LI-ION TAMER RACK MONITOR DESIGN GUIDE

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The following typographic conventions are used in this document.

Convention	Description
Bold	Used to denote: emphasis Used for names of menus, menu options, toolbar buttons
Italics	Used to denote: references to other parts of this document or other documents. Used for the result of an action

The following icons conventions are used in this document.

Convention	Description
	Caution: This icon is used to indicate that there is a danger to equipment. The danger could be loss of data, physical damage, or permanent corruption of configuration details.
	Warning: This icon is used to indicate that there is a danger of electric shock. This may lead to death or permanent injury.
	Warning: This icon is used to indicate that there is a danger of inhaling dangerous substances. This may lead to death or permanent injury.

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Contents

1 General

1.1 Scope

This document provides details on how to design the Li-ion Tamer® Rack Monitor system for different battery system designs and applications. The environments envisaged include the following:

1. Lithium-ion battery stationary energy storage systems
   a. Containerized – battery racks within shipping containers
   b. Modular – battery racks within small pods with less than or equal to 11 m^3 (388.5 ft^3) free volume
   c. Built Environment – battery racks within a room or building
2. Data centers utilizing lithium-ion batteries as back-up or uninterruptable power supplies

Important Notes!

- This device detects off-gas from lithium-ion batteries. It does not prevent fires or thermal runaway. This device is not a stand-alone safety device and should be incorporated into a proper safety system. If device responds, there is a risk of battery fault which could lead to thermal runaway. To avoid injury, leave area immediately.
- The information contained in this Design Guide is intended to aid in the design of Li-ion Tamer systems that are optimized for response time and cost. Deviation from the guide to reduce cost further may negatively impact response time.

1.2 Codes, Standards or Regulations

The Li-ion Tamer® Rack Monitor system is to be installed in battery systems according to the following codes and regulations:

1. Any national or international standards or fire codes that require off-gas monitoring detection
2. Local codes and standards

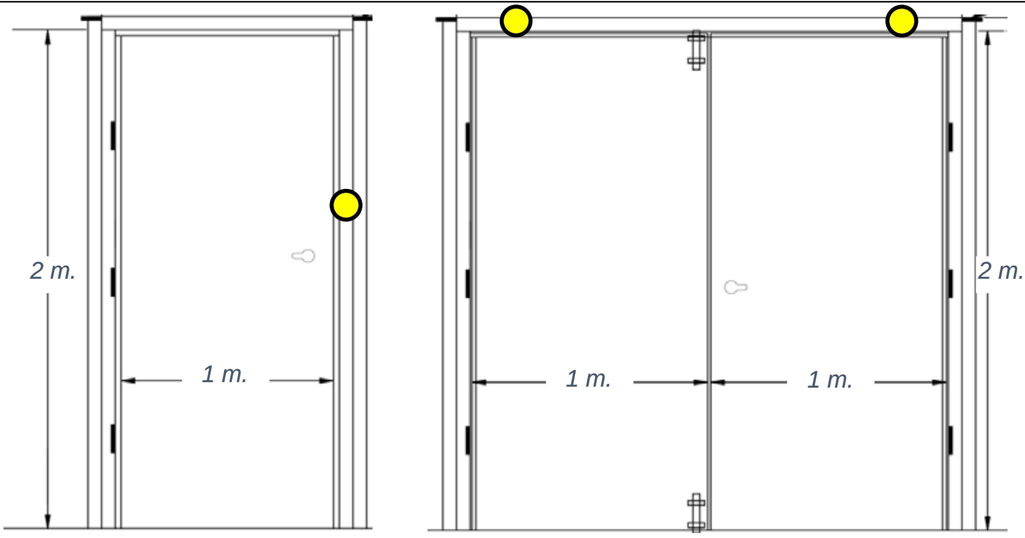
1.3 Key Design Considerations

There are several key design considerations that need to be provided prior to optimized system design. The following sections detail them separately and they are outside air penetration points, air exchange rate/pattern, battery rack design, battery rack layout, possible mitigating actions, and Battery Energy Storage System (BESS) constraints.

1.3.1 Outside Air Penetration Points

One of the main protections against false-positives is the placement of Reference Sensors throughout the battery system. Therefore, it is important to ensure that any locations where foreign contaminants can enter the battery system are identified. Some examples are as follows:

1. Personnel entry points
   a. A single Reference Sensor should be mounted near each personnel entry point that measures less than or equal to 2 m^2 (21.53 ft^2).
   b. Multiple Reference Sensors are necessary to provide adequate coverage if the entry point exceeds the specified area. Examples are shown below.
   c. Mounting height is not crucial and may be located wherever mounting is easiest.
   d. Sensor must be oriented so fresh air passes over the sensing face.



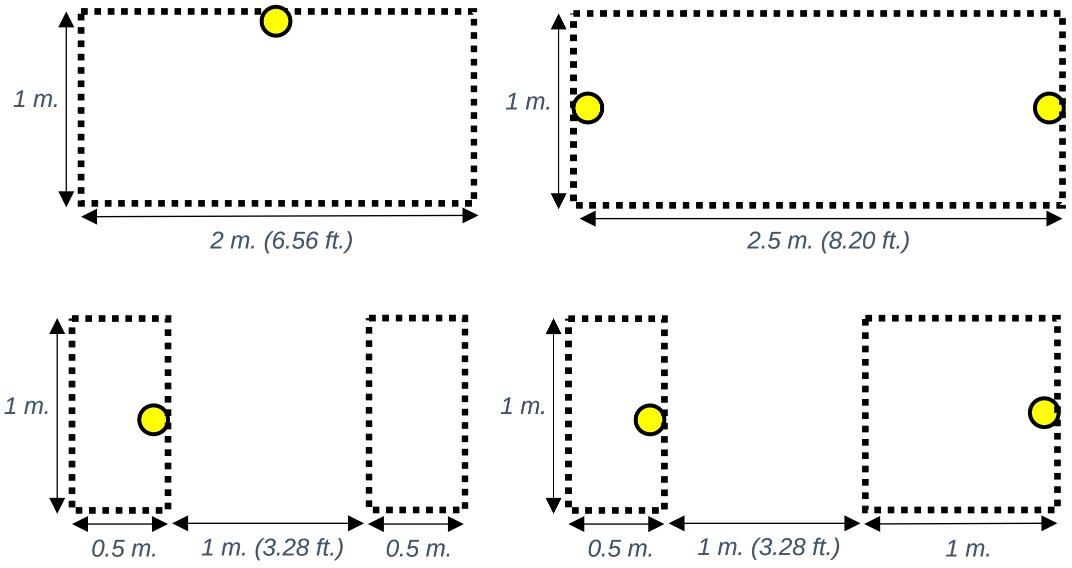
2. Make up air (gas) entry points

> **Important Note!**
>
> Make up air entry point Reference Sensor placement assumes uniform air quality across the specified area.

a. A single Reference Sensor should be mounted near each make up air entry point that measures less than or equal to 2 m^2 (21.53 ft^2).

b. Multiple Reference Sensors are necessary to provide adequate coverage if the entry point exceeds the specified surface area. Examples are shown below.

c. Multiple entry points identified on one surface (i.e. geometric plane) can be monitored with one Reference Sensor if the maximum separation distance between entry points is less than 1 meter (3.28 ft.), they are not obstructed by a physical barrier or air flow pattern, and the surface area is less or equal to 2 m^2 (21.53 ft^2).

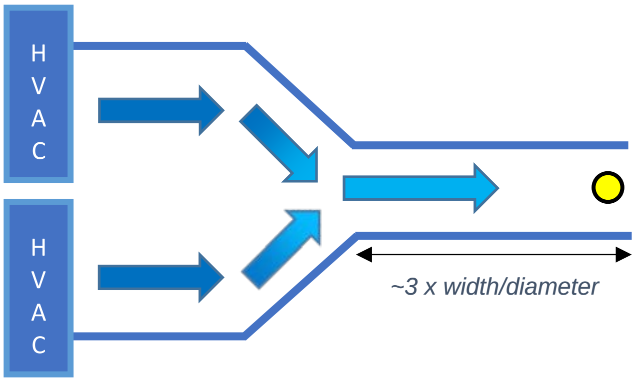


3. HVAC supply points

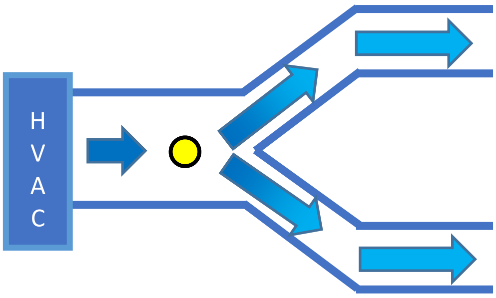
a. One Reference Sensor is necessary for each HVAC unit supply vent (not ducting vents) regardless of vent size.

b. Sensor must be oriented so cold air passes over the sensing face.

c. If air flows converge, a single Reference Sensor may be mounted ~3 widths or diameters downstream from the converged opening. If ducting is not long enough to mount the specified distance downstream, mount the sensor near the duct ending.



d. If the supply air flow diverges, then a single Reference Sensor should be located prior to the point of divergence. The precise mounting location is not crucial.



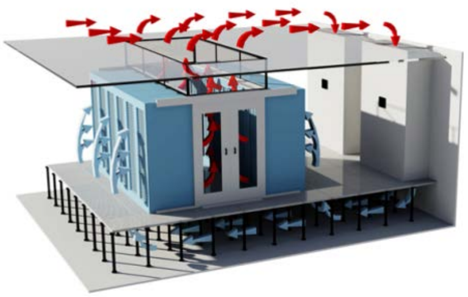
Important Note!

Ensure minimum of 1 meter (3.28 ft.) separation between Monitoring and Reference Sensors. If the minimum separation distance is not possible, there must be a physical barrier between the sensors.

1.3.2 Air Exchange Rate and Pattern

The most important information related to air exchange rates are the locations of the “hot” and “cold” aisles and whether there are any physical barriers separating them. This is because Monitoring and Reference Sensors should only be located in the hot and cold aisles, respectively.

The battery racks themselves may also have their own guided air flow, with the intention of cooling and ventilating the battery modules. The air flow generated by these module-level fans will coincide with the HVAC flow patterns, with hot air being expelled from the battery modules into the hot aisle. Section 1.3.3.2 will cover this “rack-level air flow” further.



Beside the locations of the hot and cold aisles, the air velocity is also a crucial factor when considering sensor placement. Li-ion Tamer sensors have been tested over a broad range of gas velocities and sensor orientations, yielding the specification below:

$$Minimum\ Air\ Velocity = 0.0\ \frac{m}{s}\left(0.0\ \frac{ft}{s}\right)$$

$$Maximum\ Air\ Velocity = 9.0\ \frac{m}{s}\left(29.5\ \frac{ft}{s}\right)$$

If the air velocity is unknown, the following equation should be used to estimate the velocity at a specific sensor location:

$$\frac{Airflow\ (CFM)}{Cross\ Sectional\ Area\ of\ Ducting\ or\ Aisle\ (Sqft)} \div 60\frac{min}{s} = Air\ Velocity\ \left(\frac{ft}{s}\right)$$

In applications where the air velocity falls within the specified range, the sensors should be oriented based on the recommendations in the following section for optimal performance.

1.3.3 Battery Rack Design

The industry has many different definitions of what a “battery rack” is, with a few shown below. Li-ion Tamer defines a battery rack as a single vertical string of battery modules. Therefore, it is crucial to know what brand and model the battery rack is, since each rack design is different.

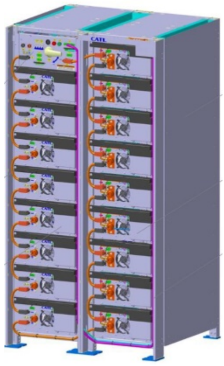
Important Note!

Make note of the common rack manufacturers and their Li-ion Tamer rack definition equivalencies, as the remainder of this guide will use the term “battery rack” to refer to the Li-ion Tamer definition.

LGChem (Equivalent to 1x battery rack)

Samsung (Equivalent to 1x battery rack each)

Lishen (Equivalent to 3x battery rack)



Air-cooled CATL (Equivalent to 2x battery rack)

Narada (Equivalent to 2x battery rack)

Kokam (Equivalent to 2x battery rack)

Powen (Equivalent to 2x battery rack)

Important Note!

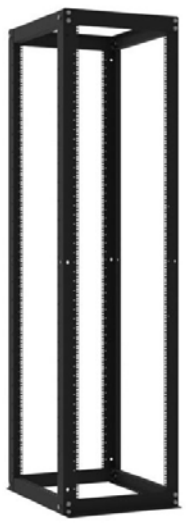
If the rack design information is not available, a conservative approach of 1x Monitoring Sensor per 2x battery racks (Li-ion Tamer definition) should be taken; however more information may cause the sensor quantity to either increase or decrease.

Once the battery rack model/design is known, there are several key features to look for that can help reduce the quantity of Monitoring Sensors. All important design features are detailed in the following sections.

1.3.3.1 Rack Design Features

There are two primary types of rack designs, and all battery racks can be categorized as being one of the following types:

1. Open Frame Rack
   a. Battery modules are mounted in a rack frame, similar to the image below, with limited panelling that would restrict air flow.
   b. Ease of gas escape can reduce sensor quantity.
   c. The following battery rack manufacturers and models are considered open frame racks, along with the recommended ratio of Monitoring Sensors to battery racks (sensors: racks):
      i. Samsung (not UPS) – 1 : 2
      ii. Air-cooled CATL – 1 : 2
      iii. Lishen – 2 : 3



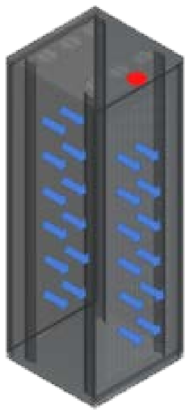
2. Cabinet (Enclosed) Rack
   a. Battery modules are mounted in a cabinet, similar to the image below, with panelling and vents that restrict/direct air flow.
   b. The following battery rack manufacturers and models are considered cabinet racks, along with the recommended ratio of Monitoring Sensors to battery racks (sensors: racks):
      i. Samsung UPS – 1 : 1
      ii. LGChem – 1 : 2
      iii. Narada – 2 : 3
      iv. Kokam – 1 : 1
      v. Powin – 1 : 2
      vi. Liquid-cooled CATL – 1 : 1

1.3.3.2 Rack-level Air Flow

In addition to the rack design type, **rack-level air flow** is another important consideration. Rack-level air flow is defined as how air moves through the battery rack from a high-level perspective. As covered in Section 1.3.3.3, battery modules may be equipped with fans that generate this air flow; however, the HVAC system design may also contribute.

The rack-level air flow will always coincide with the **“hot” and “cold” aisles** of the HVAC system. The cold aisle is defined as the location where fresh air enters the battery system, prior to passing through the battery racks. The hot aisle is defined as the location where exhaust air from the battery racks is expelled and then returned to the HVAC units. Therefore, the **Monitoring Sensors should only be located in the hot aisles and the Reference Sensors should only be located in the cold aisles**.

Several examples of potential rack-level air flow patterns and their corresponding sensor placement are shown below.

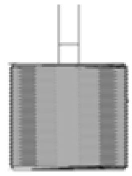


Example #1

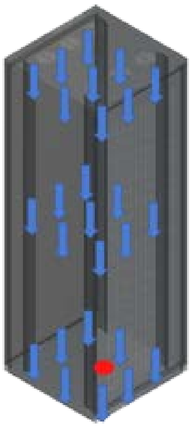
Type: air enters from the back of the rack and exits out the front

Sensor placement: top front of the rack

Sensor orientation: sensing face pointing down (±45˚)



Sensing face pointing down

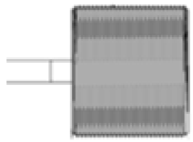


Example #2

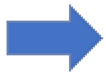
Type: air enters from the top of the rack and exits out the bottom

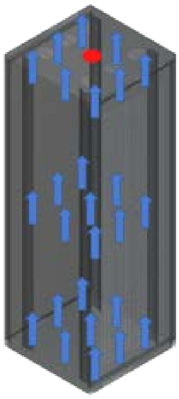
Sensor placement: bottom center of the rack

Sensor orientation: sensing face pointing at 90˚ to vertical (±45˚)



Sensing face pointing horizontal



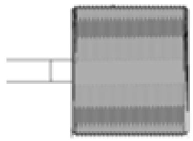


Example #3

Type: air enters from the bottom of the rack and exits out the top

Sensor placement: top center of the rack

Sensor orientation: sensing face pointing at 90° to vertical (±45°)

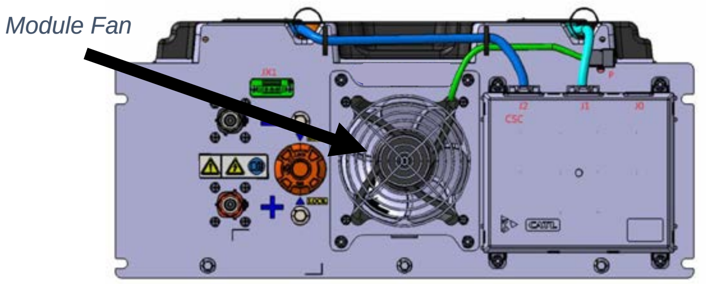


Sensing face pointing horizontal

1.3.3.3 Module Design Features

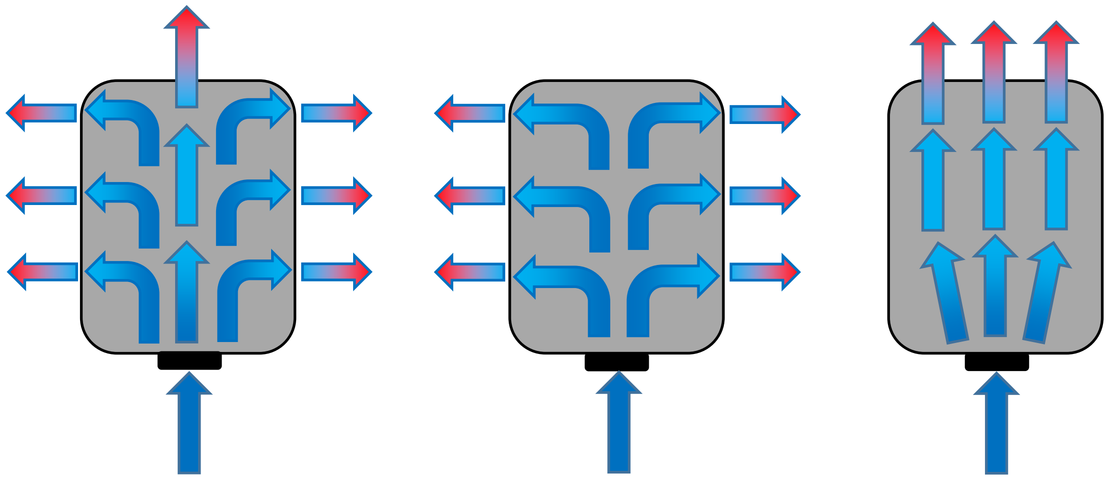
There are several key design features that may be present on battery modules, which are detailed below:

1. Module Fans
   a. Battery modules are often equipped with fans to aid in cooling and ventilating the batteries, as shown below:

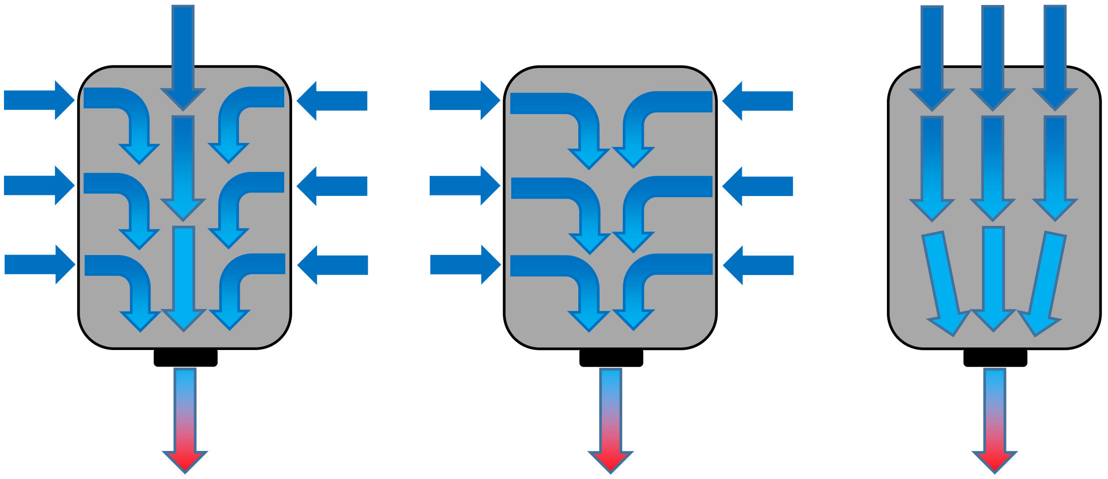


   b. There are two ways that fans may direct air flow through the modules.

i. Fan pushes air through the module – variations are shown below:



ii. Fan pulls air through the module – variations are shown below:



c. Monitoring Sensors must be mounted on the side of the rack where hot air is being expelled by the fan(s), coinciding with the rack-level air flow (see Section 1.3.3.1).

2. Module Burst Discs and Vents

   a. Sealed battery modules may have pressure burst discs to release gas that may be generated.

      i. Monitoring Sensors should be located on the same side of the rack as the burst discs.

   b. Battery modules, especially those with air-cooling and module fans, may have ventilation points designed into them.

      i. These allow for ease of gas escape from the modules, which can reduce Monitoring Sensor quantity.

1.3.4 Mitigating Actions

The mitigating actions taken corresponding to the alarming of Li-ion Tamer is an important conversation to have with customers. End users should always be aware of the different output options as follows (signal specifications can be found in the Li-ion Tamer User Manual):

1. Digital Outputs – conveyed over 10-pin Molex connector cable, terminating in bare-wire conductors
2. Serial Output:
   - Modbus RTU – conveyed over male DB9 port via RS-232

     or
   - Modbus TCP/IP – conveyed over MOXA MGate TCP/IP adapter (RJ45 ethernet cable not provided by Li-ion Tamer)

In general, the Digital Outputs are best for integrating into fire panels or relays to drive action within the system. The Modbus serial outputs are ideal for data gathering and other, more granular system controls.

With the different output options in mind, the end user should at least enact a “system shutdown”, meaning the forced charge and discharge of the batteries is halted. Additionally, any of the other recommended mitigating actions, shown below, may be taken.

System shutdown | Initiate ventilation | Increased cooling | Local alarm | Remote alarm

Lastly, it is important to work with the customer to determine how they should integrate the output signals to effectively enact their mitigating actions.

Important Note!

The mitigating actions discussed in this section are to be enacted upon detection of off-gas by Li-ion Tamer, indicated by either the individual sensor alarms, the Alarm Any signal from each controller, or the System Alarm from a single controller in a daisy-chained loop. The Sensor Error signal should only be used to indicate required maintenance of the Li-ion Tamer system and does not require a battery system shutdown.

1.3.5 BESS System Constraints

System constraints are any other potential factors that could affect the installation and integration of Li-ion Tamer. Some example questions to ask customers are below:

1. Will the controllers and adapters be able to be mounted near the power supplies and signal integration points?
   - Controllers must be mounted within 10 ft. (3.048 m.) of the power supply and signal integration points. Otherwise, the standard cables will need to be patched to increase length.
2. How many signal integration points are available for Li-ion Tamer?
   - If there are not enough available ports, the customer will need to purchase other hardware to accommodate Li-ion Tamer integration (Modbus RTU, Modbus TCP/IP, Digital Outputs, both Modbus and DO).
3. Will it be possible to mechanically mount the sensors on the battery racks?
   - If sensors cannot be mounted on racks due to warranty issues, they will need to either be mounted non-mechanically or on nearby walls.
4. Will it be possible to mount sensors within the HVAC supply flow?
   - The ideal placement for Reference Sensors is within the HVAC supply ducting but, if that is not possible, alternative locations must be determined.

2 Frequently Asked Questions

1. **How do you know if the Li-ion Tamer monitor is functioning properly?**
    - The output of the Li-ion Tamer OGM is fail-safe and has self-diagnostic capability.
    - Errors from sensors are detected at the controller through transmission of the “Sensor Error” signal and diagnostic lights at the port.
2. **What happens if a sensor malfunctions?**
    - The output of the Li-ion Tamer OGM is fail-safe and has self-diagnostic capability.
    - Errors from sensors are detected at the controller through transmission of the “Sensor Error” signal and diagnostic lights at the port.
    - The Li-ion Tamer controller will continue to operate using the remaining off-gas monitors.
3. **What happens if a sensor is disconnected from the controller?**
    - This is detected by the controller that generates a “Sensor Error” signal at the output.
    - The diagnostic LEDs on the port will indicate that a sensor has been disconnected.
    - The Li-ion Tamer controller will continue to operate using the remaining off-gas monitors.
4. **What happens if the PLC freezes or becomes unresponsive?**
    - The Modbus communication includes a heartbeat timer that can be used to verify that the PLC is still running.
5. **Can the Li-ion Tamer system be installed with less than one sensor per rack?**
    - Refer to the Li-ion Tamer Design Guide for details on reducing sensor quantities and designing custom systems for applications.
6. **Can the Li-ion Tamer system be tested with a test-gas to activate the off-gas monitor?**
    - Yes, the sensors can be activated with a bottle of battery off-gassing compounds (LT-ACC-TST), which is supplied by Li-ion Tamer.
    - It should be noted that the bump test kit does not simulate the amount of gas released during an off-gas event. It should only be used to release gas into the head of the gas monitor for the purpose of confirming operation of the gas sensor. It should not be used to release off-gas compounds into the rack or general vicinity to see if a nearby off-gas monitor detects it.
    - When using the bump test kit care needs to be taken not to activate a reference sensor.
    - Bump test kits should be used according to instructions provided by Li-ion Tamer.
    - Bump tests should only be performed by appropriately trained and qualified personnel.
7. **Are all the off-gas monitors on the system interchangeable?**
    - Off-gas monitors with the same part number are interchangeable.
    - Reference (LT-SEN-R) and Monitoring (LT-SEN-M) Sensors are not interchangeable.
    - Reference and Monitoring Sensors are color coded along with their cable and input ports on the controller to ensure proper connection of the system.
    - Monitoring Sensors and associated ports are BLACK.
    - Reference Sensors and associated ports are BLUE.
8. **Does the earth ground connection on the Power Input cable need to be connected to ground?**
    - Yes, the earth ground connection should be connected for all controllers in the system.
    - This is propagated throughout the system to connect the cable shielding to earth ground to help protect the system against EMI.
9. **Can any RJ45 cable (i.e. Ethernet cable) be used to connect an OGM to the controller?**
    - No, only cables provided by Xtralis are used to maintain minimum requirements and color coding.
    - All cables must be shielded with connected drain wires, have 26 AWG conductors or larger and be less than 30m (100 ft).
10. **Does the Li-ion Tamer off-gas monitor need to be tuned for different battery chemistries?**
    - No, the monitor detects the presence of solvents that are common in all lithium-ion battery chemistries; therefore, it is chemistry agnostic.
11. **How do we know the parts have not been tampered with between shipping and receival?**
    - Every sensor and controller package is heat sealed in an ESD bag. If that seal is broken prior to commissioning and installation, please contact an Xtralis representative to request a replacement.

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