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Application Note – AC11-004
Overpressure testing of AC3055-010

This Application Note presents information on the overpressure capabilities of AC3055 series die. While specific to the AC3055 die, the results are extendable to the AC3050 and AC3030 die series as well. This document should only be used as a design guide.

Overpressure of Low Pressure Sensor Die
Two parameters are usually cited as a measure of overpressure performance.

- **Burst Pressure**: the maximum pressure that may be applied to the sensor without a catastrophic failure.
- **Proof Pressure**: the maximum pressure that may be applied to the sensor without causing a change in performance with respect to the specifications.

All pressure die will ultimately fail if high enough pressure is applied. In some pressure sensors, the diaphragm goes thru what is call plastic deformation when the stress gets too high. Stainless steel diaphragm devices are one such class of devices where this can occur. After the device goes thru the plastic deformation region, the diaphragm remains permanently distorted, changing both the span and zero performance. Silicon pressure sensor elements, on the other hand, do not go thru this plastic deformation. At some point, some part of the packaging or die attach may change and you get a change in performance and the sensor has exceeded its *Proof Pressure*. Once the stress gets too high, the device simply breaks and the diaphragm leaks (*Burst Pressure*). The exact pressure where this occurs is dependent on many variables – the design, the processing, how the pressure is applied, and, to some extent, the past history of the device.

There are two separate parameters used, in general, to quantify the over-pressure characteristics. Proof pressure is the pressure that a sensor can routinely see without a permanent change in the output. Burst Pressure is where the device breaks or fails. Historically, pressure manufacturers prefer to be safe and have rated sensors with a proof pressure of 3X of the rated full-scale and a burst pressure of 5X. For very low-pressure sensors, this very safe set of specifications really needlessly limits the useable range of the sensor. For instance, a 10 mBar part, limited to a 5X overpressure means that it could only be used handled with less than 50 mBar, or 1/20th of one atmosphere.

There are other reasons to be concerned about proof-pressure and burst-pressure. Typically in very low pressure applications, a very soft elastomer is used to attach the pressure sensor die to the sensor housing. This die-attach needs to be cycled and stressed for the maximum reproducibility. Effectively the die-attach needs to be cycled to eliminate non-plastic deformation/hysteresis. This, then, creates a balance between how high this cycling can go and where damage to the sensor will occur.

Parameters that Impact Overpressure
Several different parameters can impact over-pressure and survivability. Virtually without exception, silicon pressure sensors exhibit different front vs back pressure characteristics. This is because the silicon diaphragm is supported differently when one compares top vs bottom. As a result, there tends to be higher stress on the diaphragm when the diaphragm is deflected upwards from the backside.

In addition, modeling shows that sharp, abrupt edges lead to higher stresses. Thus, one method to reduce peak stress is to round the transitions both in the thickness (Z) as well as the planar (X-Y) dimensions. Thus rounding corners tends to reduce peak stress and improves overpressure.

The actual pressure transient may impact the overpressure. Many times, a part appears to fail at below the rated pressure but subsequently, it is found that the pressure system had a “water-hammer” effect where instantaneous peak pressure was significantly higher than the intended static pressure.

<u>Tests performed in this study</u>

Several tests were performed:

1) Pressure cycling at below the Proof Pressure – This test was to determine a safe limit to optimize long-term span and zero stability as a result of pressure cycling well above the rated pressure range. Parts were cycled 100 times at the cycled pressure.

2) Overpressure to destruction – Burst Pressure Testing – Multiple parts were taken in progressive steps until the part no longer held pressure. Different parts were used for front and back side testing.

<u>Tests Results – Proof Pressure</u>

Parts were initially tested at rated pressure (10 mBar or 0.15 PSI). The parts were then pressurized at 1, 2, 3, 4, and 5 PSI (app 7X, 13X, 20X, 27X and 33X the full-scale pressure). The span and zero at rated pressure were then measured. Then they were subjected to 100 cycles at 2 PSI and then again pressurized at 1, 2, 3, 4, and 5 PSI. Between pressure cycles, they were again re-measured at zero and the rated pressure. The span and zero changes were then computed. Finally several parts were cycled at 4 PSI and then the pressure step test was once again performed.

Acuity does recommend pressure cycling parts to at least 5X the intended pressure range prior to calibration. This relieves stress in the die-attach mostly. Figure 1 shows how the cycling tends to stabilize the zero for the parts. It is apparent that there are some changes up to the 50 to 60 cycle range. Figure 1 assumes that the true value of the zero is after cycling. Thus all data was referenced to give zero error at the final, 100th cycle reading.

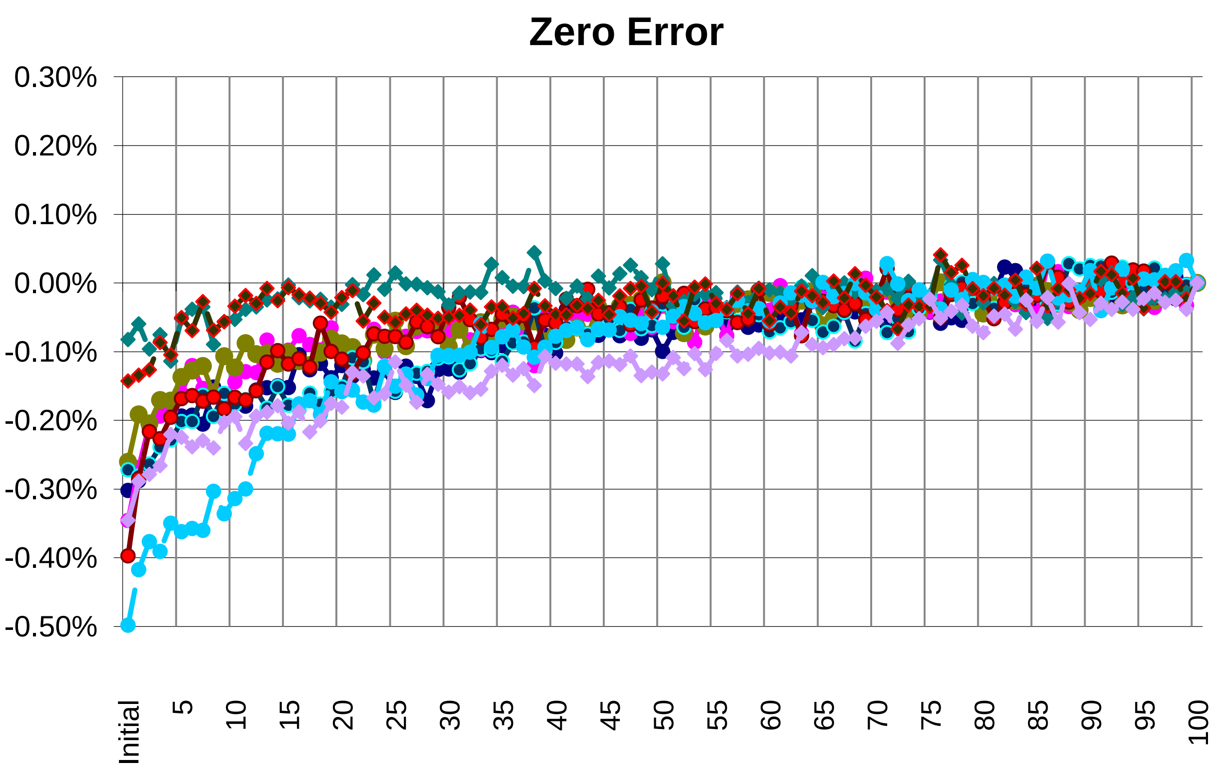

FIGURE 1 – EFFECT OF PRESSURE CYCLING ON ZERO

To further demonstrate this effect, parts were tested without cycling. The results of then pressurizing them to 1, 2, 3, 4, and 5 PSI is shown in the top plots in Figure 2. They were then cycled 100 times at 2 PSI. This reduced most of the changes in span and offset as the parts were over-pressured. Note in particular, that the parts all perform well up to 2 PSI in the second set of charts. However, three parts did show drift above 2 PSI. Finally, the three worst parts were cycled 100 times at 4 PSI. This cycling reduced the error to below 0.2%. This is in the range of the measurement reproducibility

While parts with no pressure pre-conditioning showed upwards of 1.18% drift when over-pressured to 5 PSI, parts that were conditioned ended up with a change of less than 0.2% after overpressures that exceeded 30X the rated pressure.

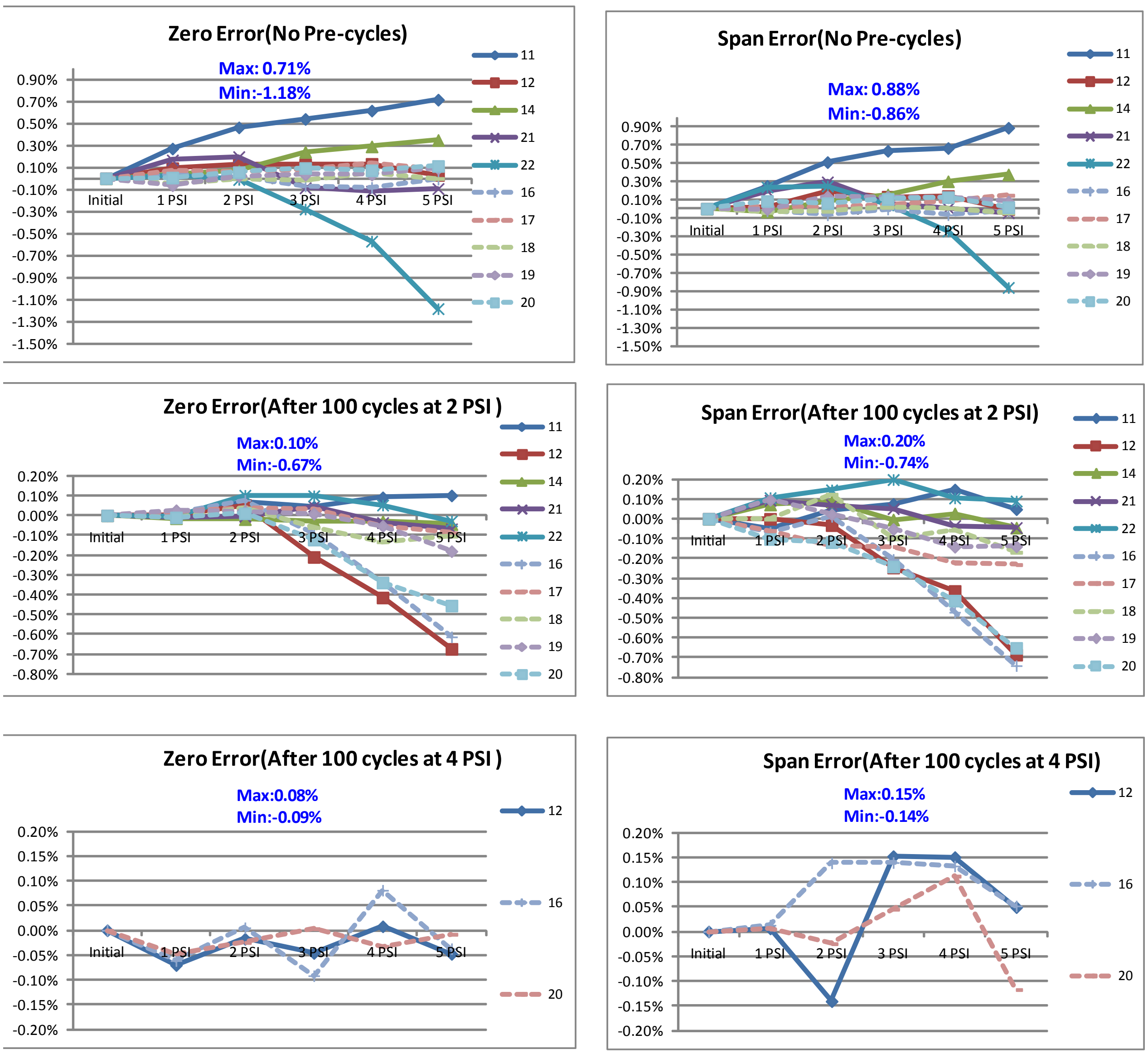

FIGURE 2 – SPAN AND ZERO CHANGES AS A FUNCTION OF OVERPRESSURE , PRESSURE CYCLING AND THE VALUE OF PEAK PRESSURE DURING CYCLING

Test Results – Burst Pressure

Multiple parts were tested. Parts were stepped in pressure at 0.5 PSI increments. The Pressure source would be turned off at each pressure and then the pressure would be monitored to see if the sensor system maintained the set pressure. Once the part developed a leak, the pressure was not maintained and the sensor was classified as destroyed by exceeding its burst pressure. Some parts were tested with back pressure while others were tested with top pressure. Because of the destructive testing, separate parts had to be used for these two tests.

Front-side Pressure Test

Front	Passed	Leaked
6	14.5	14.75
7	13.25	13.5
8	13.25	13.5
9	7.5	7.75
10	13	13.25
Ave	12.30	
Std	2.75	
LCL	4.06	

Back-side Pressure Test

Back	Passed	Leaked
1	9.25	9.5
2	7.75	8
3		14.25
4	8.25	8.5
5	7	7.25
Ave	8.06	
Std	0.94	
LCL	5.23	

As can be seen, the Front-side pressure test had one failure at 7.5 PSI while the Back-side pressure test had one abnormally high part. That one was excluded from the average. The conclusion is that the 10 mbar parts withstood easily in excess of 20X overpressure. The lowest failure in this test was >45X the rated pressure.

Conclusions

The AC3055-010 was tested for survivability after over-pressure. What has been demonstrated in the study is that:

1) It is recommended that parts be cycled roughly 100 times at an elevated pressure (10X or 20X the intended pressure range). This improves long-term stability by flexing the die-attach.
2) Burst Pressure is in excess of 45 X the full-scale pressure, based on the lowest failure in this sample lot of 7 PSI (47X).
3) Proof Pressure has been demonstrated for all of the part at >33X and, under repeated cycling at in excess of 13 X, parts demonstrated highly reproducible results.

For further information

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