PARTICLE MEASURING SYSTEMS
www.pmeasuring.com
5475 Airport Boulevard, Boulder, Colorado 80301-2339
303.443.7100 1.800.238.1801 Fax: 303.546.7380
Customer Service Center 1.877.475.3317
Instrument Service 1.800.557.6363

LiQuilaz® S05 Thermal Test

Introduction

Optical particle counters like the LiQuilaz® S05 are used in a variety of environments which may be subject to changes in ambient temperatures. In addition, the LiQuilaz itself generates heat due to warming of its internal components. Particle Measuring Systems (PMS) tested the S05 in an environmental chamber to determine if true particle counts are influenced by temperature when measuring ambient distribution of particles in water. Tests with calibration particles were also conducted in order determine the effect of temperature on sizing accuracy.

Environmental Test

Two S05 sensors were connected in parallel to an ultrapure water (UPW) source. A variable speed particle injector (VSPI) was connected upstream of the sensors in order to introduce a fixed concentration of particle contamination. The sensor's case temperature was measured using a thermocouple taped to the top of the lid on the outside of both sensors. One S05 sensor was mounted inside an environmental chamber and the second sensor remained outside the chamber to serve as a control. The environmental chamber reaches thermal equilibrium in about one minute. The chamber's temperature was increased from 22°C to 40°C by raising the temperature setting every 15 minutes in increments of approximately 3°C. The temperature of the control S05 remained relatively constant during the test. DC light stayed at 0.010 volts throughout the test at PMS on both sensors. DC light measurements correlate to increase in background scattering.

Particle concentrations measured by the control S05 remained constant throughout the test at 57 cts/mL +/- 1.2 cts/mL Particle concentrations measured by the S05 in the chamber remained constant at 54 cts/mL +/- 0.8 cts/mL. The results show excellent agreement as documented in Table 1. Absolute differences between the sensors are insignificant and well below the expected matching range of 20%. The plots of both sensors are shown in Figure 1.

Table 1. LiQuilaz S05 temperature test at Particle Measuring Systems

	S05 Sensor Under Test		S05 Control Sensor	
Environmental Chamber Temperature (ºC)	Case Temperature (ºC)	Particle Concentration (cts/mL)	Case Temperature (ºC)	Particle Concentration (cts/mL)
22	23.4	54.8	28.4	58.2
25	25.5	52.8	28.0	58.0
28	28.2	53.4	27.7	56.8
31	31.3	54.1	27.4	57.0
35	35.1	53.7	27.4	55.8
40	40.0	55.0	27.3	55.0
Average		**54.0**		**56.8**
Std. Dev.		**0.8**		**1.2**

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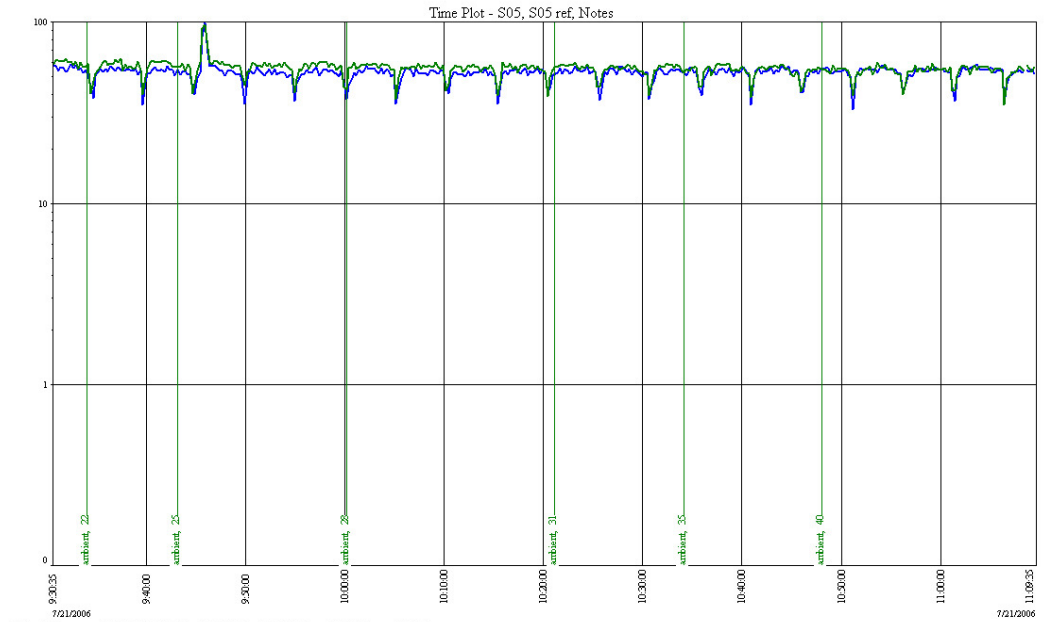

Item	Plot	Channel	Data Type	Minimum	Maximum	Average	Std Dev
S05	Norm Counts	x > 0.50	Value	33.200	99.050	52.716	5.237
S05 ref	Norm Counts	x > 0.50	Value	35.250	97.400	55.552	5.447
Notes			Value	0.000	0.000	0.000	0.000

Plot filter: None
Alt plot filter: None
Filter join: Off
Flyer filter: None

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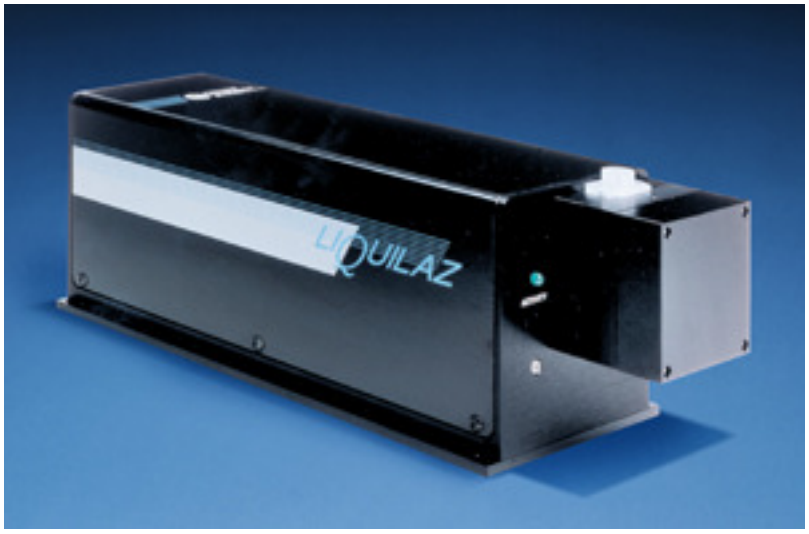
Figure 1. Particle concentrations for LiQuilaz S05 under test and S05 control at various environmental chamber temperatures. The plot demonstrates the independence of true particle counts with change in temperature.

Internal Sensor Temperature

The LiQuilaz sensor takes approximately 90 minutes to reach a stable internal temperature of 30ºC, as shown in Figure 2, when operated in an ambient temperature of 23ºC. The internal temperature was measured with a thermocouple located on top of the S05 power supply. The internal temperature increase in Figure 2 occurs due to the heat being generated by the SO5's electronics.

Although it does not affect data interpretation, internal temperatures may still have been increasing slightly in the previous environmental test. Longer stabilization times (90 minutes vs. 30 minutes) may have caused an additional 5-10% increase in internal



temperatures. In order to demonstrate operation throughout the temperature range of the sensor, the temperature was raised to 40ºC in the above test (5°C above specification) with no affect on particle counts. Further results from preliminary testing using internal and external sensors are discussed below.

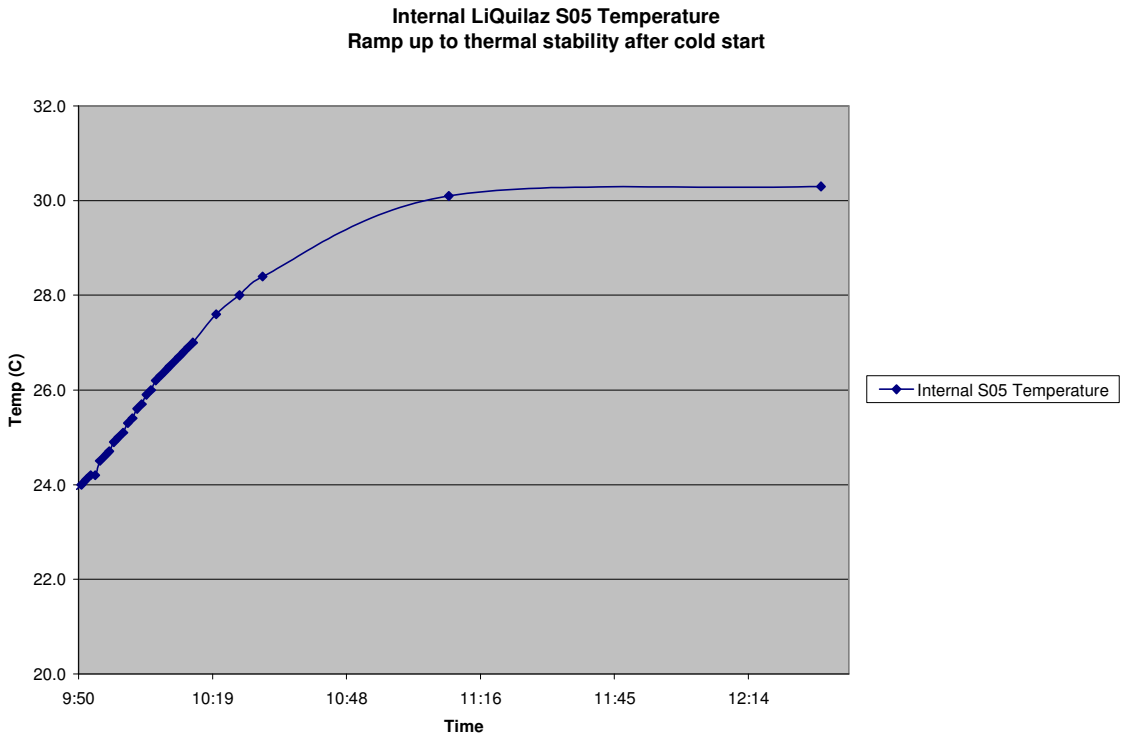


Figure 2. Thermal equilibrium occurs after 90 minutes when operated in an ambient environment of 23°C

Preliminary testing monitoring internal temperature

A preliminary S05 temperature test was performed in the environmental chamber using a similar setup as described above. Temperatures were increased from 22ºC to 35ºC and back down to 15°C. Particle concentrations decreased with time throughout the test and showed no relationship to temperature. Temperatures were measured inside and outside the S05 sensor as described above. Temperatures inside the LiQuilaz were recorded after about 30 minutes with a typical delta of about 3.5°C. This data is shown in Figure 3.

The particle concentration data shows the SO5 is insensitive to temperature changes. The downward drift in the data is a result of the VSPI and plumbing cleaning up. In addition, zero count measurements were successfully made at 15°C and 35°C on UPW, indicating that electronic noise does not influence particle counts over the temperature range.

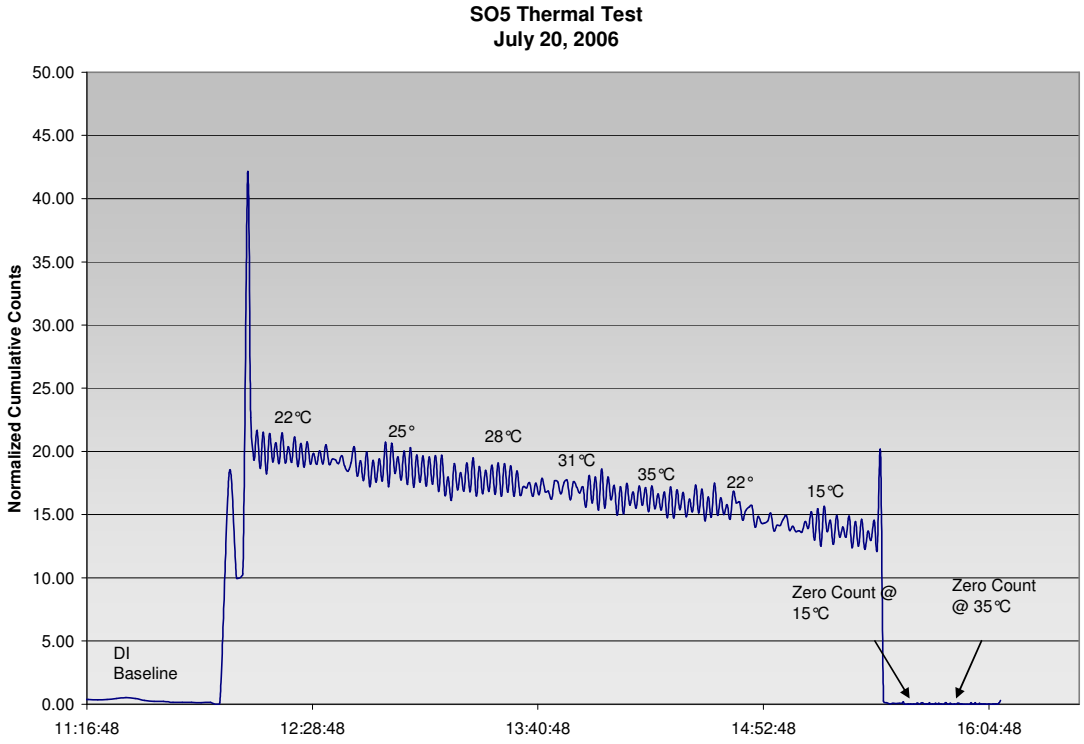


Figure 3. Particle concentrations at various casing temperatures. This demonstrates the independence of true particle counts and temperature. The decreasing counts are caused by the plumbing becoming clearer.

Particle Sizing

Measuring the sizing errors is one of the best ways to verify that the sensor is working properly. Particle Measuring Systems has developed a spreadsheet tool that calculates sizing error based upon the measurement of calibration polystyrene latex spheres (PSL). Sizing errors are typically less than 5% for a sensor with good calibration. A calculation of sizing errors in elevated temperatures is presented in Table 2. Temperature has a negligible impact on sizing error.

Table 2. 0.5 micron PSL Testing at temperature

	Counts Measured	Split	Sizing error
Control S05 Room Temp	337	43.5%	-0.82%
Control S05 Room Temp	315	40.6%	-1.19%
Control S05 Room Temp	326	42.1%	-1.00%
S05 Test Room Temp	331	42.7%	-0.92%
S05 Test 35°C	379	48.9%	-0.14%
S05 Test 30°C	378	48.8%	-0.14%
S05 Test Room Temp	357	46.1%	-0.49%
Total counts	775		

Conclusion

True particle counts in water for ambient distributions showed no effect when changing temperature over the normal operating range of the S05 sensor. Measurements of calibration particles showed no significant difference in sizing error at elevated temperatures. The measured sizing errors were 1% or less. This is significantly less than typical sizing errors of 3 -5% for a calibrated sensor. The LiQuilaz S05 is a robust sensor capable of making very repeatable particle measurements over a wide temperature range.

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Prepared by Ed Terrell, Roger Carlone, Jerry Gromala

PARTICLE MEASURING SYSTEMS
www.pmeasuring.com
info@pmeasuring.com

Particle Measuring Systems Headquarters
5475 Airport Blvd., Boulder, CO 80301
1-303-443-7100 1-800-238-1801 Fax: 1-303-546-7331
Instrument Service & Support: 1-800-557-6363
Customer Response Center: 1-877-475-3317

Particle Measuring Systems Europe
Tel: +44 1684 581000
PMSEurope@pmeasuring.com

Particle Measuring Systems Japan
PMSJapan@pmeasuring.com

Particle Measuring Systems Asia Pacific
PMSAsiaPacific@pmeasuring.com

Particle Measuring Systems Singapore
Tel: +65-6496 0330
PMSSingapore@pmeasuring.com

Particle Measuring Systems China
PMSChina@pmeasuring.com

Particle Measuring Systems Mexico
PMSMexico@pmeasuring.com

Particle Measuring Systems Puerto Rico
PMSPuertoRico@pmeasuring.com