



Battery Safe Handling Guide

SeaPower™ 57-Ah Battery Documentation



Document Version History

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1 Introduction

The purpose of this guide is to provide the users of Kraken SeaPower™ batteries with an overview of safe handling of lithium-ion battery packs produced by Kraken Power GmbH. The guide provides information on handling the batteries under normal and emergency conditions. The guide does not provide information on a specific design of battery. Instead, an overall ‘best practices’ for high energy density systems of >1kWh is provided.

1.1 Terminology

- **Primary battery** – non rechargeable battery.
- **Secondary battery** – rechargeable battery.
- **Cell** – the smallest individual element of a battery which consists of an anode and a cathode and can store and discharge energy.
- **Battery** – an assembly of cells that are connected in series or parallel and which may contain control electronics for monitoring the units electrical and mechanical properties.

1.2 General Product Information

The SeaPower battery is a pressure tolerant, high-capacity, high-energy density, lithium ion-based battery with an integrated Battery Management System (BMS). The technology is based on Kraken Power’s proprietary silicone potting techniques, which produce pressure tolerant components without the need for oil compensators or additional compensating liquids.

1.3 Responsibilities

The SeaPower batteries are designed to be used in applications which may or may not be known to Kraken at time of delivery. It is the responsibility of the user of the SeaPower battery to:

- Receive and review all documentation that is provided with the battery.
- Use all the applicable recommendations found in this guide and all other provided product documentation.
- Operate the battery within the electrical, mechanical, and environmental conditions specified in the interface control documents provided with the battery.
- Only use the SeaPower battery with approved chargers.

- Perform hazard analysis on the system that the battery will be used with and incorporate as many safeties related design and testing criteria into the system design as is feasible for the application.
- Ensure that written standard operating procedures for the battery are developed for the system in question and that these procedures are followed.
- Verify the battery is in good condition and monitor the battery and the battery system for degradation in performance, damage, abuse etc. to minimize the risk of out of specification operation of the device.

2 General Safety Information

This section describes the skill set required and the general safety requirements to handle and operate SeaPower lithium-ion batteries produced by Kraken Power GmbH.

This guide is written for professionals who will be using and maintaining the SeaPower battery or battery system. As such, it is expected that operators of the SeaPower battery should possess the following experience:

- A basic understanding of electrical systems
- A basic understanding of computer and software usage
- A basic understanding of requirements and specifications of lithium-ion batteries

SeaPower lithium-ion batteries are composed of a series of lithium cells and complementary mechanical components and electronics which form a system capable of storing a large amount of energy. The storage and discharge of this energy occur through a controlled chemical reaction within the cells. Under normal operating conditions, there are no known hazards associated with the use of SeaPower batteries. When used appropriately the battery is designed to be inherently safe.

All safety recommendation provided herein are intended to minimize the risk of safety issues occurring, assuming the batteries are operated by professionals. Read all relevant documentation before handling any battery.

A typical documentation set includes:

- Interface Control Document (ICD)
- Installation and Operation Guide
- SeaPower Battery User manual

2.1 Technical and Emergency Contacts

The SeaPower batteries are designed and fabricated by Kraken Power GmbH. Their contact information and the contact details for technical support and emergency response are provided below.

Company Name	Kraken Power GmbH
Address:	Alter Hafen Süd 6 D-18069 Rostock
Emergency:	For Chemical Emergency Spill, Leak, Fire, Exposure, or Accident 24 Hr. Emergency CONTACT via Infotrac

	GBK/Infotrac ID 112531: USA domestic 1 800 535 5053 International (001) 352 323 3500
Technical Information:	+49 381 66098699 Kraken Power GmbH (Germany/Europe) +001 709 757 5757 Kraken Robotic Systems Inc. (Canada/NA)

2.2 Misuse

The batteries provide reliable service in extreme ocean environments under normal operating conditions (which are shown in the battery's interface control document, relevant guides, and manuals). If operation occurs outside of these specifications, or the battery is exposed to unreasonable physical or electrical abuse, the safety systems built into the battery may not be capable of maintaining safe operation.

Adhere to the following precautions:

- Follow all procedures and recommendations laid out in the provided documentation.
- Follow the recommendations regarding maximum recommended currents and operating temperature range.
- Handle wet connectors according to the manufacturer's best practice and examine for damage before and after each mating cycle.
- Follow all recommended installation and operational guidelines provided in the system/design-specific documentation with regards to mechanical mounting, cable arrangement, and system configuration.
- Do not connect the batteries in a series or parallel arrangement not explicitly documented and approved in writing by Kraken Power GmbH. An unapproved battery arrangement may not be capable of handling the current.
- When the batteries are not in use, ensure that all dummy plugs are installed in the battery to prevent accidental short circuit of the battery.
- Do not store the battery in an orientation not documented and approved in writing by Kraken Power GmbH. The battery has several surfaces that are not designed to accommodate the mass of the unit and may fail under extended loading.
- Do not mix batteries of varying sizes, vendors, chemistries, or types.

- Reverse charging of SeaPower batteries is prohibited. Connect the battery and the charger correctly.
- Do not do short the circuit of the lithium polymer battery. It can cause permanent damage.
- Do not use the lithium polymer batteries under extreme conditions, such as extreme temperature, deep cycles, extreme overcharge, and over-discharge.
- Do not store the lithium polymer battery in a hot or moist place.
- Do not ship the lithium polymer battery fully charged. Depending on method of transport varying levels of state of charge (SOC) are allowable. Kraken recommends discharging the battery to 20% SOC capacity prior to shipment for all modes of transport.
- Do not use the battery if you notice any of the following:
 - Noise coming from the battery
 - High temperature of the battery housing
 - Leakage or rupture of the battery housing
 - Swelling or abnormal coloration of the battery

2.3 Abuse

The batteries have been designed to survive the extreme environment of the deep ocean; however, they have not been designed to allow for extreme abuse.



If the battery is exposed to unreasonable physical or electrical abuse the safety systems built into the battery may not be capable of maintaining safe operation.

To avoid abuse, adhere to the following precautions:

- Do not open the battery case. If there are any problems, please contact Kraken.
- Do not drop the battery. If it drops and breaks, handle the lithium cells with care. They may cause heat, smoke, or ignition of the battery. If the battery is dropped, the user should no longer use the battery. The battery should be decommissioned or returned to Kraken for evaluation.
- Avoid shorting out the lithium cells or exposing them to water. This may result in a fire.
- Do not force any probe, wire, or other instrument or hardware into the battery connectors.
- If you notice any malodor, heating, discoloration, deformation, or any other change from what you are used to while using, charging, or storing the battery, take it out of equipment or charger, and avoid further use of the battery. Using the battery in such state may result in heat, smoke, or ignition.

- Do not put the battery in an oven, or any device that may cause heat. Sudden heat may damage the seal of the battery and may cause heat, smoke, or ignition of the battery.
- Do not attempt to overcharge or over-discharge a battery or attempt to defeat the built-in safety features of the battery management system.
- Do not expose the battery to fire or open flames.
- Do not puncture, deform, incinerate, or heat above 60 °C.

2.4 Off-Gassing

The battery may experience abuse or out of specification operation that could cause off-gassing. The gas is colorless to pale yellow and has a pungent odor. To minimize the risk of off-gassing, avoid the following conditions:

- Do not expose the lithium polymer cell material directly to water.
- Do not overcharge/over-discharge the battery.
- Do not expose the battery to > 60 °C ambient temperature.
- Do not charge battery when the ambient temperature is < 10 °C or > 40 °C.

Any fumes released from the battery may contain hydrofluoric acid and by-products of the battery's base materials decomposition. If off-gassing is noted, avoid breathing in the fumes and immediately air out the space where the batteries are being stored. If physical contact is made with venting gases, it may cause irritation to the eyes, skin, and mucus membranes. Remove the affected people to fresh air and seek medical attention.

If handling of a venting cell or battery is required, wear proper personal protective equipment to minimize contact with venting gasses. This equipment includes at a minimum:

- Chemical-resistant gloves suitable for handling hydrofluoric acid.
- Respirator suitable for organic solvents.
- Full length clothing which minimizes exposed skin.

2.5 Explanation of Lithium-Ion Battery Decomposition

Under normal operating conditions and general storage conditions, the battery does not contain hydrofluoric acid. The battery is made up of the constituent components listed below:

- Negative electrode: Carbon (C₆)
- Positive electrode: Lithium Cobalt Manganese Nickel Oxide (LiMnNiCoO₂)

- Electrolyte: Solution of lithium hexafluorophosphate (LiPF₆) dissolved in mixture of organic solvents ethylene carbonate ((CH₂O)₂CO) + ethyl methyl carbonate (C₄H₈O₃)

Under normal conditions, the reaction inside the battery cell produces free electrons. This reaction can be reversed by applying current in the opposing direction. This normal cycle of the battery does not produce hydrofluoric acid. Although the exact molar reaction is proprietary to Kokam and unknown to Kraken, the reaction for this cycle is described below.

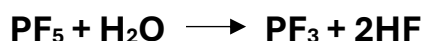


As shown above (and from a review of the composite materials), under normal operation there is no potential for hydrogen fluoride (HF) or hydrofluoric acid to form. However, there are cases where hydrofluoric acid can be generated.

2.6 Kokam Cell Failure

During a failure of the Kokam cell, the heat generated within the cell can lead to the evaporation of the electrolyte, which can then lead to the decomposition of the constituent compounds. This decomposition in the presence of moisture or water can lead to the formation of hydrofluoric acid.

During a failure the electrolyte can be exposed to moisture after the pouch cell vents. In the presence of moisture or water the decomposition of the LiPF₆ occurs as described below.



During combustion of the PF₆⁻ ions, the free fluorine ion can collect H ion to form HF.

Both reactions can yield HF. This compound (when not exposed to water) is called hydrogen fluoride. High energy density cells, such as those used in SeaPower batteries, can generate between 20 and 200 mg of HF per Wh of energy storage. The production of HF when the electrolyte evaporates and is exposed to water is a variable and unknown quantity, because the exact composition and ratio of lithium hexafluorophosphate, ethylene carbonate, and ethyl methyl carbonate are unknown. The rate of HF generation during an event like combustion is very poorly understood and can be impacted by many factors.

According to Larsson et al. “The immediate dangerous to life or health (IDLH) level for HF is 0.025 g/m³ (30 ppm) and the lethal 10 minutes HF toxicity value (AEGL-3) is 0.139 g/m³ (170 ppm)” (Larsson, Andersson, Blomqvist, & Mellander, 2017). Standard personal protective equipment in the form of body worn HF sensors can be used to ensure that personnel operating around failed batteries are not exposed to dangerous levels of HF. These sensors generally have alarms at 1ppm and 3ppm which are well below the specified limits.

Once this decomposition takes place, dilution with excess water or exposure to salts containing hydroxide can neutralize the acid.

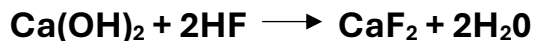
2.7 Hydrogen Fluoride Dilution

Dilute HF acid when a vehicle is deployed, and a battery failure occurs. With such a vast quantity of water relative to the small amount of HF generated during a failure event the pH of the solution of seawater and HF should be trivial as long as the vehicle remains in a large body of water or is flushed thoroughly with large amounts of water.

Neutralization of the acid can be accomplished through reaction with hydroxides such as sodium hydroxide NaOH as described below.



Or through the reaction with calcium hydroxide ($\text{Ca}(\text{OH})_2$):



2.8 Fire

In the event of a fire involving the SeaPower batteries, the cells will emit irritating and/or toxic fumes due to off-gassing. Other chemicals may also be present due to the decomposition of the battery's component materials.

3 Materials

The materials contained in this battery represent a hazard if the integrity of the battery is compromised or if the battery is physically or electrically abused.

The battery is composed of many different materials including but not limited to the following list:

- **Carbon fiber** - frame and internal structure
- **Copper wire** - internal electronics
- **Silicone** - potting material and external pouch
- **LiMnNiCoO₂** - lithium cobalt manganese nickel oxide - cell electrode
- **C₂ – Carbon** - cell electrode
- **LiPF₆** - lithium hexafluorophosphate - cell electrolyte
- **EC** - ethylene carbonate - cell electrolyte
- **EMC** - ethyl methyl carbonate - cell electrolyte

Review the relevant material safety data sheets (MSDS) provided with the battery. The general technical details regarding the cell level chemical process are presented below to provide the user with an insight into what chemicals may be present in the battery's cells.

Cell Level Chemical Process Details

Chemical Description	Lithium Cobalt Manganese Nickel Oxide
Cell Model:	SLPB Series
Electrochemical System:	Negative Electrode: Carbon Positive Electrode: Lithium Nickel Cobalt Manganese Oxide (LiNi_xCo_yMn_zO₂) Electrolyte: Solution of lithium hexafluorophosphate (LiPF₆) in a mixture of organic solvent Ethylene Carbonate (EC) + Ethyl methyl Carbonate (EMC)
Overall Chemical Reaction	$\text{Li}_x\text{C}_6 + \text{Li}_{1-x} \longrightarrow \text{C}_6 + \text{LiMnNiCoO}_2$

3.1 Physical Materials

The lithium-ion polymer rechargeable cells described in the provided MSDS are sealed units which are not hazardous when used according to the recommendations of the manufacturer.

Under normal conditions and use, the solid electrode materials and liquid electrolyte they contain are non-reactive, provided the battery integrity is maintained and seals remain intact.

NOTE: Abuse of the batteries can increase risk of exposure and can lead to the activation of safety valves and/or the rupture of the battery containers. This can result in electrolyte leakage, electrode materials reaction with moisture/water or battery vent/explosion/fire.

3.2 Chemical Materials

The battery contains packages of cells, which include the following substances:

Substance CAS Number	Chemical Symbol	Melting Point	Boiling Point
182442-95-1	LiMnNiCoO2	>1000 °C	N/A
EC: 96-49-1 EMC: 623-53-0	Organic Solvents (EC-EMC)	EC: 38 °C EMC: 4 °C	EC: 243 °C EMC: 90 °C
21324-40-3	LiPF6	N/A (decompose at 160 °C)	N/A

For exposure limits, observe local/state/federal regulations.

4 Operation

Follow the procedures, specifications, and limitations outlined in the provided documentation. The user must contact Kraken in advance if the customer requires applications or operating conditions other than those described in the provided documentation.



Failure to follow the guidelines below can result in battery damage, battery failure, and dangerous conditions.



To ensure safe operation of the battery unit, the following specific recommendations must be followed.

4.1 Charging Current

The charging current must be controlled by an approved charging unit and be maintained within the limits specified in the product's interface control document. The charging current must not exceed the maximum charge current specified in the design specification for the battery or battery system.

Charging with higher than recommended current may cause damage to the cell which could lead to reduced performance or failure of the cell or battery. The battery's management system includes both soft and hard fuses to prevent excessive charging current. Failure to maintain safe charge currents will result in the failure of the battery. Additionally, continuously operating the battery close to the maximum charge current may result in reduced capacity or cause overheating. This could lead to damage of the cell or battery beyond repair and may cause violent failure of the battery unit.

4.2 Charging Voltage

The charging voltage shall be controlled by an approved charging unit. The cell voltages must be maintained between the maximum charge voltage and minimum discharge voltage. Failure to adhere to this voltage range may damage the cell or battery beyond repair and may lead to violent failure of the battery unit.

4.3 Battery Charging Temperature

The battery shall be charged within the range specified in the design's interface control document. Failure to adhere to this temperature range during charging could result in damage to the cell or battery beyond repair and may lead to violent failure of the battery unit.

4.4 Reverse Charging

Reverse charging is prohibited. The battery must always be connected as described by the Kraken-provided documentation. The polarity must be confirmed before operating the battery or battery system. The battery management electronics are designed to prevent reverse charging. However, extreme reverse

voltage potential across the terminals may cause damage to the cell which may lead to degradation of cell performance and damage the cell safety, and could cause reduced performance or lead to failure of the battery unit.

4.5 Battery Discharging Temperature

Discharge the battery within the range specified in the design's interface control document. Failure to adhere to this temperature range during discharge of the battery could result in damage to the cell or battery beyond repair and may lead to violent failure of the battery unit.

4.6 Discharge Voltage Cut-off

Design the system so the battery is never discharged past the minimum voltage specified by the cell manufacturer. Failure to adhere to this voltage range may damage the cell or battery beyond repair and may lead to violent failure of the battery unit.

4.7 Discharging Current

Design the system so the current drawn from the battery never exceeds the discharge current specified in the design-specific interface control document. The battery's management system includes both soft and hard fuses to prevent over discharge however failure to maintain safe discharge currents will result in the failure of the battery.



Operating the battery continuously close to the maximum discharge current may result in reduced capacity or cause overheating. This could lead to damage of the cell or battery beyond repair and may cause violent failure of the battery unit.

5 Storage

When the batteries are not in use, store the batteries according to the following recommendations:

- Store batteries in the provided shipping containers during prolonged periods between operations.
- During continuous charge/discharge operation cycles, store the batteries in a water basin capable of covering the battery. This ensures that adequate cooling is provided during charge cycles and minimizes the risk of fire should a failure occur.
- Store the batteries in a well-ventilated area away from combustible materials.
- Store depleted batteries separate from fresh batteries. Ensure that the batteries are monitored for self-discharge as per the recommendations in the design-specific documentation.
- Do not store batteries in a manner that allows terminals to short circuit. When storing the batteries, always ensure that all the appropriate dummy plugs are installed to prevent accidental short circuiting.
- Separate batteries from other materials and stored in a non-combustible, well ventilated, sprinkler-protected structure with enough clearance between walls and battery stacks.
- Do not store batteries above 45 °C or below -10 °C. Elevated temperatures can result in reduced battery service life. Battery exposure to temperatures in excess of 130°C will result in the battery emitting flammable liquid and gases.
- Store batteries in a cool (below 30°C), dry area that is subject to little temperature change.
- Do not place batteries near heating equipment or expose to direct sunlight for long periods of time.

6 Transportation Information

Only trained and authorized personnel may prepare, package, and ship lithium-ion batteries. Kraken can provide a guide for preparing the shipment. Kraken can also be contracted to assist in the preparation of the shipment if necessary. Review the shipping guide as well as any local regulations regarding the shipment of lithium-ion batteries specific to the mode of transport required.

Lithium batteries must be prepared, packaged, and shipped in accordance with all applicable requirements, including Department of Transportation (DOT), International Air Transport Association (IATA), and International Maritime Organization (IMO). Fines and penalties for non-compliance can be substantial. In general, Kraken SeaPower batteries ship under the provisions for low production or prototype batteries. An example summary of these provisions is shown below.

Transportation Mode	Prototypes Truck/Rail/Sea Freight	Prototypes Airfreight
	Prototypes: Batteries not tested according UN Test 38.3 Only for transport of • small production series of max. 100 batteries (IATA: p.a.) • prototypes for testing reasons only	
Packing Instructions	ADR/RID/IMDG Code: SP 310, P910	IATA SP A88, P910: Approval required from the Competent Authority of the state of origin Note: to/across/via USA additional approval required from US Authority (DOT)
Max. Quantity	n/a	as defined in approval
Weight Limit	n/a	as defined in approval
Packaging	UN approved packaging: e.g. fibreboard box (Packing Group II: e.g. UN 4G/Y30/...) • Each battery shall be individually packed in an inner packaging, e.g. in a plastic bag • Non-combustible, non-conductive thermal insulation material, e.g. Vermiculite • Must be secured against movement within the outer packaging	as defined in approval
Marking	ADR/RID: UN 3480 IMDG: UN 3480 LITHIUM ION BATTERIES (100 x 100 mm)	as defined in approval
Transport Document	Shipper's & consignee's address UN 3480 LITHIUM ION BATTERIES, 9, (E) Number of packages and packaging type (e.g. 1 fibreboard box) Battery weight (e.g. xx kg) "CARRIAGE IN ACCORDANCE WITH SPECIAL PROVISION 310" IMDG Code: IMO-DANGEROUS GOODS DECLARATION (SOLAS 74, KAP. VII, REG 5, MARPOL 73/79, ANNEX III REG. 4 OF IMDG-CODE	as defined in approval
Miscellaneous	Work instruction of involved staff	as defined in approval

7 First Aid

In the event of a battery rupture or explosion, evacuate personnel from contaminated area and provide maximum ventilation to clear out fumes/gases. In all cases, seek immediate medical attention.

Issue	Response
Eye Contact	Flush with plenty of water (eyelids held open) for at least 15 minutes.
Skin Contact	Remove all contaminated clothing and flush affected areas with plenty of water and soap for at least 15 minutes. Do not apply grease or ointments as these may react.
Ingestion	Dilute by drinking plenty of water and seeking immediate medical help. If substances are swallowed, be sure that aspiration of vomit does not occur. Ensure that mucus does not obstruct the airway.

8 Battery Failure Emergency Response

Due to the size of the lithium-ion battery pack produced by Kraken Power GmbH it is extremely important to carefully control a failure if it were to occur.

The battery is designed to store a tremendous amount of energy. This energy, when released during a failure of the battery cells or battery subsystem, can produce extreme temperatures, fire, and toxic gases from which the user must protect themselves and the surrounding infrastructure.

If smoke or excessive heat is noted during operations, the assumption is that one or more of the batteries have experienced a failure and has started to vent. The reaction cannot be stopped and must be allowed to self-extinguish. The chemical reaction will cease once all products have been exhausted. The vehicle may or may not be contaminated with electrolyte or by-products of the reaction.

The following section provides steps to take when a battery is assumed to have failed while in service.

8.1 Case 1: Battery Failure During Vehicle Operations

If the vehicle appears on the surface and smoke is billowing from the vehicle, follow the procedure below:

1. Leave the vehicle in the water for at least two hours until after the smoke has stopped.
2. All personnel handling the emergency event require the appropriate personal protective equipment (PPE). While waiting for the batteries to stop smoking, get protective equipment ready, including the following:
 - Full face respirator suitable for organic solvents, specifically, hydrogen fluoride
 - Chemical resistance gloves made of butyl rubber or neoprene rubber or those
 - specifically made for handling strong acids
 - Safety glasses
 - Acid-resistant apron
 - Full skin-covering clothing
 - PPE as required for worksite
3. Any personnel not responding to the battery event should leave the working area.
4. Get the vehicle back on deck outside of the hangar with launching device still in place. Leave the vehicle outside of the hangar for one hour to ensure that reaction has ceased.
5. During this time, measure the temperature of the batteries or the surface covering the batteries with a noncontact IR temperature sensor at 5-minute intervals.

6. If the temperature rises above ambient temperature or smoke starts appearing again, submerge the vehicle back in the water.
7. If the temperature remains stable or falls below observed values, open the battery compartment and fill it with water, if possible.
8. Remove all covers or foam so the view to the batteries is not obscured.
9. Leave the AUV with the batteries inside, preferably covered with water, and monitor the temperature for 1 hour while taking measurements at 2-minute intervals.
10. If the temperature rises above ambient temperature, more than 10 °C, leave the water and batteries in the battery compartment and wait for another hour. Ensure the water temperature stays below 35 °C by adding cold water into the battery compartment. If there is no possibility to cover the batteries in water. Flow water over the batteries and submerge the vehicle back in the water and start again with temperature tests on deck one hour later.
11. When the water temperature stays below or equal to ambient temperature for 1 hour, drain the compartment.
12. Flush the vehicle with water to rinse off any acidic residue that may be present. Rinsing the vehicle will also help to dilute any acid that has collected in areas of the vehicle.
13. Prepare a water basin adjacent to the vehicle being worked on. This basin will be used to store the batteries in case smoking or deforming starts again while lifting or separating them.
14. Measure the battery voltage by using a digital multimeter to measure the voltage between the positive and negative terminals of the batteries. It should be below 3V. If the voltage is not below 3V, take extra care when disconnecting the batteries from the AUV.
15. Disconnect the Kraken Power power/com rails from the AUV connectors and install dummy plugs to any open terminals.
16. Attach the lifting device on top of the battery stack containing the faulty battery. If you have not determined which battery has failed, you must assume that all batteries have failed.
17. Ensure the carbon fiber frame has not sustained any damage prior to lifting. If damage is noted, an ad-hoc lifting solution may need to be designed for the batteries as further damage to the battery internals could cause further chemical reaction to occur. Please contact Kraken Power for further direction in this situation.



Only proceed with the following steps after the off-gassing has stopped and temperature has stabilized.

18. Move the batteries out of the vehicle.

19. If while moving the batteries smoke appears or the batteries start to deform, place the back into the battery compartment and flood them with water or put them into the prepared basin of water next to the vehicle.
20. Separate the battery units from the cables and place dummy connectors onto all of the open connections on the batteries.
21. Put each battery into a box (e.g., Kraken Power BM450V45-C reusable storage and shipping aluminum boxes). If using the battery shipping boxes, take out the gray foam to give more water volume to cool the batteries.
22. Move the box containing the batteries to a safe and shaded place on the open deck and fill up the box with water.
23. Ensure that the lid or cover of the box remains open to allow for any gases to escape, should off-gassing begin again.
24. Repeat from step 17 until all batteries are removed from the vehicle.
25. Monitor the temperature of the boxes and the water inside the box at 15-minute intervals. Ensure that those taking the measurements use the appropriate PPE to protect themselves against possible acid exposure.
26. If the temperature rises above ambient temperature, flush the boxes with cold water to keep the surrounding materials cool and remove as much excess heat from the batteries as possible.
27. If the temperature remains below or equal to ambient temperature, the batteries can remain stored in water and the temperature monitoring can be moved to 2-hour intervals.
28. Contact Kraken Power to discuss the appropriate next steps and to help investigate the cause of the failure.
29. Rinse the vehicle with large amounts of water to remove traces of electrolyte and other by-products from the reaction.

8.2 Case 2: Battery Failure during Charging/Discharging

If the batteries installed in the vehicle (or the battery bays next to the vehicle stands) begin to deform or smoke during charging/discharging or maintenance, please follow the procedure below:

1. If charging or discharging the batteries, push the emergency button on the charger immediately, disconnect the BMC cable, and switch off the AUV.
2. If possible, ventilate the area immediately to prevent the build-up of toxic gasses and put on a full-face respirator suitable for organic solvents, specifically, hydrogen fluoride.
3. If possible, fill the battery compartment with water.
4. Leave the area and initiate firefighting measures, assuming that the escaping gases may ignite. Any personnel not responding to the battery event should leave the working area.
5. All personnel handling the emergency event require the appropriate personal protective equipment (PPE). While waiting for the batteries to stop smoking, get protective equipment ready, including the following items:
 - Full face respirator suitable for organic solvents, specifically, hydrogen fluoride.
 - Chemical resistance gloves made of butyl rubber or neoprene rubber, or those
 - Specifically made for handling strong acids
 - Safety glasses
 - Acid resistant apron
 - Full skin covering clothing
 - PPE as required for worksite
 - Self-contained breathing apparatus (SCBA) and full firefighting PPE for those responding to a lithium-ion battery fire
6. If possible, move the vehicle to an area where it can be submersed in water while the reaction continues.
7. If Immersing the AUV is not possible, try to cool down the batteries as much as possible with water to reduce the temperature of the batteries.
8. During this time, measure the temperature of the batteries and/or the water surrounding the batteries with a noncontact IR temperature sensor at 5-minute intervals.
9. Check for the cessation of bubbles forming around the failed battery. This indicates that the reaction has completed.

10. If the temperature stays stable or falls below values observed, leave the AUV or the battery bay with the flooded batteries inside and monitor the water temperature for 1 hour, taking measurements at 10-minute intervals.
11. If the water temperature rises above ambient temperature more than 10 °C, leave the water and batteries in the battery compartment and wait for another hour. Make sure the water temperature stays below 35 °C by adding cold water into the battery compartment.
12. When the water temperature stays below or equal to ambient temperature for 1 hour, drain the compartment.
13. Flush the vehicle with water to rinse off any acidic residue that may be present. Rinsing the vehicle will also help to dilute any acid that has collected in areas of the vehicle.
14. Prepare a water basin adjacent to the vehicle being worked on. This basin will be used to store the batteries once they are removed from the vehicle.
15. Measure the battery voltage by using a digital multimeter to measure the voltage between the positive and negative terminals of the batteries. It should be below 3V. If the voltage is not below 3V take extra care when disconnecting the batteries from the AUV.
16. Disconnect the Kraken Power power/com rails from the AUV connectors and install dummy plugs in any open terminals.
17. Attach the lifting bar on top of the battery stack containing the faulty battery. If you have not determined which battery has failed, you must assume that all batteries have failed.
18. Ensure the carbon fiber frame hasn't sustained any damage prior to lifting. If damage is noted, an ad-hoc lifting solution may need to be designed for the batteries as further damage to the battery internals could cause further chemical reaction to occur. Please contact Kraken Power for further direction in this situation.



Only proceed with the following steps after the off-gassing has stopped and temperature has stabilized.

19. Lift the battery stack out of the vehicle.
20. If while lifting the batteries, smoke appears or the batteries start to deform, place it back into the battery compartment and flood it with water or put it back into the prepared basin of water next to the vehicle.
21. Separate the battery units from the cables and place dummy connectors onto all the open connections on the batteries.

Put each battery into a box (for example, Kraken Power BM450V45-C reusable storage and shipping aluminum boxes). If using the battery shipping boxes, take out the gray foam to give more water volume to cool the batteries.

22. Move the box containing the batteries to a safe and shaded place on the open deck and fill it up with water.
23. Ensure that the lid or cover of the box remains open to allow for any gases to escape should off gassing begin again.
24. Repeat from step 17 until all batteries are removed from the vehicle.
25. Monitor the temperature of the boxes and the water inside the box at 15-minute intervals.
Ensure that those taking the measurements use the appropriate PPE to protect themselves against possible acid exposure.
26. If the temperature rises above ambient temperature, flush the boxes with cold water to keep the surrounding materials cool and remove as much excess heat from the batteries as possible.
27. If the temperature remains below or equal to ambient temperature the batteries can remain stored in water and the temperature monitoring can be moved to 2-hour intervals.
28. Contact Kraken Power to discuss the appropriate next steps and to help investigate the cause of the failure.
29. Rinse the vehicle with large amounts of water to remove traces of electrolyte and other by-products from the reaction.

9 Fire Protection Measures

Only trained and properly equipped emergency responders should attempt to fight a lithium battery fire. Cells exposed to excessive heat beyond their recommended temperature range can ignite. A cell fire within a battery pack can lead to a chain reaction that involves multiple cells.

During a lithium-ion battery fire there are two main objectives:

1. Preservation of life.
2. Preventing the spread of fire to other cells, preventing cell venting, and protecting the building/property.

Take the following precautions if a battery is involved in a fire:

- Use a SCBA when attending to a fire involving batteries.
- Cool down the battery using large amounts of water.
- As extinguishing the fire is not possible, move or protect the surrounding area and materials to prevent the fire from spreading.
- Use appropriate PPE when handling any battery or cell damaged due to fire. This includes:
 - Chemical resistant gloves suitable for handling hydrofluoric acid
 - Respirator suitable for organic solvents
 - Full length clothing which minimizes exposed skin

9.1 Shore-Side Facility Fire

The general shore-side facility fire procedures for primary lithium-ion batteries are listed below:

1. Activate the fire alarm.
2. Call emergency services from a safe location to report the emergency.
3. Fight the fire if it is small (incipient stage), safe to do so, and you are adequately trained for lithium-ion battery fires.
4. Douse fire with water to prevent spread.
5. Evacuate the area.

9.2 Vessel At-Sea Fire

The general vessel at sea fire procedures for primary lithium-ion batteries are listed below:

1. Notify the Bridge.
2. Initiate the vessel emergency response procedures.
3. Fight the fire if it is small (incipient stage), safe to do so, and you are adequately trained for lithium-ion battery fires.

10 Legal Notices & Contact Information

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10.3 Feedback / Support

To suggest improvements or report errors, please contact: documentation@krakenrobotics.com

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