

Engineering Specifications



Revision 03192020



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1 GENERAL

1.1 Scope

This document provides specification details of the Li-ion Tamer® Rack Monitor system and is intended to aid users in installation, operation, and maintenance.

1.2 Key Features

- 1. Early warning of lithium-ion battery failures
- 2. Enable thermal runaway prevention with proper mitigation actions
- 3. Single cell failure detection without electrical or mechanical contact of cells
- 4. Extended product lifetime
- 5. Calibration-free product
- 6. Highly reliable output signal
- 7. Low power consumption
- 8. Compatible with all lithium-ion battery form factors and chemistries
- 9. Easy installation
- 10. Independent and redundant perspective on battery health
- 11. Auto diagnostic capabilities
- 12. Reduction/removal of false positive signals
- 13. Several communication protocols including digital outputs and serial communication

1.3 Certifications

The Rack Monitor system has been designed and tested to meet the following certifications:

- 1. UL/IEC 61010 for product safety
- 2. EN 60326-1 for EU Directive (2014/30/EU)
- 3. RoHS 3 EU 2015/863

1.4 Codes, Standards or Regulations

The 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 requires off-gas monitoring detection
- 2. Local codes and standards

1.5 Quality Assurance

1.5.1 Manufacturer

Nexceris has an ISO 9001:2015 registered quality system and is committed to achieving the following objectives:

- 1. Development of innovative process and product solutions.
- 2. On-time delivery of products and services to our customers.
- 3. Provide for the safety and empowerment of our team members.

4. Continual improvement of operations and our quality system.

1.5.2 Equipment Supplier

- 1. The equipment supplier shall be authorized trained by the manufacturer to calculate/design, install, test and maintain the Li-ion Tamer system.
- 2. The equipment supplier shall be able to produce a certificate of training from the manufacturer.

1.5.3 Installer

- 1. The equipment installer shall be authorized and trained by the manufacturer and shall have the ability to design a system based on code requirements.
- 2. The installer shall be capable of providing calculations, design, and testing documents upon request.

1.5.4 Warranty

- 1. The manufacturer shall guarantee the product by warranty for a period of one year with a target lifetime of more than ten years.
- 2. The installation and dip switch configuration of the Li-ion Tamer Rack Monitor system shall be performed by trained suppliers or commissioning parties.

1.5.5 Training

1. The manufacturer or agent of the manufacturer shall train all personnel involved in the supply, installation, commissioning, operation and maintenance of the Rack Monitor system.

1.6 Documentation

The following documentation shall be supplied by the manufacturer:

- 1. Product technical datasheets and site layout drawings for sensor placement, when applicable.
- 2. The manufacturer's signal integration, operation and maintenance manuals shall be supplied to all installing and purchasing parties.
- 3. The manufacturer's commissioning manual shall be supplied to all suppliers and commissioning parties.

2 SYSTEM SPECIFICATIONS AND OPERATION

2.1 Off-gas Monitor Hardware Overview

2.1.1 Design Level

The off-gas monitor (OGM) hardware includes the Monitoring Sensors (PN 241022) and Reference Sensors (PN 241023). Monitoring Sensors are indicated by black cables and corresponding controller port labels. Reference Sensors are indicated by blue cables and corresponding controller port labels.

The sensor dimensions are shown on the following page.



A simplified function model of the off-gas monitor is depicted below. Note that all programming and calibration is performed by the manufacturer.



2.1.2 Detection Method and Output

The detection method for all off-gas monitors is as follows:

- 1. Raw sensor signal is gathered as a continuous function.
- 2. Nexceris' Event Detection Algorithm processes the signal with a discrete algorithm function indicating event detection.

The gas detection specifications are as follows:

- 1. Targets lithium ion battery off-gassing compounds
- 2. Minimum detection threshold of less than 1 [ppm/sec] and response time of 5 seconds
- 3. Single-cell failure fault detection capabilities

The off-gas monitor expected output signal is depicted below. Note that the individual OGM outputs are not visible when connected to the Li-ion Tamer controller.



The "fail-safe" error states provide numerous diagnostic capabilities, which are detailed below for both 0.0 VDC and 0.1 VDC outputs.

Li-ion Tamer Output	Condition	Diagnostic Capability			
0.0 VDC	Error state – Power failure	 Loss of power to device Loss of internal DC/DC regulation Failure of A/D output Failure of critical component on circuit board Component failure on output circuit Provides a "fail-safe" diagnostic state 			
0.1 VDC	Error state – Signal out of range	 Gas sensor signal exceeds max threshold Gas sensor signal resistance below min threshold Loss of sensor continuity Failure of sensor heater Failure of communication between sensor and micro 			

2.2 Controller Specifications

The Li-ion Tamer controller (PN 241026), detailed in Section 3, has the general specifications as follows:

- 1. Dimensions: 210 (W) x 113 (L) x 63 (H) [mm]
- 2. Input power range: 8 28 VDC
- 3. Maximum of fifteen (15) sensors per controller
- 4. System outputs both digital outputs and MODBUS signal





A simplified function model of the controller is depicted on the following page. Note that all programming and is performed by the manufacturer.



2.2.1 Power Consumption

The power consumption requirements are detailed below for a variety of conditions.

Power consumption specifications					
Detail Specification					
Controller (no concorr)	2.4 W (@ 24VDC)				
Controller (no sensors)	1.4 W (@ 12 VDC)				
Sensor	275 mW (@ 5 VDC)				
Controller	6.6 W (@ 24 VDC)				
(fully populated, 15 sensors)	5.6 W (@ 12 VDC)				
Fuse Rating	3.5 A				
Fuse Rating	3.5 A				

2.2.2 Environmental Specifications

The environmental operating conditions are detailed below. Operating outside of the specified ranges may lead to decreased performance and part damage.

Environmental specifications				
Condition Specification				
Temperature	-10 to +60°C			
Humidity	5 to 95% RH			
Max temperature change	8.6°C/min			

2.2.3 Digital Outputs

The Monitoring & Reference Controller (PN 241026) provides multiple digital signal outputs via two (2) 10-pin Molex ports. Nexceris PN 241158 may be connected to those ports in order to access the following outputs via bare-wire connections:

- 1. Unique rack-specific outputs
 - Ready: 8 28 VDC (Supply Voltage)
 - Alarm State: 0 VDC
- 2. Alarm Any: aggregated output signaling if off-gas is detected by any Monitoring Sensor connected to the controller
 - Ready: 8 28 VDC (Supply Voltage)

- Alarm State: 0 VDC
- 3. Sensor Error: diagnostic output signaling if any sensor connected to the controller is in an error state (detailed in Section 2.1.2)
 - Ready: 0 VDC
 - Alarm State: 8 28 VDC (Supply Voltage)

The wire colors for each signal are detailed below with the corresponding digital output ports labelled on the controller.

Pin	Assignment	Wire Color		
1	Rack 1	Blue		
2	Rack 2	Orange		
3	Rack 3	White		
4	Rack 4	Green		
5	Rack 5	Red		
6	Rack 6	White/Black		
7	Rack 7	Red/Black		
8	Rack 8	Green/Black		
9	Sensor Error	Orange/Black		
10	GND	Black		

DIGITAL OUTPUT 1

Pin	Assignment	Wire Color			
1	Rack 9	Blue			
2	Rack 10	Orange			
3	Rack 11	White			
4	Rack 12	Green			
7	Alarm Any	Red/Black			
9	Sensor Error	Orange/Black			
10	GND	Black			

DIGITAL OUTPUT 2

2.2.4 Modbus Output

The Monitoring & Reference Controller (PN 241026) provides a single Modbus RTU signal over RS-232 3-wire (TX, RX, GND). A standard DB-9 serial cable may be used to obtain the output with the following specifications below.

MODBUS communication specifications					
Detail	Specification				
Description	Modbus RTU over RS232				
Baud rate	9600 None				
Parity					
Stop bit	One				
Hardwara	RS232 3-wire				
naruware	(TX, RX, ground)				

The outputs are comparable to the digital outputs, where there is an output for each Monitoring Sensor, an Alarm Any output, and a Sensor Error output. Each bit from the serial string is either a 1 or 0, indicating alarm and normal states, respectively.

The controllers natively have MODBUS RTU and the signal can be converted to TCP/IP with an adapter provided by Nexceris, which is detailed in Section 4.2.2.

Outputs	Function Code	Bit/ Register Address
Monitoring 1 Alarm	01 (0x01)	1
Monitoring 2 Alarm	01 (0x01)	2
Monitoring 3 Alarm	01 (0x01)	3
Monitoring 4 Alarm	01 (0x01)	4
Monitoring 5 Alarm	01 (0x01)	5
Monitoring 6 Alarm	01 (0x01)	6
Monitoring 7 Alarm	01 (0x01)	7
Monitoring 8 Alarm	01 (0x01)	8
Monitoring 9 Alarm	01 (0x01)	9
Monitoring 10 Alarm	01 (0x01)	10
Monitoring 11 Alarm	01 (0x01)	11
Monitoring 12 Alarm	01 (0x01)	12
Alarm Any	01 (0x01)	16
Sensor Error	01 (0x01)	17
PLC 'Heartbeat'	04 (0x04)	6

The outputs and their corresponding function codes are shown in the table above. The "Heartbeat" is a watchdog timer that continuously increases every second until 3600, when it resets to 0. It can be used to confirm that the controller is providing live information and has not timed out, frozen, or lost power.

2.3 Li-ion Tamer Part Numbers

The full list of Li-ion Tamer Rack Monitor component part numbers is detailed below.

Part Number	Item	Description			
241022	OGM, Monitoring Sensor	Mounting on/near rack to detect off-gas from cells			
241023	OGM, Reference Sensor	Mounting around the ESS			
241026	Monitoring & Reference Controller	Controller with 12 ports for monitoring and 3 ports for reference sensors			
241157	10' Power Cable	Power cable for all Li-ion Tamer controllers			
241158	10' Digital Output Cables	Digital output cable for all Li-ion Tamer controllers			
311265, 311266, 311267	Monitoring Sensor Cable (various lengths)	Shielded RJ45 connector cable used with Monitoring sensors, Black			
311268, 311269, 311270	Reference Sensor Cable (various lengths)	Shielded RJ45 connector cable used with Reference sensors, Blue			
311271, 311272, 311273, 902998, 902997	Controller Daisy Chain Cable (various lengths)	Shielded RJ45 connector cable used to daisy-chain reference network signal to other controllers, Gray			

3 CONTROLLER CONFIGURATIONS

3.1 Monitoring & Reference Controller

The Monitoring & Reference Controller configuration specifications are as follows:

- 1. Connect up to 12 Monitoring and 3 Reference Sensors
- 2. The Monitoring & Reference Controller is the only controller that can always be used on its own.
- 3. "REF INPUT" is used to connect this controller to a larger Reference Sensor network.
- 4. "REF OUTPUT" is used to connect Reference Sensor network to another controller.

onitoring & Refer	ence Contro	ller						
	Mon 1	Mon 3	Mon 5	Mon 7	Mon 9	Mon 11	Ref 1	Ref 3
			D annual d		Party of	-	(Second Second	the state
	Sund					T.		
4	Mon 2	Mon 4	Mon 6	Mon 8	Mon 10	Mon 12	Ref 2	REF

3.2 System Configuration

The Rack Monitor controllers and sensors can be configured in a variety of ways, depending on the application area. Optimized controller configurations are to be determined by the manufacturer or a trained Nexceris representative.

The basic layout for a system utilizing Monitoring & Reference Controllers is shown below. Note that the system may be scaled by daisy-chaining multiple controllers in the manner shown.



4 APPLICATION

4.1 Sensor Placement

The following sections are general guidelines for sensor placement. Precise location and orientation are to be determined by a trained Nexceris representative upon installation.

4.1.1 Monitoring Sensor Placement

The Monitoring Sensors are to be placed near or on the battery rack to detect off-gas events from the rack. While airflow is not required for sensor operation, the air flow patterns should be taken into consideration when positioning the Monitoring Sensors. Several examples of potential air-flow patterns and their corresponding sensor placement are shown on the following page.



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 front of the rack and exits out the back Sensor placement: top back of the rack

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



Sensing face pointing down





Example #4

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

Sensing face pointing down



4.1.2 Reference Sensor Placement

The Reference Sensors are to be distributed throughout the ambient environment to monitor air inlets into the system, such as HVAC exchangers, doors, and other media which can serve as air inlets. Appropriate quantities and locations of sensors are to be determined by a trained Nexceris representative. The following information may be used as guidelines for Reference Sensor placement.

- 1. Any entrance or exit locations to the battery space (doors, access points, etc.)
- 2. Any possible gas entry points to the battery space (forced air or passive vent, unsealed gaps, etc.)

Sensor placement: top center of the rack

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

- Multiple points identified on one surface (i.e. geometric plane) can be monitored with on reference sensor if the separation distance between points is less than 3 feet and not obstructed by a physical barrier or airflow pattern that would prevent a gas entering from a point to be detected by a single monitor.
- Ensure adequate separation between Monitoring and Reference Sensors. Reference Sensors should never be mounted near battery racks unless they are separated from the hot aisle by a physical barrier (i.e. HVAC barrier, ducting, etc.).

3. Any HVAC entry points into the battery space

4.1.3 System Layout Example

As an example, a potential installation environment may be a 40 foot shipping container containing 24 battery racks. Additionally, there may be two (2) HVAC units on either ends of the container and four (4) doors for personnel entry. The layout for such a system is shown below.



Note that there are a total of twenty-four (24) Monitoring Sensors and six (6) Reference Sensors that are aggregated by two (2) Monitoring & Reference Controllers.

4.2 Signal Integration

The Li-ion Tamer controller has two primary outputs, including digital voltage signals and MODBUS serial communications, which are detailed in Sections 2.2.3 and 2.2.4, respectively.

4.2.1 Digital Output Signal Wiring

The digital output signals are generated by the controllers and can be accessed by connecting the Digital Output Cables (PN 241058) to the ports indicated below.



Typically, the digital output signals are wired into relays in order to actuate responses from other systems in the ESS. The correct wiring procedure is shown below for the relay provided by Nexceris (PN 902847), which is an SPDT Form C relay. Note that the Initiating Device Circuit (IDC) is wired to a different relay connection depending on which signal is being integrated and whether the relay signal is NO or NC. Additionally, due to the behavior of the signals, the alarm any signal will activate the relay by default whereas the sensor error signal will not – the appropriate wiring is shown for an IDC wired to both NO and NC relay connections.

NOTE: The sensor error signal should be integrated to indicate required maintenance of the Li-ion Tamer Rack Monitor system. Alternatively, the alarm any signal should be integrated to instigate fire suppression, increased cooling, or system shutdowns.

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4.2.2 MODBUS Signal Wiring

To access the MODBUS signal, regardless of whether TCP/IP is being utilized, the MODBUS Cable (PN 902783) will need to be connected to the controller at the port indicated below.



The wiring procedure detailed below should be used when integrating the MODBUS signal via a TCP/IP adapter. The adapter provided by Nexceris is the US2000B RTU to TCP/IP adapter.



5 INSTALLATION, OPERATION AND MAINTENANCE

5.1 System Installation

All installation should be performed by a trained Nexceris representative. The following steps outline the installation process:

- 1. Mount sensors (off-gas monitors)
- 2. Mount controllers
- 3. Route cables
 - Follow color-coded convention to prevent wiring errors (Black = Monitoring, Blue = Reference, Gray = REF signal daisy-chain)
 - If applicable, locate the main cabling distribution area close to the central region of the installation site to minimize the cable distances
 - Avoid mounting the cabling components in places that block accessibility to other equipment (such as a power strip or fans) in and out of the racks
 - Label the cables with their destination at every termination point (to ensure that both the ends of the cable are labeled for identification and traceability).
 - Test every cable during installation and termination. If a problem occurs, tag the malfunctioning cables and separate them out.
 - Avoid exposing cables to areas of condensation and direct sunlight.
 - Utilize cable trays whenever possible.
 - Provide strain-relief when mounting cables to prevent connection issues.
 - Observe all recommended practices from the cable manufacturer including bend radius, etc.
- 4. Make all connections to controllers

WARNING: Ensure that cables are not in tension when connected to controller. Make sure to provide enough slack to avoid potential damage.

5. Follow commissioning process

5.1.1 Sensor Mounting

The Monitoring and Reference Sensors may be mounted using one of two methods. Option 1 is to create a throughhole on the panel the sensor is to be mounted on. Option 2, depicted below, is to use a custom mounting bracket available through Nexceris. The following procedure should be used:

- 1. Fasten mounting bracket in position determined in the system layout
- 2. Secure sensor to bracket using 1 1/8-24 mounting nuts
- 3. Hand tighten nuts to secure the sensor to the bracket



5.1.2 Controller Mounting and Earth Grounding

The controllers should be mounted according to the procedure below. Additionally, a mounting template is available from Nexceris to locate mounting holes for the controller.

- 1. Disable any unused sensor ports, detailed in Section 5.2.1.
- 2. Secure controller to mounting surface using four (4) mounting holes.
- 3. Connect controller to earth ground and power via Power Cable (PN 241157) according to the table below. Earth grounding the controller provides earth ground to the sensor network and reduces signal noise due to EMI.

Earth ground connection points for various DC supplies:							
DC supply with earth ground connection	DC supply without earth ground connection						
VDC+	VDC+						
GND	GND						
Earth	[Ring terminal to ground location]						
	DC supply with earth ground connection VDC+ GND Earth						

Earth ground connection points for various DC supplies:

4. Make all connections to the controller.

NOTE: If required, the power input can be connected to a DC power supply with a battery back-up.

5.2 System Commissioning

5.2.1 Controller Commissioning

Unused channels on each controller shall be disabled on the controller to prevent the empty ports from being detected as a faulty or missing sensor. Disabling a port will force the LED diagnostic light on the RJ45 port to be 'green'. The procedure for controller configuration and sensor disabling is as follows:



WARNING: Use proper ESD protection when handling controller motherboard.

- 1. Remove controller enclosure and locate "Sensor Disable" switches
- 2. Locate switch number associated with port – use number printed directly on PCB, not the number on the red switch block
- Disable sensor channel by moving switch to "ON" position 3.



"Mon 1" Disabled

Confirm 'green' light on all unused channels 4.



Mon 1 "Mon 1" Enabled

Showing "error" at port because sensor not connected

The table on the following page lists the sensor ports and their corresponding sensor disable switches. Note that the REF INPUT port LED will remain green regardless of switch setting, and therefore can not be used in error diagnosing, which is detailed in Section 5.2.5.

"Sensor Disable" Switch	Monitoring & Reference Controller PN 241026
1	"Mon 1"
2	"Mon 2"
3	"Mon 3"
4	"Mon 4"
5	"Mon 5"
6	"Mon 6"
7	"Mon 7"
8	"Mon 8"
9	"Mon 9"
10	"Mon 10"
11	"Mon 11"
12	"Mon 12"
13	"Ref 1"
14	"Ref 2"
15	"Ref 3"
16	"REF INPUT"

5.2.2 Final Tests

The installer shall:

- 1. Confirm proper earth grounding by measuring resistance between connector block and earth ground
 - Use a multimeter or an equivalent device to check the effectiveness of the connectivity between the different parts of the installed equipment (such as cable shielding at reference and monitoring ports) to the ESS ground.
 - Check at 2 points for each controller installed in the system. Measure earth ground resistance between both of the 4x2 RJ45 connector blocks on the controller.
 - Using IEEE Std 142-2007 "Recommended Practice for Grounding" and IEEE Std 1100-2005 "Recommended Practice for Powering and Grounding Electronic Equipment", the ideal grounding value would be less than 1Ω from the equipment into the Earth.
 - Recommended ground resistance measurements for Li-ion Tamer are *less than 25\Omega* from the RJ45 connector block to earth ground.
- 2. Confirm input conditions at each input port (using port diagnostic lights).
- 3. Gas bump tests can be conducted to verify tip-to-tail operation of the system with the MODBUS Software. See Section 5.2.3 for testing procedure.
 - Confirm operation of signal connection to the energy storage system. Alarm signals can be generated by bump testing to ensure proper operation of systems connected to the Li-ion Tamer controller.
- 4. Power cycle each controller and sensor network after installation and testing.

5.2.3 Bump Test Procedure

The Li-ion Tamer DEC Test Bottle (PN 902889) may be provided by Nexceris upon request. The bottle is filled with a small amount of diethyl carbonate to be used for bump testing of sensors. Follow the procedure below to correctly test sensors.

NOTE: It is important that the bottle never be turned up-side down during use and is not intended to be refilled.

Required Materials for Testing:

- Li-ion Tamer DEC Test Bottle
- Li-ion Tamer MODBUS Software
- Latex gloves
- Safety glasses
- Respirator with organic cartridges (recommended)

How to Use:

1. Disconnect all Reference Sensors from the system. Visually confirm that the LEDs located on controller's sensor ports are amber for ONLY the disconnected sensors. If any Monitoring Sensor ports display amber LEDs, check the wire connections for the relevant sensors.

NOTE: If testing Reference Sensors, it is not necessary to disconnect all Monitoring Sensors; however, the controller should be power cycled between each round of bump tests and should be allowed 30 minutes prior to testing.

- 2. Open and run the included Li-ion Tamer MODBUS Software. See Section 5.2.4 for instructions on connecting controllers to retrieve their serial output. Confirm that all Monitoring Sensor status indicators are OFF.
- 3. Position the bottle relative to the desired Monitoring Sensor, like the example shown below.



- 4. Open the tab on the cap.
- 5. Firmly squeeze the bottle to release a puff of headspace gas towards the sensor face. WARNING: Avoid ejecting liquid from the bottle, especially onto the sensor. If the sensors were recently powered on, wait at least 30 minutes prior to testing. Additionally, confirm that the heartbeat shown in the MODBUS Software Interface is changing.
- 6. Proceed to bump test all Monitoring Sensors, close the tab on the cap, and observe the sensor response. Please see Section 5.2.4 for details on the MODBUS Software.

WARNING: Power cycle controllers every 30 minutes during testing or data corruption will occur.

7. Save data after testing, as shown below.



8. Power cycle each controller and sensor network after testing.

5.2.4 MODBUS Software

The Li-ion Tamer MODBUS Software may be provided by Nexceris upon request. The following steps are intended as a guide to software's user interface:

1. The Modbus State switch, depicted on the following page, may be used to alternate between RTU and TCP/IP connections. When using RTU, simply select the correct serial port. When using TCP/IP, enter the correct IP address and port number.





2. Select "Start Program" to begin serial connection with controller. See below for potential error codes and the method for resolving them. If an error code appears that is not listed below, please contact a Nexceris representative.

Error Code	Error Handling	
54	Invalid IP addressCheck controller IP address and confirm correct entry	
56	 Connection timed out Check controller IP address or Serial Port and confirm correct entry Check wire connections 	

3. Once connection is properly made, select the correct controller from the Product Selector drop down menu, as shown below.



- 4. Follow the guidelines in Section 5.2.3 for correct bump testing procedure.
- 5. When a sensor is activated the "Current Status" and "Triggered?" indicators will be illuminated. After the sensor exits the alarm state, only the "Triggered?" indicator will remain illuminated. Both possible displays are shown below.



6. Confirm that the tested sensors have been "triggered" and verify that the controller generated the correct output, as detailed in Section 2.2.4. See Section 5.2.5 if any sensors are not activated by bump testing.

5.2.5 Error Handling and Diagnostics

The table on the following page details potential system errors and their corresponding diagnostic indicators. Sensor-specific error diagnostics are detailed in Section 2.1.2.

Function	Error Handling	Diagnostic
Sensor Input	Loss of sensor signal Sensor disconnected Loss of continuity on sensor cable	 "Error Any" signal on digital output/Modbus Port diagnostic light on controller turns amber System will continue to operate with remaining sensors
Sensor Input	Sensor gives "Out-of-Range" error state signal, 0.1V	 "Error Any" signal on digital output/Modbus Port diagnostic light on controller turns amber System will continue to operate with remaining sensors
Digital output	Loss of output signal Loss of system power Loss of output cable continuity	 Output designed to be "fail-safe" "Ready" signal is high-state of digital output "Alarm" signal is low-state of digital output Loss of signal errors result in alarm state
Serial Output	Loss of output signal Loss of system power Loss of serial cable continuity PLC is frozen	 Modbus handshake communication (i.e. 'heartbeat') will indicate loss of output or if the PLC has frozen Heartbeat increases every second. Counts 0 – 3600, and roll over to 0)

The following details troubleshooting steps that may be taken if an "Error Any" signal is generated:

- 1. If the port is not being used, make sure the "Sensor Disable" switch is ON (detailed in Section 5.2.1).
- 2. Ensure the cable is connected and has proper continuity.
- 3. If necessary, replace the sensor connected to that port. Be sure to replace the affected part with a device of the same part number.

The REF INPUT port will always indicate a green LED. This port, though it aggregates reference input signals from other controllers, does not aggregate error signals. Therefore, troubleshooting must be performed on each controller. Additionally, the port light is not an indicator of a disconnected cable. Ensure RJ45 cables between the REF OUTPUT and REF INPUT ports of separate controllers are securely connected.

5.3 Maintenance and Service

5.3.1 Maintenance Tests

The Li-ion Tamer Rack Monitor system requires minimal operation and maintenance procedures as the off-gas monitors are designed to be calibration-free and have comparable lifetime to that of the ESS battery system. The general procedure is detailed below and should be performed annually.

- 1. Immediately attend to any errors generated by the system's self-diagnostics (detailed in Section 5.2.3).
- 2. Perform a visual inspection.
 - Confirm that LEDs at all ports are Green. Amber lights indicate an error is present at that port. "Error Any" signal communicated over Digital Outputs and Serial Output can be used to remotely monitor the system for errors.
 - Inspect for physical damage to controller, sensor network, cabling, sensor placement, or other visual changes to the original system construction.
 - Inspect sensor for excessive dust build up at the inlet. Sensor inlet is protected by a 40µm breather vent. This
 prevents diffusion restriction from dust build up from impacting the operation of the off-gas monitor;
 however, excessive dust should be removed from the inlet of the sensor as a best practice.
 - Ensure that mounting nuts are tightened to secure sensor to mounting bracket.
- 3. Bump test the sensors to verify gas response.
 - The sensors can be activated with a bottle of battery off-gassing compounds (PN 902889), which is supplied by Nexceris.
 - Note 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 in Section 5.2.3.

5.3.2 Fuse Replacement

The controller and sensor network power is protected by a 3.5A fuse which is located on the printed circuit board inside the controller. Remove the backplate and gently remove the circuit board to access the fuse shown below. Fuses must be replaced with an appropriate substitute 3.5A fuse.



WARNING: Use proper ESD protection when handling controller motherboard.



5.3.3 Spare Parts

Spare parts may be provided by Nexceris upon request.

6 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 "Error Any" 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 "Error Any" 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 and generates an "Error Any" alarm 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?

- It is not recommended to install less than one sensor per rack.
- However, this is permitted under the following circumstances:

- When back-to-back racks share a common exhaust channel
- When large scale fire testing demonstrates less sensors are sufficient

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 (PN 902364), 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 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 (PN 241023) and Monitoring (PN 241022) 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, Li-ion Tamer recommends that only cables provided by Li-ion Tamer 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 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 at all lithium-ion battery chemistries; therefore, it is chemistry agnostic.

NOTICE: 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.

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