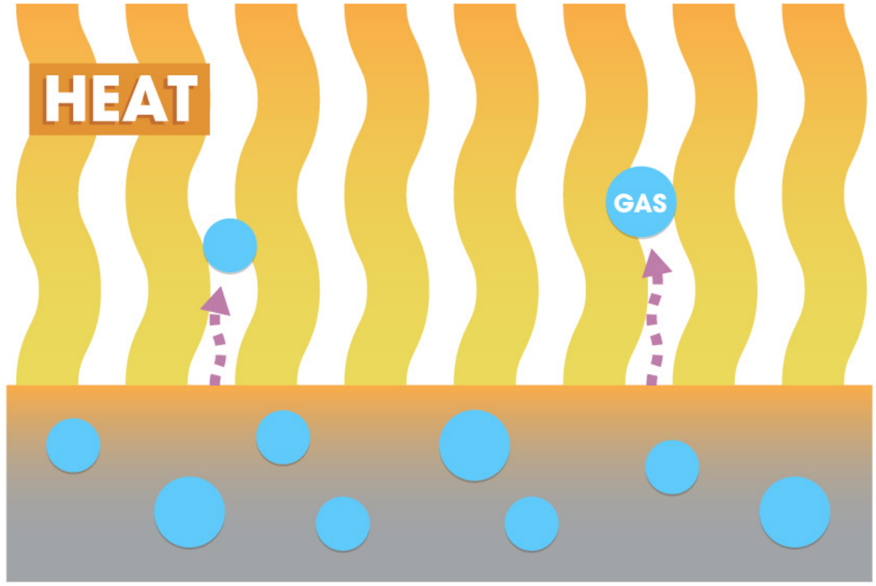
Figure 4: Before and after outgassing formed a thin film on Cassini's CCD sensor.

HOW IS OUTGASSING MITIGATED?

Preventing outgassing can be extremely challenging, but there do exist several methods and procedures that can help in reducing its effects.

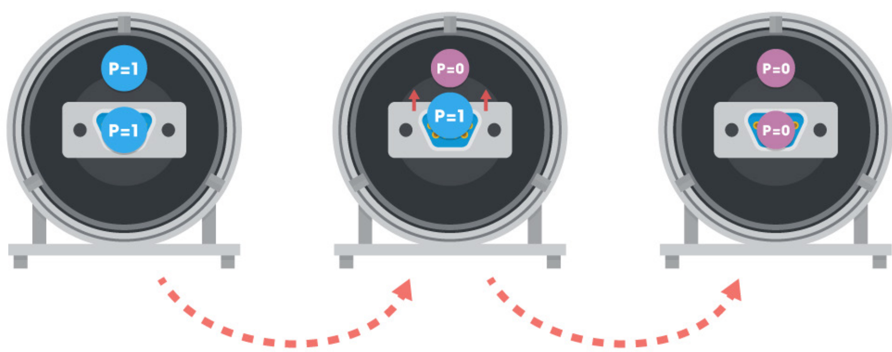
By far the most important method for mitigating against the worst of outgassing is to pre-bake parts. As raising the temperature of parts increases the internal pressure of microscopic gas bubbles, these gas bubbles can be encouraged to diffuse prior to deployment. Furthermore, the application of heat (especially for plastics) can help reduce the formation of fissures from expanding gas, especially when considering that the pressure difference between the internal trapped gas and the outside atmosphere is minor.

Figure 5
Prebaking connectors forces problematic gases out before they can cause trouble.



Parts can also be placed in a vacuum chamber to allow for outgassing prior to installation. The major benefit of this method is that not only are parts pre-tested in a vacuum before deployment, but are virtually guaranteed to have minimal outgassing when used as they would have most of their gas content removed. This is particularly useful for applications that need to deploy sensors that are vulnerable to outgassing.

Figure 6:
Vacuum chambers can be used to simulate the environment of space and pre-test products.



When it comes to material selection, it is important that engineers choose low-outgas variations that have been studied and proven thoroughly (institutions such as NASA have procured a long list of materials suitable for the space industry). Furthermore, engineers can also opt for manufacturing techniques that limit the amount of outgassing, such as pulling a mild vacuum when forming molten plastic parts.

However, the simplest solution, especially when designing electronic systems, is to choose components that have been tested and verified for their low-outgas properties. While there are several testing standards available, the ones to pay close attention to are NASA SSP 30426, NASA SP-R-0022A, ASTM E595-07, and IPC-1601.

NASA SSP 30426 is concerned with controlling external contamination when designing parts for use with the International Space Station. Without going into too much depth, this standard reflects the importance of having parts that are clean and free of grease, volatiles, and gaseous substances that could otherwise interfere with the operation of the ISS.

NASA SP-R-0022A is concerned with controlling outgassing in parts that are used near thermal and optical systems. This standard was introduced after issues were found on the Cassini and Stardust programs and outlines the minimum amount of material loss that a part can sustain when exposed to a vacuum. This standard also outlines exactly how to test such parts, including temperature, pressure, and test duration.

ASTM E595-07 is a standard published by ASTM International, and similarly to NASA SP-R-0022A, it outlines the tests and requirements of parts to minimize outgassing in aerospace applications. During this testing standard, a part is exposed to a vacuum at a temperature of 125°C for a period of 24 hours, and the resulting outgassed material is collected. Once the test is complete, the part must not lose more than 1% of its mass, and the collected volatile compounds must not exceed more than 0.1% of the total mass.

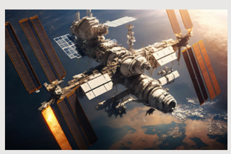
IPC-1601 is a standard that describes how to bake parts to help reduce outgassing when used in military and aerospace applications. It also describes methods for storing manufactured circuit boards to minimize the amount of absorbed moisture, which can lead to disastrous effects in high-performance, high-reliability applications.

TIME TESTED SOLUTIONS

While testing procedures have been developed by NASA and other international organizations, trying to apply these to custom parts can be extremely time consuming and expensive. Instead, it is often far more economical for engineers to opt for parts that have been tried and tested for many years, manufactured by experts with decades of experience. Cinch has decades of experience in the field of connector development, and has routinely been the choice of major NASA missions, including the Apollo missions that landed man on the moon, the Voyager probes that continue to explore the edge of the solar system even after 46 years of continued use, the sentinel satellites that actively provide high-resolution images of the Earth’s surface, and the Beagle 2 Mars lander.

Figure 7: Cinch space rated solutions for digital, optical, RF & Microwave interconnect

All of Cinch's space rated connectors are compliant with ASTM E595 testing standards, making them suitable for applications where outgassing needs to be minimized as much as possible. Because of their low outgas properties, they are also ideal for use in satellites and probes fitted with sensors, including CCDs, but being space-ready, they are also ideal for use in launcher systems.



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