2015 Powered Life Reliability Update

TEST DESCRIPTION

Powered Life test is designed to move one step closer to the end-use environment. Fully assembled transducers, composed of circuits, crystals, and mechanical interconnects are placed into ovens and continuously powered until failure occurs. Transducers are monitored daily using automated equipment. Failures are removed from test and diagnosed to determine root cause. Powered life testing is limited due to the capacity of the test system, higher cost of assemblies, and longer times to failure.

2015 POWERED LIFE UPDATE

Powered Life reliability data was last reported on in March of 2013. The update contained herein is exclusive to Powered Life testing and contains the analysis of failures that have occurred between 2008 and April 2015.This report is heavily focused on the reliability testing of the transducer, which contain hybrid circuits. Testing has been conducted at multiple temperatures and is identified in the legend of the reliability charts contained throughout the report.

Interconnects have remained the dominate failure mechanism for transducers in Powered Life (56 failures or ~62% of total tested). Time to failure for each unit is plotted in the figure below. HMP solder is generally used for connecting wires to the circuits and connectors. The solder breaks down over time at temperature and will ultimately lead to a hard failure of the transducer.

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2015 Powered Life Reliability Update

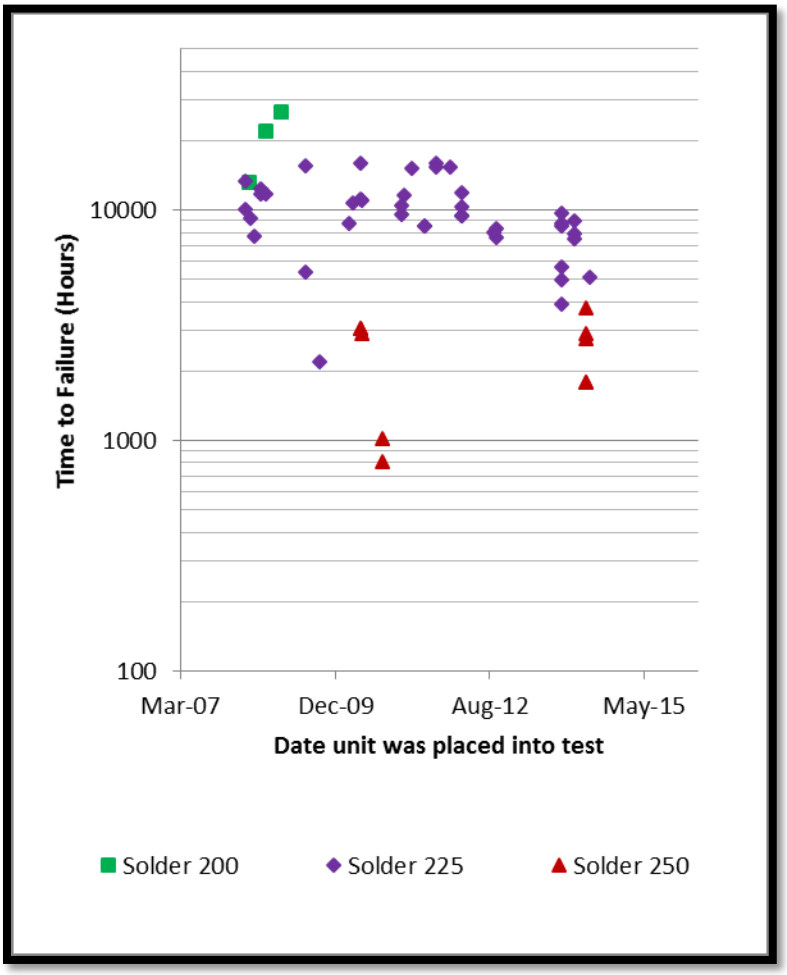

Figure 1: Solder Failures by Temperature since 2008

Since 2008 (41 Units) solder failures at 225°C have demonstrated an average life to failure of 9839 hours, with the high of 16086 hours, and a low at 2202 hours. Since 2008 (10 Units) solder failures at 250°C have demonstrated an average life of 2388 hours, with a high of 3768 hours, and low of 805. Failures are aggravated by handling and thermal cycles. This type of stress is not part of the test by design, but does happen on occasion when replacing cable connections or adding additional units to test.

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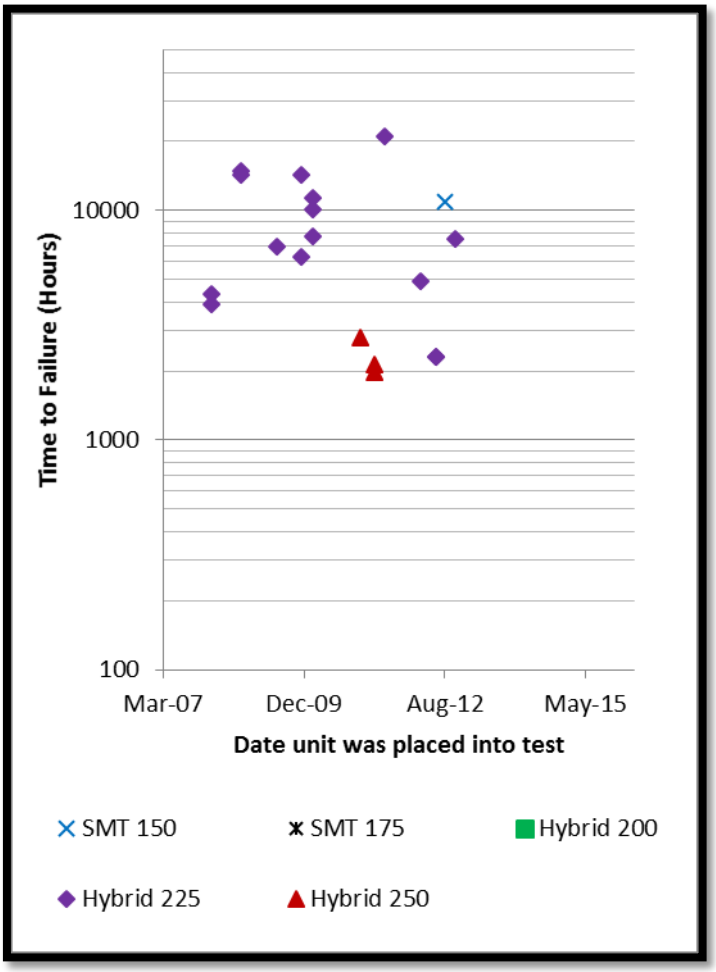

Figure 2: Hybrid Circuit Failures by Temperature since 2007

Hybrid circuit failures are the next most common failure mode in Powered Life testing. A hybrid circuit failure is any failure mode involving the hybrid package that is not an interconnect. Since 2008 (15 Units) hybrid failures at 225°C have demonstrated an average life to failure of 8828 hours, with the high of 21144 hours, and a low at 2304 hours. Investigating the failure data further the sub component in the hybrid that was the root cause of the failures has been shunting capacitors. Quartzdyne uses ceramic capacitors inside the hybrid circuit that when shunted to ground will cause the transducer to fail.

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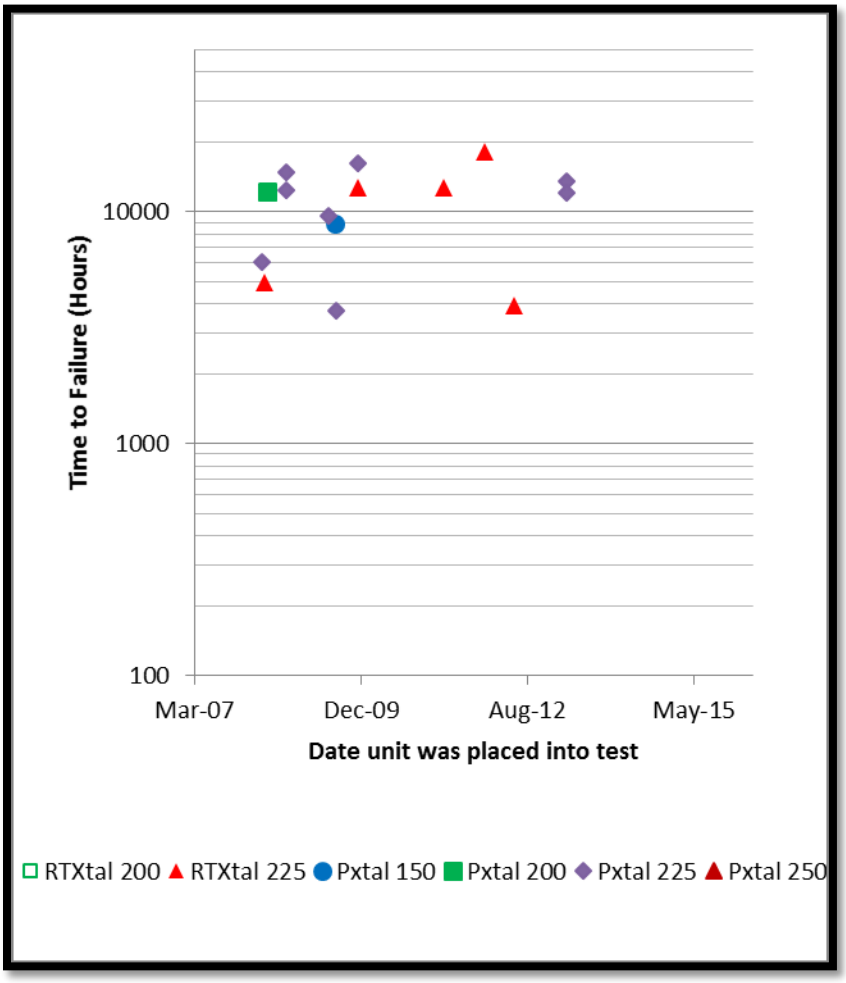

Figure 3: XTAL Failures by Temperature since 2007

In addition to the hybrid circuit the transducer contains three quartz crystals. These are labeled by their sensing function: pressure (PXTAL), temperature (RTXTAL), and reference (RTXTAL). Due to the commonality of packaging and placement in the transducer, reference and temperature have been grouped together in the following chart. Crystal failures were a common failure mode at temperature in the early days of Quartzdyne. Since 2005 significant improvements have been made in order to reduce this failure mode. Since 2008 (13 Units) XTAL failures at 225°C have demonstrated an average life to failure of 10816 hours with the high of 18072 hours and a low at 3734 hours.

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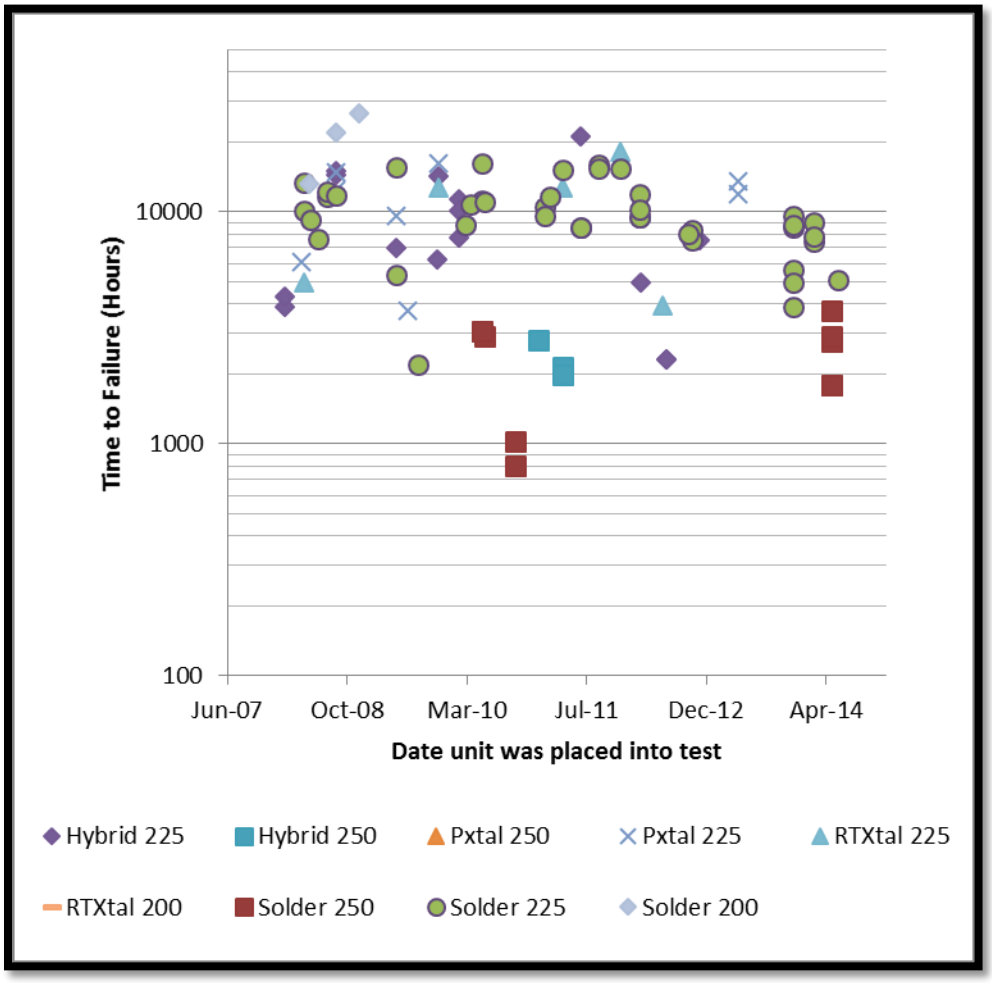

Figure 4: Combination of Failures by Temperature since 2007

The above chart is the collection of the three charts on the previous pages. Looking at just the 225°C temperature data set (which contains 69 samples) the average time to failure of a transducer is 9803 hours. Looking at just the 250°C temperature data set (which contains 13 samples) the average time to failure of a transducer is 2368 hours. Looking at the 225°C data prior to 2008, the average life of a transducer was 4,575 hours. This increase in life is a result of continuous improvement in circuit design, crystal updates, and better mechanical design. As Quartzdyne continues this test we will identify new failure modes and investigate technologies and methods to improve transducer life even longer.

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SINGLE ASIC CIRCUIT POWERED LIFE RESULTS

In late 2013 Powered Life Testing began on the Single ASIC Circuit. To date 11 units have failed in Powered Life testing; the graph below highlights the time to failure and the temperature the units were tested. To date there have been zero failures for hybrid circuit. All 11 failures were the result of interconnect failures. At 225°C (6 units) the average life was calculated to be 6912 hours with a maximum achieved of 9648 hours. At 250°C (5 Units) the average life was calculated to be 2606 hours with a maximum of 3768 hours. Although the average life at 225°C is less than the average 9803 hours, as we test more samples we anticipate the gap in average life between the two configurations to close. We expect to see longer life with the Single ASIC Circuit as we integrate new technology to remove solder interconnects and ceramic capacitors.

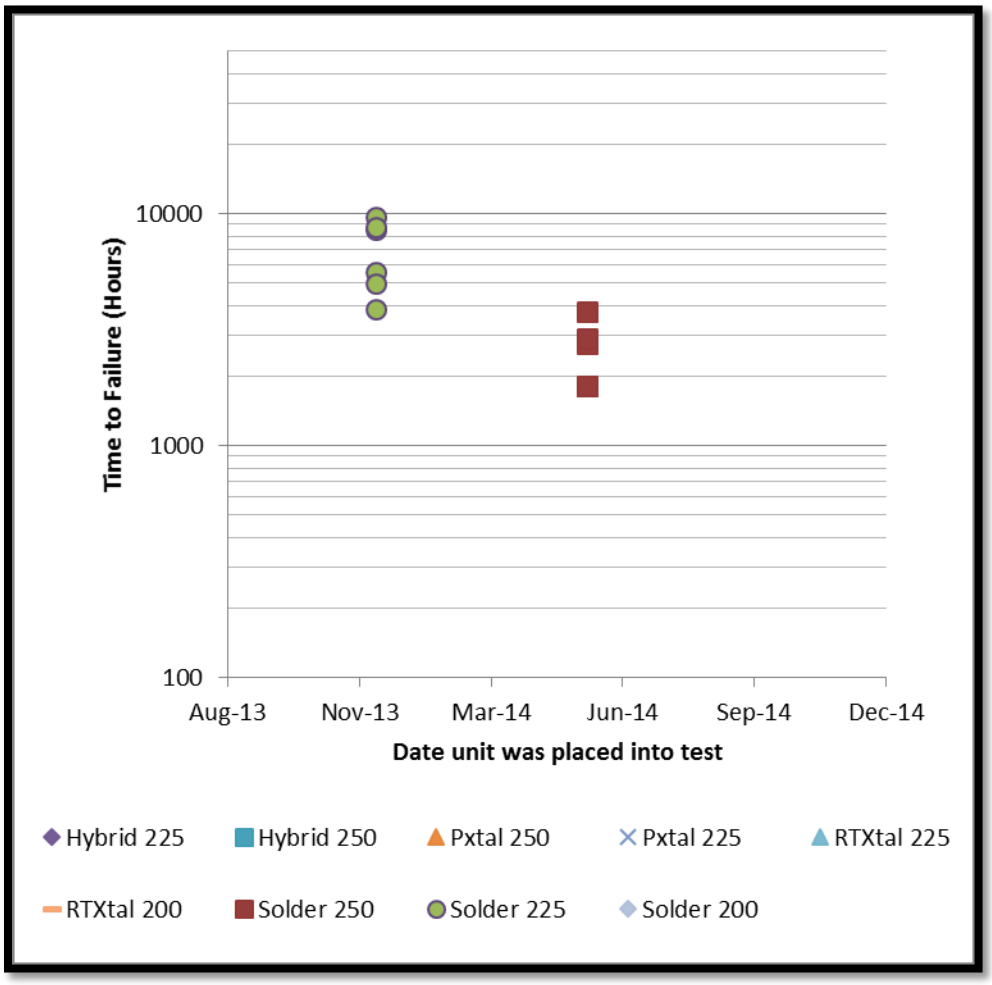

Figure 5: Single ASIC Circuit Failures by Temperature and Failure Mode

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