Determining Moisture Resistance Through Accelerated Product Life Testing

Contributors

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Introduction

Small, cosmetically appealing BTEs that can be fit in an open configuration are popular due to positive attributes, including ease of fitting, comfort, sound quality, and cosmetic appeal. But often this style of devices can be more susceptible to moisture damage because of the small size and the promotion of use with an active lifestyle. If you tell people they can be more active while wearing amplification, they will be. Other issues that increase the likelihood of problems and damage include:
1. Placement on head – These devices are more likely to sit above the ear, right where perspiration will drip off the hair-line;
2. Style over practicality – The devices are not supposed to look like a conventional hearing aid and these stylistic choices can make devices less robust; and 3. Battery size – Smaller batteries are easier to short out with a small drop of moisture between the positive and negative terminals and will therefore have more corrosion. But a large battery will increase size and make devices less attractive. Designers need to be aware of the trade-offs and compensate for this. Any compromise for cosmetics must be accommodated with engineering changes to decrease the likelihood of damage. This paper proposes a standardized method to evaluate the moisture and corrosion resistance of hearing aid designs to help focus changes to improve moisture and corrosion resistance.

What Do We Do?

Accelerated Life Testing is a method to expose devices to unrealistically harsh environments to find weaknesses during product design or development. By exposing devices or components to extreme environments and measuring how long it takes for the device to fail, we are in effect speeding up the process to discover potential trouble before it happens in the field. This process also can be used to compare devices with respect to their designs. Which designs will have what types of problems in the future?

For the current evaluation, accelerated life testing can be used to measure a device's sensitivity to moisture with respect to the corrosion that is generated by moisture on the battery and the damage that results from this corrosion. By comparing how easily moisture infiltrates the device, how quickly this generates rust and corrosion, and where a device eventually fails, we can learn methods for improving moisture resistance and reducing the likelihood of problems in the field.

What's Wrong With Moisture?

There is a long history of moisture versus hearing aids. Anyone living in extreme climates knows this problem well. It is assumed that the most problems occur in areas of high humidity, but there are as many problems in hot and dry climates. Humidity isn't really necessary to have moisture problems; it is the extreme heat and perspiration that accompanies it that causes the problems.

Devices eventually give out and require repair, either from blockage in the receiver or tubing, corrosion in the battery compartment, blockage of the microphone, or internal damage. Moisture will short out the battery and release corrosive secretions which will interact with metal parts and create corrosion. The purpose of accelerated life testing is to find what will corrode first to determine weaknesses in the design and compensate or change them. There are moisture-proof coatings that can be placed on some internal electronics to protect from corrosion, so solutions are available for moisture prone components. In addition, moisture can block sound in tubing or block air from batteries and starve the circuit. Therefore, designs need to keep moisture away from critical paths to avoid short term failures.

How to Measure Potential Moisture Issues

The American Society for Testing and Materials (ASTM) has a standard (B117-03) which specifies a consistent method to submit components or devices to an accelerated corrosive environment that allows evaluation and comparison of devices. The standard specifies an environment with respect to humidity, temperature, air pressure, and salt content, as well as the required stability of the environment. The test is performed by submerging items in a corrosive fog at a constant temperature (95° F), salt content (5%), and pressure until something fails. The standard was created for the automotive industry in order to evaluate susceptibility of components to corrosive winter driving conditions.

Test Chamber

The Singleton Corrosion Test Chamber was created specifically to test items to the ASTM standard (see Figure 2). The test chamber consists of a base chamber which is filled with water as an insulator. It is lined with plastic to prevent the chamber itself from corroding. The channel along the top edge allows condensation to collect, creating a seal during testing while the lid is closed.

The neighboring humidifying tower contains distilled water to humidify the air. The level is maintained with a valve from the top storage chamber. The air entering the base chamber bubbles through the water, which humidifies the air before combining it with salt spray to form the corrosive fog. Temperature, humidity, salt content, etc., are all monitored and maintained at a constant level while the chamber is operating.

Devices are placed on artificial ears, which sit on the green platform in the chamber. Devices are complete, including receiver assemblies, any tubing, and are powered with a battery while in the test chamber. Corrosive fog fills the chamber and surrounds the devices for approximately 24 hour periods before the devices are checked to see that they are still working.

Testing: What Does It Tell Us? (from ASTM standard)

This practice provides a controlled corrosive environment which has been utilized to produce relative corrosion resistance information for specimens of metals and coated metals exposed in a given test chamber.

Prediction of performance in natural environments has seldom been correlated with salt spray results when used as stand alone data. Correlation and extrapolation of corrosion performance based on exposure to the test environment provided by this practice are not always predictable. Correlation and extrapolation should be considered only in cases where appropriate corroborating long-term atmospheric exposures have been conducted.

Simplified Version

The salt fog test is designed to find potential metal corrosive failure modes quickly as the environment consists of a very dense atomized fog at 95° F created from a 5% salt water solution. It is very aggressive towards metals. Correlation between accelerated life testing and real-world usage is difficult to determine. Rather, the results determine potential and comparative weaknesses in design that could lead to moisture or corrosive failures. It would be possible to determine the relationship between time in the chamber and time in the real-world, but this would require extensive testing, and is beyond the scope of this study, which is to justify the use of this standard in a comparative evaluation.

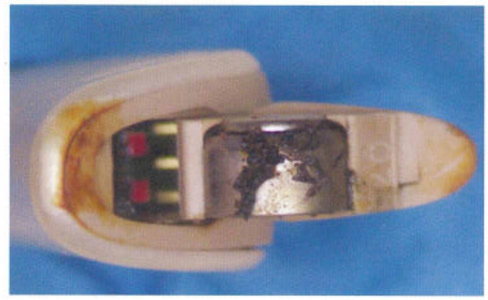

Figure 1: An example of moisture damage

Figure 2: The Singleton Corrosion Test Chamber

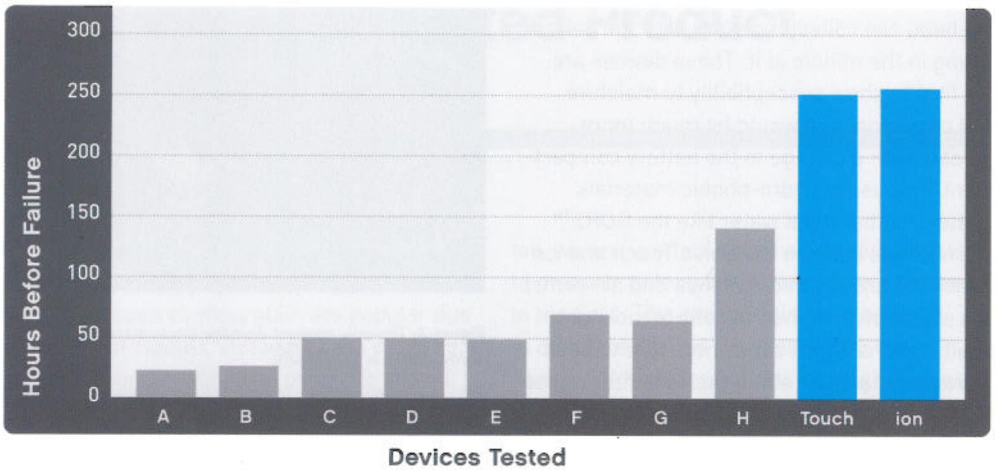

Figure 3: Measured hours before failure for the 10 devices tested in the corrosion chamber.

Test Methods

We evaluated 9 receiver-in-the-canal ("RIC") products from six different manufacturers, including the new Sonic Touch product, as well as the Sonic Innovations ion thin-tube device. Devices were placed on artificial ears and kept in the chamber 24 hours per day. Devices were evaluated once per day. They were dried off and cleaned with a cotton swab and checked for "dead".

If not "dead", they were placed back in the chamber for another 24 hours. Because of experience with rust problems from batteries when exposed to moisture, only stainless steel batteries (PowerOne brand by Varta) were used. This reduced the likelihood of rust and focused on design weaknesses between devices.

Definition of 'Dead'

In order to be considered a dead hearing aid:

1. The receiver was not responsive when the microphones were rubbed.
2. The hearing aid produced no feedback or produced sounds that were scratchy, contained static, or were intermittent.

In other words, the only sound was so distorted that it would lead to customer dissatisfaction and a repair. Otherwise, there was no sound. So, a dead hearing aid was only defined in terms of sound quality, not physical appearance. The first time a device met the definition of dead even after replacing the battery or cleaning with a swab was considered the time to failure. Time in hours was recorded and plotted on a column chart

Test Results

The 'Hours Before Failure' is defined as the time it took a device to meet the definition of dead even after replacing the battery and cleaning with a swab. The time in hours before the device was deemed dead is recorded in Figure 3. Devices designated by letters are competitive devices. The seven devices to the left all died either on the first, second, or third day (as seen by the three plateaus on the column chart). Device H lasted approximately 6 days, while the Sonic Touch and ion devices lasted 10 days. It is important to note that these are not predictions of device life expectancy in the real-world, and significance cannot be determined as only one device of each style was tested. But the large difference between the first device to die and the last suggests there is a wide range of sensitivity and important differences in design. There is no evaluation possible as to the range of performance within a design without additional testing, which is expensive and time consuming.

Battery rust was the most common and first visible response to time in the corrosion chamber, as battery terminals are often construction of plated iron which rusts upon contact with moisture. This can be reduced by use of stainless steel battery, but even these will short out which releases corrosive materials. The corrosive secretions from the batteries contaminate the device, and will eventually infiltrate the electronics and destroy metal connections and part. Certain devices appear to be more sensitive because the design allows moisture and condensation to collect in the battery compartment, which increases the probability of shorting and corrosion.

Receiver Damage

The only receiver damage encountered during the entire study appeared at the glue joint in one device receiver assembly (see Figure 4). The end cap came unglued, allowing the salt to build up on the receiver itself. The receiver was still able to generate sound as the corrosion had not blocked the sound port or eaten into the case. All other receivers survived without incident

Results – Corrosion

The corrosive discharge from a shorted battery will damage metal parts. If it can enter and attack internal components, this will permanently disable the device as seen in Figure 5. There are supposed to be 3 connections between the left and right side of the photo, all of which have been eaten away by corrosion. Power from the battery compartment can no longer reach the electronics, and the device is dead.

Other Findings

Battery corrosion can build up enough to fuse the battery in place (see Figure 6). The battery had to be removed with tweezers, but because the seal between the battery compartment and the inner electronics was maintained, the electronics were not damaged.

The most obvious difference in design between devices appears to be the location and design of the battery door. Battery doors that form a cup-like cavity when positioned on the head can collect moisture with the battery sitting in the middle of it. These devices are the first to show susceptibility to moisture and corrosion, and would be much more reliable with a change to the battery compartment. The use of hydro-phobic materials (materials that repel water like the GORE™ membranes used on the Sonic Touch and ion devices to protect microphones and air-vents) is a successful method to control moisture. Shell materials that cause moisture to bead up rather than flow along the case reduce the likelihood of moisture to infiltrate seams and cause problems.

The last consideration is to control air flow to prevent battery starvation. Designs that seal off the battery compartment avoid corrosion issues, but starve batteries of oxygen. Therefore, vents must be incorporated to ensure power to run the device.

Take Home Message For Your Next Patients

To extend the life of hearing aids, warn patients against swimming, bathing, etc. with devices. They can be made somewhat moisture resistant, but these are not water proof. Use of a dri-aid, or similar, kit has been proven to extend the life of just about any hearing aid. RIC devices act more like custom devices with respect to cerumen, so anything that helps custom devices will help RIC devices. If a patient notices that moisture is present, they should wipe the outside of the case BEFORE opening the battery door to prevent moisture from being pushed into the devices.

It is useful to wipe off the battery if any moisture is present. Problems are often because of oxygen starvation, and anything to get air back into the battery can often fix the problem. Use stainless steel batteries and check for moisture or debris blocking tubing or other openings. It can often be hard to see a tiny drop of moisture blocking a thin tube device, and this will prevent any sound from being generated.

Figure 4: The only receiver damage encountered in the study, due to a glue failure.

Figure 5: Photo of destroyed metal connections between the battery compartment and internal circuitry.

Figure 6: Battery fused in the battery compartment by rust/corrosion.

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