MICRON OPTICS

Micron Optics, Inc.
Os5100 Optical Displacement Gage
Long Term Test Summary

Preliminary

The following tests have been performed on the os5100 Optical Displacement Gage to confirm the long term reliability of the product under extreme environmental conditions. These tests include temperature cycling, high temperature and humidity, fatigue and monitoring in an outdoor test bed.

Wavelength/Position Relationship

To establish a baseline criteria for the displacement gage, each gage is individually calibrated to determine a gage factor and offset. These parameters are unique for each gage and are provided on the sensor information sheet included with the gage. The calibration process produces a linear relationship between the wavelength of the two gratings and the probe position that takes the form:

$$D = m(\lambda_2 - \lambda_1) + b$$

Where: D is the displacement in millimeters
- m - Gage factor
- λ_2 - Wavelength of FBG 1(nanometers)
- λ_1 - Wavelength of FBG 2 (nanometers)
- b ï Offset (millimeters)

Calibration is performed on a high precision calibration fixture with an accuracy of 2.5µ over 60 mm. The displacement gage is calibrated over the entire 50mm range. To insure a precision calibration, the r^2 correlation coefficient between wavelength and position is checked for each gage and must exceed 0.999975.

Temperature Cycling

Three displacement gages were temperature cycled for 500 cycles over the range of -40 to +80°C. The gages were mounted to test fixtures fabricated from a cold rolled steel base with a CTE (coefficient of thermal expansion) of 10.7 µ/m-°C. The fixtures are designed to maintain constant probe position simulating zero displacement. While the gages were tested for variation at the center and at both extreme ends of travel, the center position was used for both temperature cycling and humidity soak. See test fixture in figure 1 below.

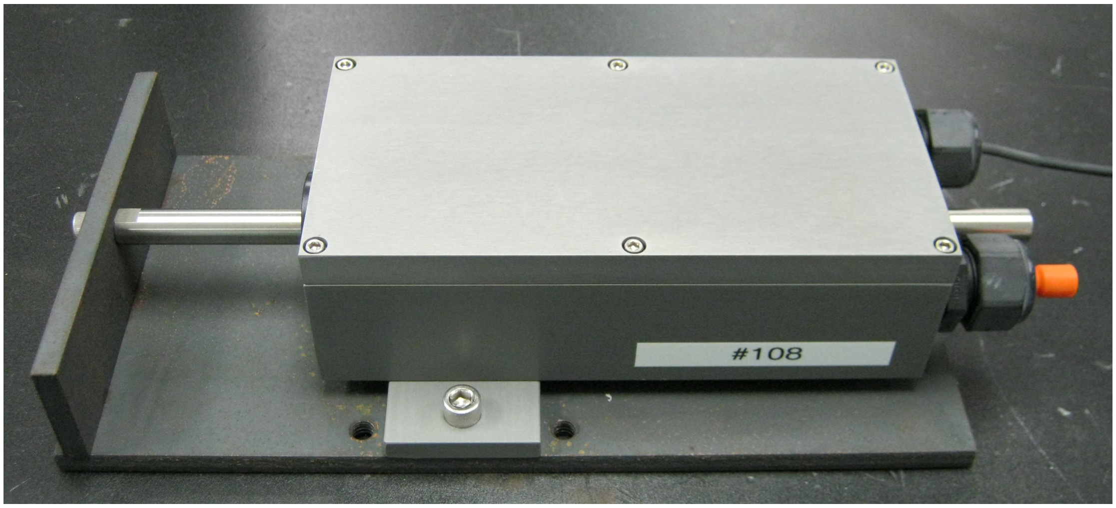

Figure 1 – Gage setup for temperature and humidity tests

The graph in Figure 2 shows the position measurement for the first 29 temperature cycles for each of the gages. Due to the thermal mass of the gage and test bed, the position variation does not produce a linear relationship during the minimum to maximum temperature change. The chamber was ramped at a rate of 1.2°/minute with a dwell of 15 minutes at 80°C and a dwell of 60 minutes at -40°C.

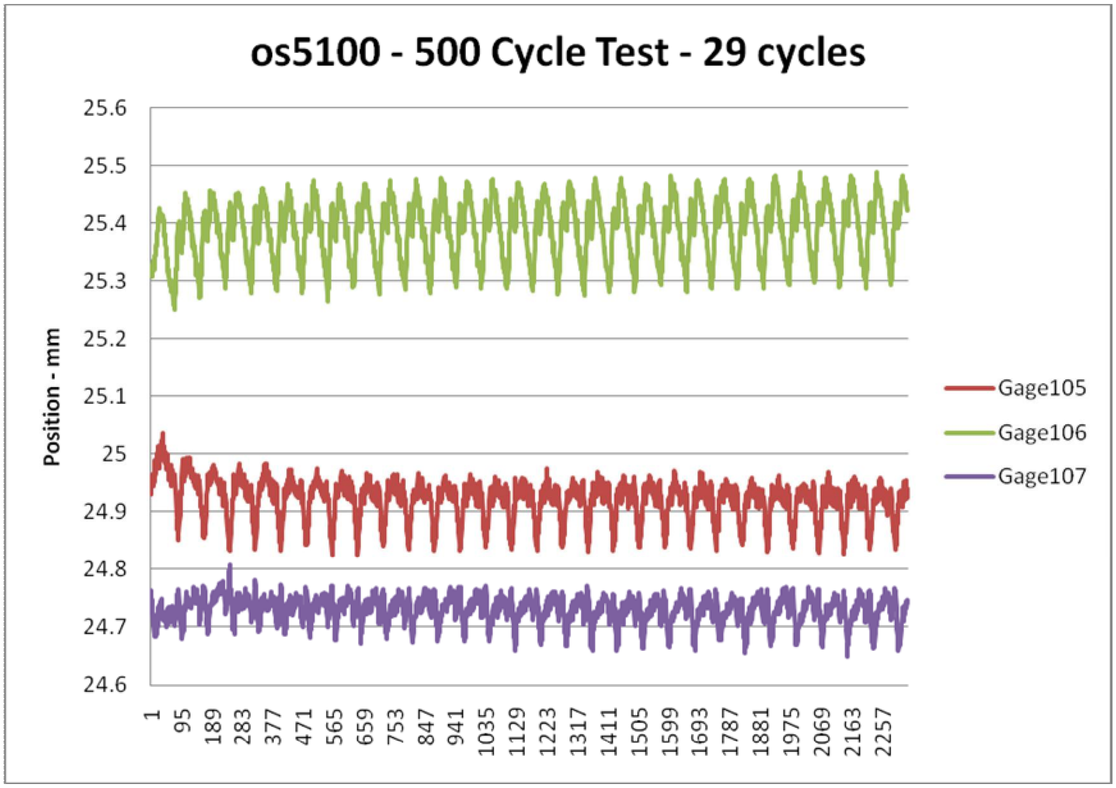

Figure 2 – Temperature Cycle – First 29 Cycles

Figure three is the graph of the same sensors for the last 20 cycles of the test.

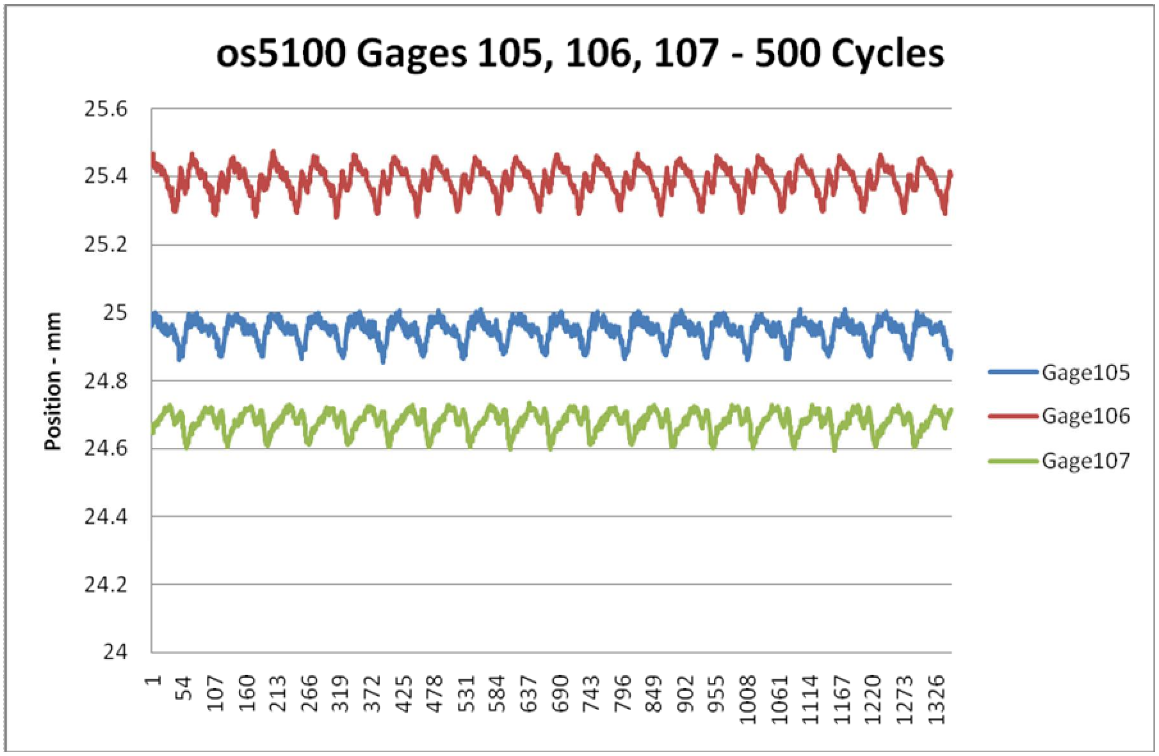

Figure 3 – Temperature Cycle – Last 20 cycles

Below is a summary of the variation for each gage for each group of cycles throughout the duration of the test. The max, min and difference represents the maximum, or minimum recorded data point for that group of cycles. The Total Diff (in bold) is the total variation or error for all 500 cycles.

Gage Movement Variation During Temperature Cycling (units - mm)									
	Gage 105			Gage 106			Gage 107		
Cycles	Max	Min	Diff	Max	Min	Diff	Max	Min	Diff
1 - 29	25.036	24.824	0.212	25.490	25.250	0.240	24.808	24.649	0.159
30 - 90	24.979	24.796	0.183	25.484	25.272	0.212	24.796	24.640	0.156
91 - 121	24.983	24.809	0.174	25.475	25.285	0.190	24.769	24.636	0.133
122 - 157	24.982	24.811	0.171	25.489	25.303	0.186	24.763	24.636	0.127
158 - 185	24.987	24.810	0.177	25.489	25.279	0.210	24.763	24.623	0.140
186 - 231	24.994	24.828	0.166	25.488	25.269	0.219	24.752	24.619	0.133
232 - 268	25.000	24.836	0.164	25.486	25.275	0.211	24.745	24.608	0.137
269 - 300	24.994	24.837	0.157	25.483	25.273	0.210	24.745	24.617	0.128
301 - 378	25.002	24.837	0.165	25.484	25.281	0.203	24.753	24.609	0.144
379 - 415	25.002	24.836	0.166	25.484	25.304	0.180	24.749	24.611	0.138
416 - 453	25.001	24.847	0.154	25.473	25.293	0.180	24.749	24.607	0.142
454 - 500	25.011	24.855	0.156	25.475	25.280	0.195	24.737	24.592	0.145
Max/Min/Total	25.036	24.796	**0.240**	25.490	25.250	**0.240**	24.808	24.592	**0.216**

Figure 4 – Temperature Cycle Gage Variation Summary

High Temperature/Humidity Soak

Two gages were soaked at 75°C and 75% relative humidity for a total of 1014 hours. The gages were mounted on the same type of fixture as were used for the temperature cycling test. The graph in figure 5 below shows a snapshot of three windows of data for the duration of the test; the first 600 data points represent the start of the test, the next 900 data points represent the middle of the test and the last group of data points represent the end of the test including the chamber cool down process.

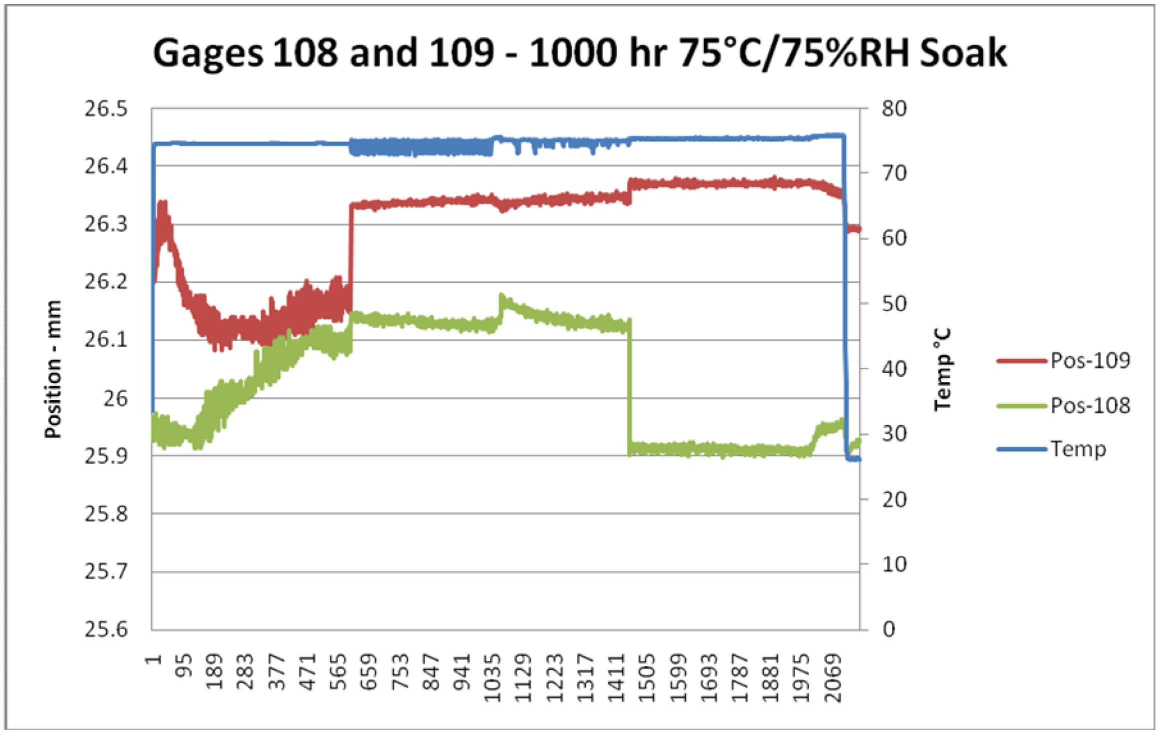

Figure 5 – Temperature/Humidity Soak

Various components of the gage were also placed in the chamber during the test to examine for corrosion. This resulted in a material change on one component from plated O1 tool steel to 17-4PH passivated stainless steel. All other components were not affected by the high temperature/humidity environment.

Fatigue

Two gages were tested for fatigue, gages 103 and 111. Gage 103 was tested for 10 million cycles with periodic examinations for wear and other detrimental effects. Several improvements were implemented in the building of gage 111 which was tested for a total of 33,000,000 cycles. Figure 6 below depicts the summary of the two tests.

os5100 Fatigue Test Summary				
Gage	**# Cycles**	**Stroke**	**Speed**	**Universal Joint**
103	10,000,000	40 mm	120 - 150 cpm	no
111a	30,000,000	40 mm	250 - 265 cpm	yes

Figure 6 – Fatigue Test Summary

During the test the gages were constantly monitored for wear, accuracy and other failure mechanisms. After 3,000,000 cycles on gage 111, the gage was opened up and internal bearings were replaced with sealed bearings (now the standard configuration). The gage was recalibrated and then tested for an additional 30,000,000 cycles. During the test, data on the position of the gage was recorded for 5 seconds at 1kHz every four hours using a Micron Optics sm130 and ENLIGHT software. Figure 7 shows a summary of the data.

Measurement Variation – Fatigue Test			
	Stroke Position (mm)		(mm)
Cycles	Max	Min	Diff
0.0	46.768	6.081	40.687
5.0	46.765	6.063	40.702
6.8	46.764	6.055	40.709
9.3	46.719	6.057	40.662
10.0	46.769	6.081	40.688
27.0	46.652	6.035	40.617
Max Position	46.769	6.081	
Min Position	46.652	6.035	
Variation	0.117	0.046	

Figure 7 – Gage 111a Repeatability Summary

In the above table the Max Position is the maximum position recorded in the snapshots of data over the 30,000,000 cycles and Min Position is the minimum position recorded over the same period. The maximum recorded variation is .117mm over the 30 million cycle test; some of the variation could also be attributed to the Fatigue Test Bed as well.

Another means of identifying the effects of wear on the gage is to recalibrate the gage and examine the curve fit near the ends of travel since the gage was tested over the range of 6 to 46mm and the calibration is measured over the full 50mm of travel. The results of the calibration are shown in figure 8 below.

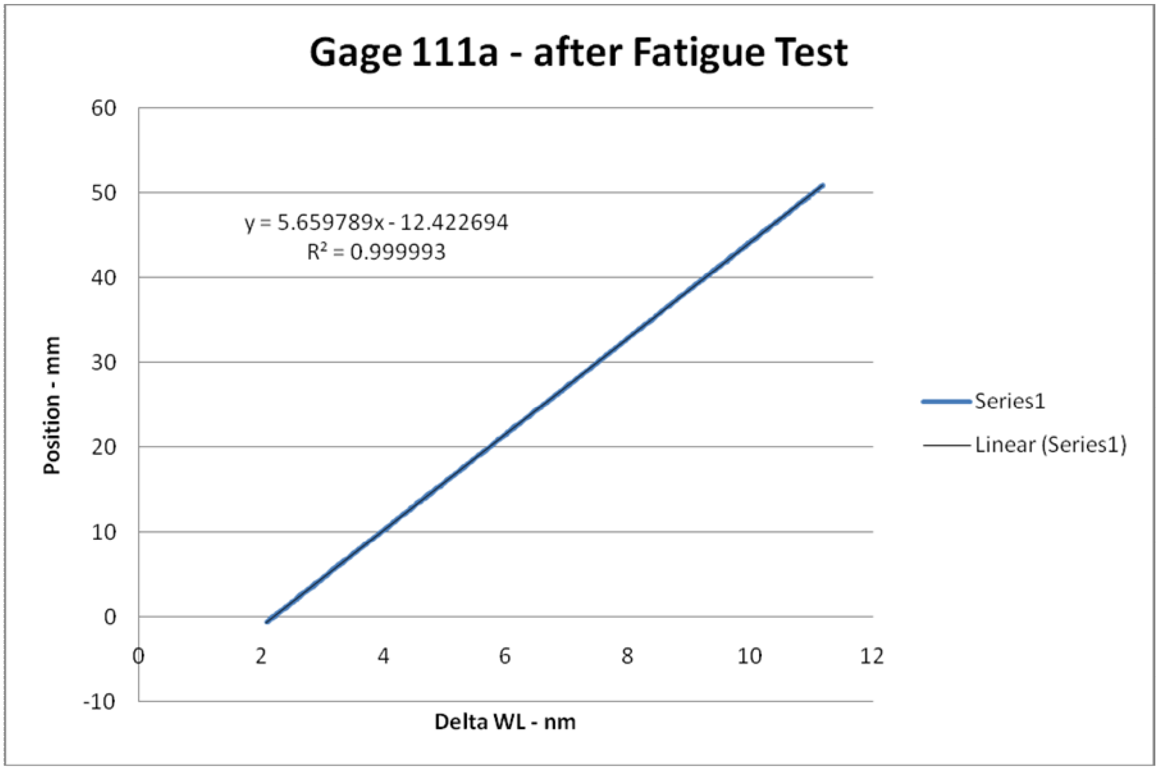

Figure 8 – Gage 111a Calibration Curve

The correlation coefficient indicates a very good curve fit with no discontinuities or undulations.

Outdoor Environmental Evaluation

To further understand real world performance of the os5100 displacement gage, three gages have been set up in an outdoor environment (figure 9) in the same test fixture as used for chamber testing. The location receives intermittent afternoon sun and is exposed to rain and other environmental effects. The test fixture is set on concrete blocks to provide a small heat sink simulating a concrete structure.

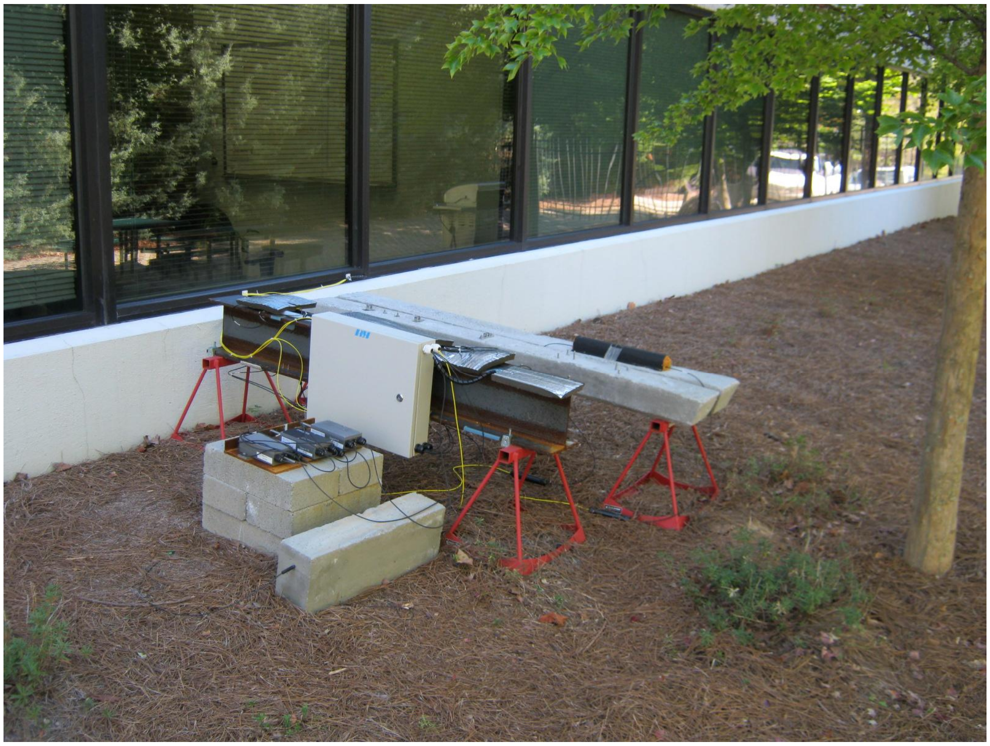

Figure 9 – Outdoor Environment Test Facility

Data for gage 112, with the most environmental history, is shown below in figure 10. The gage was installed in May of 2011 and is continuously monitored using ENLIGHT software and a sm125 optical sensing module. The gage is set at approximately 6 mm of displacement (6mm from the fully retracted position).

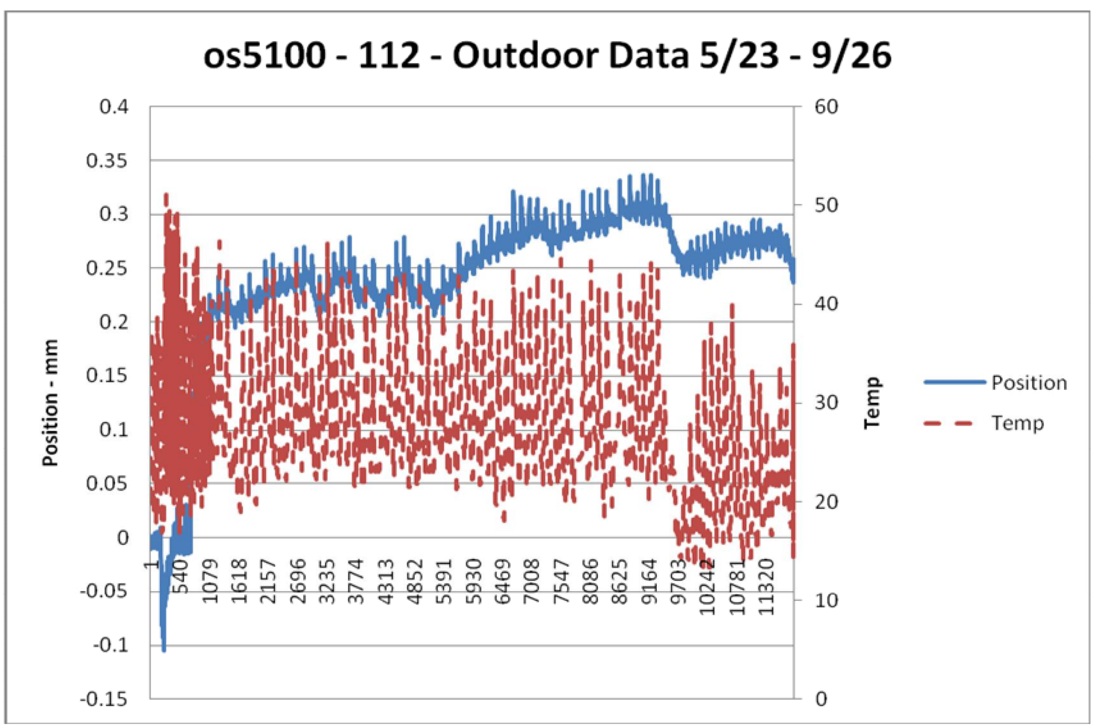

Figure 10 – Gage #112 – Outdoor Data

Ingress Protection Test

To enhance the suitability of the gage for outdoor use, bellows have been added to protect the shaft and improve dust and water ingress. The probe on the gage has seals on both ends which will prevent dust and water ingress particularly for dusty environments and rain or splashed water on the gage. However to improve that protection, bellows have been added to both ends to seal the probe to the enclosure. With the addition of the bellows, the gage has been tested and meets the IP67 rating for ingress protection as defined below:

- Definition - Ingress of water in harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time (up to 1 m of submersion).
- Test Procedure - Test duration: 30 minutes Immersion at depth of 1m

The gage was tested for 35 minutes at 1.0 meters of water pressure (.5m water depth + .75 psi) in a pressure tank. After removing the gage, two small drops of water was observed inside of the gage. This is determined to not be harmful for this gage.

Disclosure
Micron Optics continues testing of the displacement gage to establish long term history and more fully define its characteristics. Micron Optics reserves the right to make changes in the design at any time that may improve the performance of the gage.