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Optimum Cold Temperature Performance From Biosystems Portable Gas Detectors

1. Introduction

Often asked questions, which occur during the onset of colder months, relate to proper specification and use of portable gas detectors in this condition. In the 1990's, gas detectors have evolved to become more sophisticated, allowing for real-time temperature sensing and compensation of gas sensor readings. There are currently four generations of portable detector designs in use with varying capabilities and proper use conditions in colder weather. This applications note has been written to inform gas detector specifiers and end-users on how to get optimum performance from Biosystems portable gas detection equipment for use in colder environments.

2. Scope

This information principally applies to portable - PhD/Cannonball multisensor and Toxi Series single gas detectors. There are some general guidelines in regards to power systems, displays, etc., which are true for all Biosystems portable detectors. Any Detector/Model specific features will be explicitly stated as such.

3. Background/Perspective

3.1 Temperature Compensation

Rule of thumb in chemistry: "The rate of a reaction doubles for every 10°C (20°F) rise in temperature". For galvanic-type oxygen and electrochemical type toxic gas sensors, which are small chemical reactors or fuel cells, temperature compensation of response is certainly an area of great importance.

With the advent of "smart" sensors in the PhD Plus & Ultra design an EEPROM, or smart chip, has become an integral part of each plug-in sensor assembly. This has led to a rapid evolution of custom features. One of the most important of these being the sensor-specific array of temperature compensation factors for both baseline (zero) and sensitivity (span) values.

As we will explain later, these values are not static but are refined each time the detector is fresh air and span calibrated. The following table provides a summary of the sensor temperature compensation capabilities of Biosystems portable gas detectors.

Detector/Model	Temperature Compensation	Type
Toxi Series	none	n/a
PhD	Partial-O_2 Sensor Only	Fixed Polynomial for Span
PhD2	Partial-O_2 Sensor Only	Fixed Polynomial for Span
Cannonball2	Partial-O_2 Sensor Only	Fixed Polynomial for Span
PhD Plus/Ultra	Full-Smart Sensor Specific	Dynamic Array for Zero & Span
PhD Lite	Full-Smart Sensor Specific	Dynamic Array for Zero & Span
PhD5	Full-Smart Sensor Specific	Dynamic Array for Zero & Span
Cannonball3	Full-Smart Sensor Specific	Dynamic Array for

3.1.1 General Operating Principles

For detector designs before the advent of smart sensors, or for those without smart sensors, - PhD/PhD2, Cannonball2 and Toxi Series respectively, to obtain the most accurate readings the best course of action is to zero and span calibrate the detector at the temperature of use. To perform this process successfully, it is important that the detector be thoroughly acclimated to the anticipated use temperature by waiting an appropriate amount of time for the system to stabilize - typically ½ to 1 hour, depending on the physical size of the detector and the magnitude of temperature difference.

With smart sensors and on-board temperature sensing - PhD Plus/Ultra, 5, Lite and Cannonball3, this has become partly unnecessary. The general temperature compensation values factory programmed into each sensor serve the purpose described above. The next important consideration is how best to maintain, and improve the accuracy of compensation values given various conditions of use. This will be reviewed in detail in Section 5 - Operations.

4. Initial Specification & Setup

4.1 Power Systems

It is best to avoid the use of alkaline batteries, if possible, in colder weather conditions. Alkaline batteries may give as little as approximately 10% of the run time at 0°F (-18°C) than at room temperature. In general, NiMH and NiCad batteries perform best, followed by lead-acid types.

Ambient temperature has an effect on the recharge efficiency and life of NiCad and NiMH rechargeable batteries. NiMH batteries should be recharged in areas where the temperature range is 0 to 40°C (32 to 104°F). Attempts to charge NiMH batteries below 0°C may cause leakage of battery electrolyte, impair performance or shorten the operating life of the batteries. For NiCad batteries, optimum temperature range for efficient charging is narrower at 5 to 30°C (41 to 86°F). Repeated attempts to recharge NiCad batteries at temperatures below 0°C (32°F) will increase gas pressure in the cell at the end of the charge cycle which may cause a safety vent to operate and battery life to shorten.

Battery systems in Biosystems portable detectors vary in terms of types and interchangeability, as battery technology has also evolved rapidly in the past decade. For example, earlier PhD/PhD2 model detectors are all rechargeable battery units. They are either internal lead/acid battery (units have steel belt clip on bottom surface) or NiCad (pack drops out of a cutout in the unit bottom, thus no belt clip). In contrast PhD Plus/Ultra and 5 models have fully interchangeable "snap-in" alkaline and NiCad battery packs, making this exchange of battery type trivial. The following table provides a summary of battery systems and their interchangeability for portable detectors.

Detector Model	Lead Acid	Nicad	NiMH	Alkaline	Interchangeable
Toxi Series	n/a	n/a	n/a	X	n/a
Ex Chek	n/a	n/a	X	X	No
Cannonball2	X	n/a	n/a	X	Yes
Cannonball3	n/a	n/a	X	X	Yes
PhD2	X	X	n/a	n/a	No
PhD Plus/Ultra	n/a	X	n/a	X	Yes
PhD Lite	n/a	n/a	X	X	No
PhD5	n/a	X	n/a	X	Yes

4.2. Display (LCD)

Liquid Crystal Displays (LCD's) lose contrast and their refresh rate slows at cold temperatures. Biosystems standard design, extended temperature range LCD's normally become illegible at temperatures less than 5°F (-15°C). Refresh rate is the time required for a new screen to appear upon command. In all cases, decline of LCD function has nothing to do with any other aspect of detector performance. Sensors will continue to respond properly and the detector chassis audible and visible alarms will continue to function normally. The display is a completely separate system designed strictly for the convenience of the end user.

There are provisions for contrast adjustment on certain detectors. For the PhD Plus/Ultra models there is a potentiometer (pot) inside the detector that actually serves to darken the display more than it adjusts the contrast.

In the PhD Lite and 5, with their more advanced digital displays, there are two ways in increase contrast. One way is through the menu options. Please refer to the advanced functions section of your detector manual.

If the PhD Lite or 5 display has already become illegible, it is also possible to enhance contrast upon power-up by simultaneously holding down on the up arrow key which enables the contrast adjust mode. The "up" arrow enhances, and "down" arrow decreases, contrast. Pressing the mode button locks in the setting and exits from this feature. There is one difference in this routine for the PhD5 versus the PhD Lite. In the PhD5 upon entering into the contrast adjust mode the display automatically starts at the lowest contrast setting. This can be disconcerting for the uninformed as it looks as if the display has "blanked out" initially. Contrast will be restored by pressing the up arrow key.

On Cannonball2, PhD/PhD2, PhD Plus/Ultra multisensor detectors there are channel/sensor specific visible red alarm LED's on the front face of the detector. It is worth taking the time to become familiar with gas/sensor order on the display, since position denotes which gas type - and associated hazard is in the alarm state, should it occur.

4.3 Low Temp Alarms

Oxygen and toxic gas sensors contain fluid (water-based) electrolytes and membrane systems that are adversely affected in the event of freezing at very cold temperatures.

PhD Plus/Ultra, PhD Lite/5 and Cannonball3 models have in each sensor, factory programmed low temperature alarm limits. Below the preset limit, the detectors' sensor channel display alternates between the numerical reading and a "T" denoting this alarm condition. Sensor specific low temperature alarm setpoints are shown in the following table.

Sensor Type	Low Temperature Alarm Point (F)	Low Temperature Alarm Point (C)
O_2 Oxygen	-4	-20
LEL Combustible	-20	-29
CO Carbon Monoxide	5	-15
H_2S Hydrogen Sulfide	-4	-20
SO_2 Sulfur Dioxide	-4	-20
NO_2 Nitrogen Dioxide	-4	-20
Cl_2 Chlorine	-4	-20
NH_3 Ammonia	-4	-20
PH_3 Phosphine	-4	-20
HCN Hydrogen Cyanide	-4	-20

If performing monitoring sessions for limited times at temperatures anticipated to be colder than those listed, it may be acceptable to temporarily disable low temperature alarm setpoints (allowable option is either to enable or disable, not to alter the values). For specific details on how to access this feature, please consult the "advanced features" section of your detector manual. For advice on your specific end-use application, please contact Biosystems Technical Support Department.

5. Operation

5.1 Temperature Compensation & Sensor Accuracy

The following is a brief review of how "smart" sensor specific temperature compensation works and how it differs between detector models.

For each sensor, typical temperature compensation factors are programmed into an array on the "smart chip" in the temperature range of -20°F to +140°F, for both zero and span. There are sets of zero and span correction factors for every 10°F increment within this range. These "typical" values represent average/default values based on new sensor performance. With each detector fresh air (zero) and gas (span) calibration, both values are refined.

In the case where small changes occur over time, for example as sensor output gradually changes with age, localized corrections as a function of unit temperature are made to the array. Specifically, 100% of the refinement to the correction factor is made at the nearest 10F° increment of detector temperature, smaller refinements are made at the next ±10°F values, and still smaller refinements are made to values at ±20°F, etc.

Where there is a large shift in sensor performance, for example as may occur when beads shift in an LEL sensor subjected to an extreme mechanical shock, the same refinement, upon subsequent calibration is applied over the entire array of values. This effectively shifts the entire set of values or compensation curve(s) by the same amount.

We shall discuss shortly the consequences of each refinement strategy in terms of how the detector will perform based on external conditions and habits of use.

Detector Models/Versions differ in regard to which refinement strategies are accessed. For PhD Plus/Ultra, PhD Lite and PhD5 models the situation is mixed depending on the software version (shown in the initial screen upon power-up). The table below provides a convenient summary of which versions support which refinements, and how they are set-up at the factory.

Enabling small refinements to correction factors in the current PhD Plus/Ultra, PhD Lite and 5 can only be enabled via entry into a special mode. Call Biosystems Instrument Service Dept. for details. Note that in prior versions of the PhD Lite and 5 the detector program version may be updated over the internet (Biosystems website: www.biosystems.com) via modem and an IrDA for the PhD Lite and datalogger cradle & cable for the PhD 5.

Detector/Model	Software Version	Small Refinement (Temp. Localized)	Large Refinement (Universal Shift)
PhD Plus/Ultra	1.84 & higher	Yes or No(Shipped Disabled)	Yes
PhD Plus/Ultra	1.83 & lower	Yes	Yes
PhD5	1.43 & higher	Yes or No(Shipped Disabled)	Yes
PhD5	1.42 & lower	Yes	Yes
PhD Lite	1.21 & higher	Yes or No(Shipped Disabled)	Yes
PhD Lite	1.20 & lower	Yes	Yes

5.1.1 Conditions & Habits of Use, Effect on Temperature Compensation

Consider the following two situations in regard to PhD Lite – software version 1.10 detector use:

Case 1 Large multiple user setting with centralized storage of many "common use" detectors. Only (few) authorized personnel are allowed to do both fresh air and span calibrations. Calibrations are always done at an indoor calibration station.

Case 2 Delocalized individually assigned unit type setting. Units normally come back to the shop after each work assignment. Calibrations, both fresh air and span, are often done by trained/authorized personnel in the field under a variety of conditions.

For Case 1 - this version PhD Lite allows both refinement types. In this pattern of use, however, over a long time there will develop a large temperature-localized correction to zero and span correction values. If these units are then taken into the field under very different temperature conditions, both zero and span will revert to original (largely unrefined) values. This change can be quite abrupt, which may result in significant positive or negative shifts in baseline depending on sensor type and the direction of temperature change. Largely affected sensors are those with temperature dependency and very low alarm setpoints - SO2, Cl2, ClO2, NO2. In extreme cases (very long history of being calibrated at one temperature) the LEL sensor may also be affected similarly.

Solutions for this situation are as follows.

a.) Short-term solution would be to re-initialize the sensors. This will reestablish factory default values of span/zero correction for all sensors throughout the entire temperature range. Performing zero and span after this should shift the entire compensation curve, resulting in a better overall correction. In the few cases where re-initialization and re-cal does not seem to work, arrangements may be made through Biosystems Instrument Service Dept. for the return of a unit.

b.) Long-term solution would be to update software to a more current version. Then, as above, reinitialize sensors and do some zero and span calibrations. With the new software having localized temperature corrections disabled, as the default setting, continuing in this pattern of use should not result in temperature localized corrections.

For Case 2 - in this use condition, units which permit small refinements as well as larger curve shifts would work well here. A long history of zero and span calibrations in many different temperature environments, will result in constant (normally small) upgrades in unit accuracy. As the sensors age, they will become closely accommodated to the detector.

5.2 Sample Draw Systems

Be aware any potential for condensation of moisture when remote sampling from below grade to above ground if topside conditions are less than 40ºF. Moisture condensation and possibly freezing within draw systems may cause filters to clog and/or scrub out water soluble gas(es) passing through them.

5.3 Additional Power Demands

Any use conditions that result in greater power consumption should be taken into consideration when determining detector run-times. These are: dim light (use of backlight); chronic high level exposures (frequent activation of audible/visible alarms); and use of motorized pump in PhD Plus/Ultra and later PhD designs - as the pump is powered by the detector battery system.

5.4 Storage Conditions

Gas detectors are designed to be generally unaffected if kept in areas where people can be made to feel relatively comfortable. Low temperature alarms only work on units that are powered-up and in the hands of knowledgeable end-users. It should be understood that if units are kept in very low temperature environments, even when powered off, sensors could freeze. As such, it is generally considered poor practice to store units in vehicles that are left outdoors in cold climates during the colder months. In addition to the risk of freezing sensors, if vehicle chargers are used, it is also possible to short charge batteries that are too cold for proper charging, and possibly to shorten battery pack life, or cause leakage of battery electrolyte.

For any questions or concerns which are not addressed by this applications note, and for further guidance on any aspect of low temperature operations, please contact Biosystems' Technical Support Department at tel. (860) 344-1079, or via email at tech.support@biosystems.com.