# Humidity Testing for Zinc Fuses

Littelfuse
Expertise Applied | Answers Delivered

## Introduction

Since the 1960 fuses for Automotive applications are manufactured with zinc as their base material. Zinc has a good electrical conductivity and is more cost effective then copper. On the other hand, zinc is not as resistant to corrosion as copper is.

Some of our customers do have concern about corrosion in their application and therefore ask for validation testing. The standard test for Automotive is 50 % relative humidity (RH) and 85 °C. Some of our customers do have a requirement of 85 % RH and 85 °C.

## Where is this test coming from?

The 85 °C / 85 % RH Biased Temperature Humidity (THB) test is a fairly standard test for "Plastic-Encapsulated Microcircuits". It employs high temp and humidity to accelerate the penetration of moisture through the plastic IC encapsulation protective material so it can attack the semiconductor die (i.e. aluminum metallization layer).

The Arrhenius/Peck (AKA Hallberg - Peck) relation is used to determine the acceleration of the test (for Microcircuits). This relationship is not applicable to fuses. The corrosion rate for zinc has his peak at around 65 °C and then decreases at 95 °C.

Since the Fuse is not a plastic encapsulated microcircuit, this test is not applicable for fuses. Running such a test will create a failure mode that is not seen in the field.

## Test requirements

Below you can see some pullouts of various automotive specific.

**Internal Littelfuse test procedure**
Accelerated Aging Test

From the internal LF spec:

> 3.6.3 Accelerated Aging Test
>
> One group of fuses of each required current rating shall be subjected to the following test procedure. The fuses shall be subjected to a total of 60 cycles consisting of:
>
> - Sixteen (16) hours at 50 +/- 5% relative humidity at 85 +/- 2°C, at 80% rated current.
> - Two (2) hours at –40°C +/- 1°C, no current.
> - Two (2) hours at +125°C +/- 1°C, at 70% rated current.
> - Four (4) hours at room ambient, at 80% rated current.

Figure 1 Littelfuse test procedure

The Littelfuse test specification is a combination of all of the industry and customers specifications to cover a worse case scenario.

**Customer requirements**

> A. The devices under test shall be exposed to +85(±2).C ambient temperature and 85(±4)%
> Relative humidity for 1000(±72,-24) hours. The specified temperature-humidity condition shall be continuously applied except for interruptions at specified measurement points.

Figure 2 Additional customer test specification

Sometimes the tests are done with steady state loads, alternating loads or no loading at all.

## Test results

**Automotive standards**

Littelfuse products are validated to the above mentioned "Accelerated Aging Test". Fuses do pass it and will perform after this test as new. Below you can see a typical test report from Littelfuse.

**PRODUCT VALIDATION PLAN AND REPORT**

| **Littelfuse Part No.: 297010** | **Part Name: 10 Amp MINI Fuse** | **Prepared By: Peter A. Greenlimb** | | **Date: May 27, 2004** |
|---|---|---|---|---|
| TEST | ACCEPTANCE CRITERIA | RESULTS | SAMPLE SIZE | REMARKS |
| 12.Accelerated Aging | A. Per Littelfuse blueprint, cold resistance should be 6.50mΩ/8.44mΩ.<br><br>B. Per clause 3.5.1, voltage drop shall not exceed 125mV.<br><br>C. Per clause 3.6.3 (Accelerated Aging), fuses shall be subjected to 60 cycles of:<br>-16 hours at 50% humidity at 85ΩC at 0.80•IN;<br>-2 hours at -40ΩC at no current;<br>-2 hours at +125ΩC at 0.70•IN;<br>-4 hours at room ambient at 0.80•IN.<br><br>D. Per clause 3.5.1, voltage drop shall not exceed 125mV.<br><br>E. Per clause 3.5.2 (Life Test), fuses shall continuously carry 1.10•IN for a minimum of 100 hours.<br><br>F. Per clause 3.5.4, fuses shall clear the circuit within the specified times (minimum/maximum):<br>1.35•IN 0.75s/600s;<br>2.00•IN 0.15s/5.0s; 3.50•IN 0.08s/0.5s; 6.00•IN 0.03s/0.1s.<br><br>G. Per clause 3.5.5, the resistance between the terminals of each fuse shall be greater than 1MΩ when tested in a 100 VDC circuit. | A. Cold Resistance: 7.07mΩ/7.19mΩ<br><br>B. Voltage Drop: 100.2mV/106.0mV<br><br>C. Accelerated Aging Test: Pass<br><br>D. Voltage Drop: 99.9mV/106.1mV<br><br>E. Life Test: Pass<br><br>F. 1.35•IN: 55.9s/83.3s<br>2.00•IN: 0.41s/0.43s<br>3.50•IN: 0.100s/0.102s<br>6.00•IN: 0.032s/0.032s<br><br>G. Insulation Resistance: >1MΩ | A total of 12 fuses were subjected to the Accelerated Aging Testing, 3 fuses per overload. | Test report number: TL-16415 |

Figure 3 Typical Littelfuse test report

**Customer specific test**

The zinc based fuses do not pass test of 85 % RH and 85 °C. Fuses will corrode as shown in the picture below.

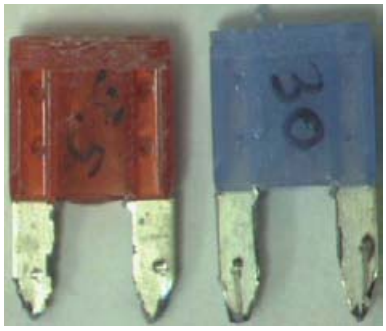


Figure 4 Fuses after test

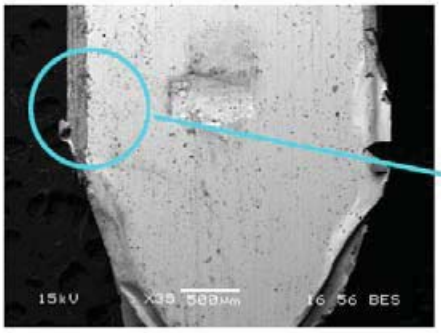


Figure 5 Detail view

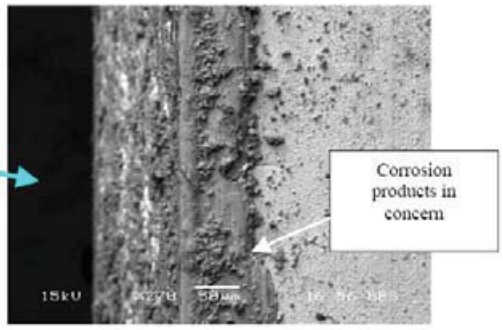



Figure 6 Microscope view

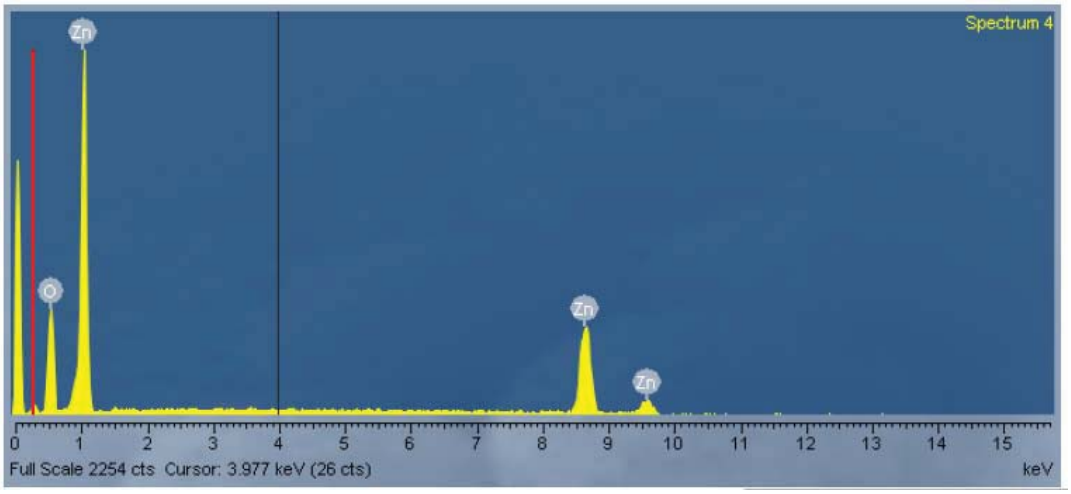



Figure 7 EDS analysis result

These parts were handed over to the LF Advanced Material Lab (AML) for an EDS analysis. The AML found following elements.

| Element | Weight % | Atomic % |
|---|---|---|
| Zn | 72.56 ± 0.89 | 39.29 |
| O | 27.44 ± 0.89 | 60.71 |
| Totals | 100.00 ± 0.00 | 100.00 |

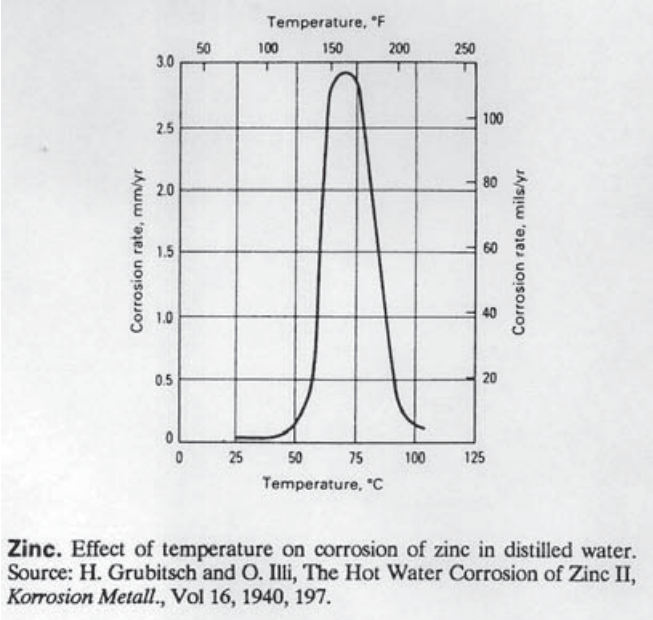
Table 1 EDS analysis result

From the analysis following points were noted:

- The corrosion were silvery white in color, pointing towards most likely formation of Zn hydroxide (as a corrosion product)
- Presence of Zn an O were detected in the corrosion product

**Analysis**

When you take the ISO 8820 specification and the LF internal specification into consideration, the 85 °C / 85 RH test ends up being a worst case condition in terms of the corrosion rates of Zinc. The figure below (Fig 8) shows that the corrosion rate of zinc at 85 °C is much greater than at other temperatures.




**Zinc.** Effect of temperature on corrosion of zinc in distilled water. Source: H. Grubitsch and O. Illi, The Hot Water Corrosion of Zinc II, *Korrosion Metall.*, Vol 16, 1940, 197.

Figure 8 Corrosion of zinc in relation to temperature

## Conclusion

Automotive fuses based on zinc material are not suitable for a high temperature and high humidity test. The rate of zinc corrosion is greatly accelerated at 85 % RH and 85 °C. The acceleration factor of zinc corrosion at these conditions is well beyond the life expectation of a vehicle and therefore not practical in real life application of fuses.

The Automotive fuses have been used in numbers of billions throughout the years in Underhood applications. Those fuse boxes are not sealed and we did not encounter any problems with our fuses. The "Accelerated Life Test" performed at Littelfuse on the industry standard and is sufficient for automotive applications.