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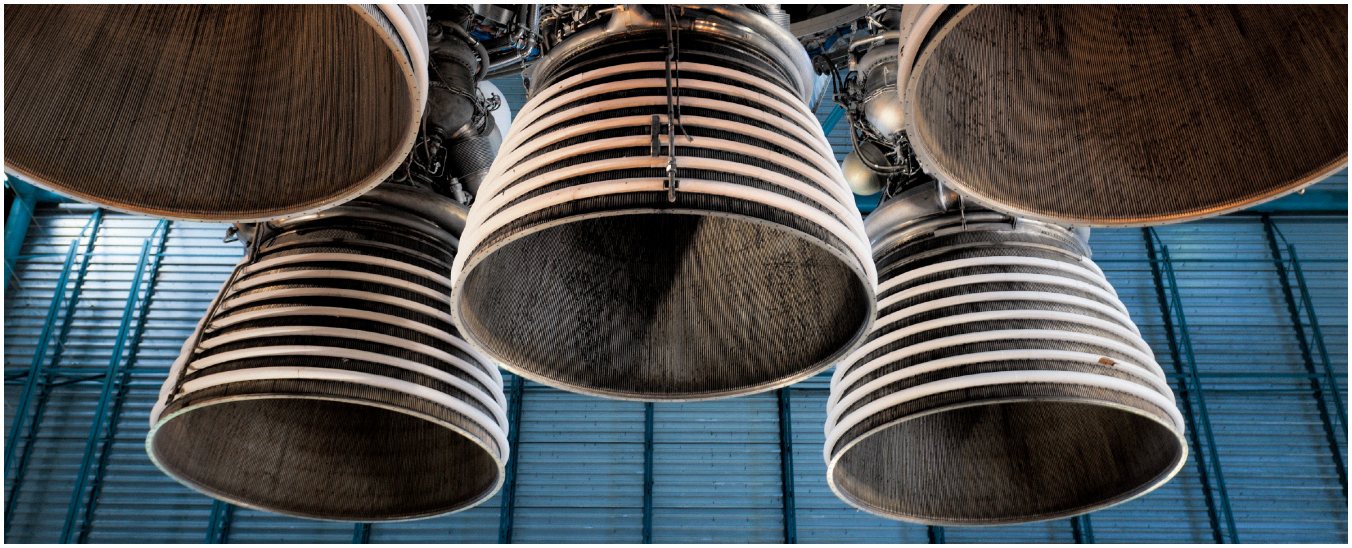

Extreme Low Temperature Pressure Measurements Using Cryogenic Dynamic Pressure Sensors

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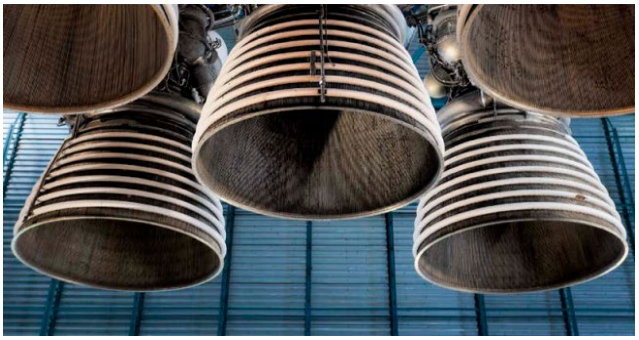

Extreme low temperature pressure measurements require specialized cryogenic pressure sensors that can withstand excessively low temperatures and minimize thermal shifting. These sensors are critical in ensuring accurate test results in cold environments, particularly in industries that operate within cryogenic conditions, such as aerospace, biomedical processing and other low temperature pressure testing.

PCB's Series 102 ICP® pressure sensors, along with the charge output Models 112B05, 112A06, and 116B, offer exceptional low-temperature operating capabilities. Their robust design makes them ideal for applications such as measuring cryogenic pumps, cryogenic fuel systems, and rocket motor combustion instability. Each sensor is hermetically sealed and individually tested to determine its thermal coefficient of sensitivity, ensuring reliable operation and accurate measurements in extreme environments. Notably, Models 112B05, 112A06 and 116B charge mode sensors are engineered to withstand both extreme cold and extreme heat, making them versatile tools for a wide range of applications.

Cryogenic Sensors for Extreme Low Temperature Testing

Testing was performed on this family of cryogenic pressure sensors to validate their performance across various temperature ranges. The test variables were temperature and pressure, with voltage output being the measured result from each unit under test.

For charge mode units, the units were tested at room temperature, which ranged from 64-74°F, and again at Liquid Helium (LHe) temperature of -415°F. For ICP® output devices, units were tested at room temperature and again at LHe temperature ranges, and included an intermediate test step just above Liquid Nitrogen (LN2) temperatures at approximately -300°F to ensure the functionality of onboard electronics. All units were pressurized for multiple dynamic pulses between 10-40 psi, and the voltage outputs were recorded. Results are summarized in Table 1.

Model	Type	Sensitivity	Measurement Range (+/- 5V)	Temperature Total Shift (%)	Temperature Shift (%/°F)
102B10, B11, B13, B14	ICP	50 mV/psi	100 psi	5.09%	0.0105%/°F
102M80A	ICP	100 mV/psi	100 psi	3.80%	0.0078%/°F
102M295	ICP	1.5 mV/psi	3,500 psi	4.13%	0.0085 %/°F
102M305	ICP	34.5 mV/psi	145 psi	7.63%	0.0157 %/°F
112B05	Charge	1.1 pC/psi	5,000 psi	1.04%	0.0021 %/°F
112A06	Charge	2.8 pC/psi	5,000 psi	0.06%	0.00012 %/°F
116B	Charge	6 pC/psi	3,500 psi	7.52%	0.0155 %/°F

Table 1: Temperature shift of various cryogenic pressure sensors.

A new test group of Model 112A06 sensors was evaluated for functionality at a minimum temperature of -415°F. As shown in Figure 1, the cumulative results of charge output versus test pressure demonstrated minimal sensitivity change between room temperature and -415°F, underscoring the reliability of these sensors in extreme cold environments.

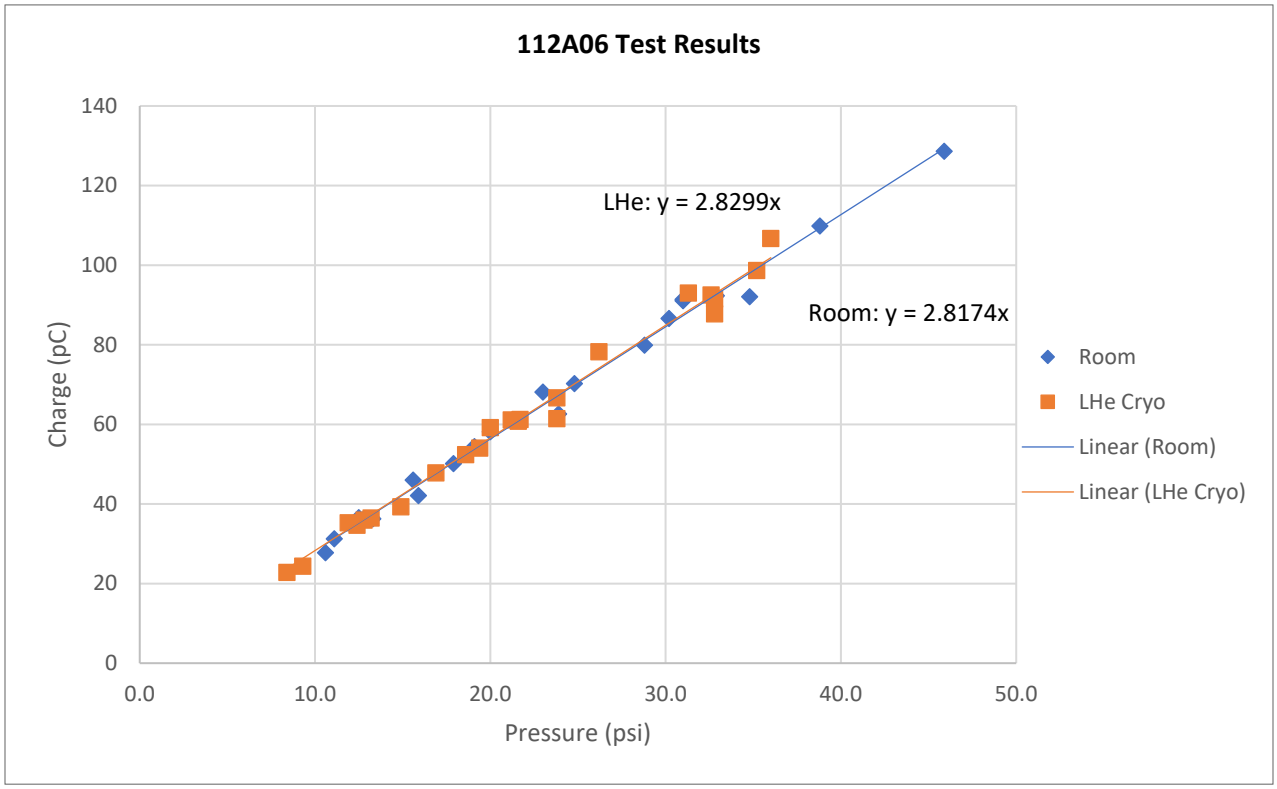

Figure 1: 112A06 cumulative outputs at various pressures and temperatures

Table 2 shows the average sensitivities for each serial number tested. Sensitivities were calculated using linear fit through zero. Note all sensitivities fell within the required **2.38 – 3.22 pC/psi** window to pass specification.

112A06 Charge Sensitivities		
S/N	**Room Temp**	**LHe Temp**
43731	2.94	2.97
43729	2.63	2.68
43724	2.84	2.81
43732	2.81	2.80
43723	2.80	2.79

Table 2: 112A06 sensitivities at various temperatures

Table 3 shows the thermal sensitivity shift observed in each unit, which represents the difference between the room temperature sensitivity and that recorded at the lowest cryogenic temperature. On average, the thermal shift was calculated to be 0.06%, or 0.00012 %/°F, and variances between serial numbers over a 500°F range were limited to ±1.8%.

112A06 Thermal Shifts	
S/N	LHe Shift
43731	0.848%
43729	1.767%
43724	-1.265%
43732	-0.544%
43723	-0.524%

Table 3: Thermal sensitivity shift for tested 112A06 units

Conclusions

The tests conclusively demonstrate that PCB's ICP® and charge mode pressure sensors can reliably operate at temperatures as low as -400°F, in accordance with their specified limits. These sensors meet industry expectations for performance in cryogenic conditions, maintaining sensitivity with minimal thermal drift. This makes them an invaluable asset in applications requiring precise pressure measurements in extreme environments, such as aerospace propulsion systems, cryogenic fuel management, and environmental testing of materials and components.

Furthermore, the ability of the charge mode Models 112B05, 112A06, and 116B to withstand both extreme cold and extreme heat adds to their versatility, allowing for their use in a broad range of testing scenarios that involve rapid temperature fluctuations. This dual temperature range resilience, coupled with their highly stable sensitivity profiles, ensures that these sensors will continue to deliver accurate and reliable data in even the most challenging conditions.

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