KRAKEN

SeaPower Battery
Interface Control Document
V1

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V1	Kraken Robotics Inc.	Initial Release

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Failure to operate this product in a safe and responsible manner could result in injury or damage to the product or other property. This document and companion documents contain instructions for safety and operation of the product. It is essential to read all documentation pertaining to the product and follow all instructions and warnings in said documentation, prior to setup or use, in order to operate the product correctly and avoid damage or injury. Kraken has made every effort to provide clear and accurate information in the documentation, which is provided solely for the user's knowledge. While thought to be accurate, the information in this document is provided strictly "as is" and Kraken will not be held responsible for issues arising from typographical errors or user's interpretation of the language used in this documentation that is different from that intended by Kraken. Kraken reserves the right to revise this document and make changes from time to time without obligation to notify any person of such revisions or changes. In no event shall Kraken, its employees or authorized agents be liable for any damages or losses, direct or indirect, arising from the use of any technical or operational information contained in this document.

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Notices and Warnings

It is important to be aware that there may be warnings and notices throughout this and any other documents included in this package.

Indicates a potential hazard that may cause injury or caution that may cause damage to equipment.

Indicates a general note.

Glossary of Symbols

 Warning - Risk of Damage or Personal Injury

 Warning - Electrical Shock Hazard

 Warning - Fire Hazard

 Warning - Corrosive Substance

 Warning - Toxic Substance

 Warning - Explosive Hazard

 Wear eye protection

 Wear foot protection

 Wear head protection

 Wear personal flotation device

Important Safety Information

Read the following information before first use.

- You must have knowledge of batteries and electrical systems to work with the batteries.
- The warnings, cautions, and instructions in this manual cannot cover all possible conditions or situations that could occur.
- Use caution when using Kraken batteries.
- Be aware of the environment when using Kraken batteries.
- Contact Kraken if you suspect damaged batteries or cell.
- Always follow the recommended cable and connector handling instructions. These instructions can be found in *SeaPower-D002- CONNECTOR AND CABLE HANDLING GUIDE*. Failure to do so can lead to connector or cable failure or unforeseen performance issues with the system.

Wear the appropriate personal protective equipment when handling the batteries.


Wear eye protection


Wear foot protection


Wear protective gloves


Wear head protection


Wear safety harness


Wear personal flotation device


Wear respiratory protection

Warning - Corrosive Substance

- Damaged cells can be contaminated with a residue that is irritating to eyes, skin, and mucous membranes. If you must handle damaged cells, wear protective gloves.
- If there is a fire near a battery, wear a “Self-Contained Breathing Apparatus” (SCBA).
- Extinguish battery fires with a class D fire extinguisher.

Warning – Risk Of Personal Injury

- Do not use damaged cells or batteries. They can cause fire or produce toxic/corrosive smoke and gas.
- Do not drop the battery. If a battery drops and breaks, the lithium cells should be treated with care. Damaged cells can cause heat, smoke, or ignition of the battery.
- When inspecting the battery, if you notice any odor, heating, discoloration, deformation, or any other change, take the battery out of the equipment or charger. Do not use the battery.
- Do not put the battery in an oven or any device that causes heat. Sudden heat can damage the battery seal and cause it to heat, smoke, or ignite.

Warning – Electrical Shock Hazard

- Do not short out the lithium cells or expose them to water.
- Do not force any probe, wire, instrument, or hardware into the battery connectors, battery housing, or silicone pouch.

Warning – Fire Hazard

- Do not expose lithium cells to water. This can cause a fire.
- Keep all burnable materials away from the battery.
- Keep sand, water, and a fire extinguisher close to the system to fight fire. Obey local fire regulations.

Warning – Toxic Substance

- Do not expose the lithium polymer cell material to water.
- Do not overcharge/discharge the battery.
- Do not expose the battery to higher than 60 °C ambient temperature.
- Do not charge battery when the ambient temperature is less than 0 °C or higher than 45 °C.
- Do not use damaged cells or batteries.
- In a fire situation, lithium polymer cells emit irritating and/or toxic fumes. If there is a fire, wear a “Self-Contained Breathing Apparatus” (SCBA) and protective clothing.

Warning – Explosive Hazard

- Do not improperly connect or disconnect battery cables. This can result in an explosion and cause serious injury or death. When removing the battery, always sconnect the communication cable first. When reinstalling the battery, always connect the communication cable last.

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1 BM513V45-2 Overview

The SeaPower™ BM513V45-2 battery from Kraken Power is a pressure tolerant, high capacity, high energy density, lithium ion-based battery with an integrated battery management system (BMS). The technology uses proprietary silicone potting techniques which produce pressure tolerant components without the need for oil compensators or additional compensating liquids.

This document details the hardware interface requirements for SeaPower™ BM513V45-2, including all electrical and mechanical interfaces.

Figure 1: BM513V45-2 with dummy plugs for use in water

Always ship Kraken products in the boxes and shipping materials provided by Kraken.

2 Mechanical Specifications

The battery unit contains an exoskeletal frame made of carbon fiber. This frame is the mechanical structure that supports installation into the host system. Within this mechanical frame there is a silicone pouch containing the battery cells as well as the internal electronics.

Table 1 describes the mechanical specifications of the BM513V45-2 battery unit.

Do not attempt to access the internal structure or components of the battery unit.

Table 1: BM513V45-2 Mechanical Specifications

Specification	Value
Part Number	BM513V45-2
Battery Unit	1 QTY
Mass (in air)	161 kg
Displacement	85 L
Length	1425 mm
Height	265 mm
Width	249 mm
External Housing	Carbon fiber
Internal Housing	Silicone
Compensating Fluid	Silicone
Hardware	316 SS

Figure 2 shows the side view of a BM513V45-2 battery unit, along with the characteristic dimensions.

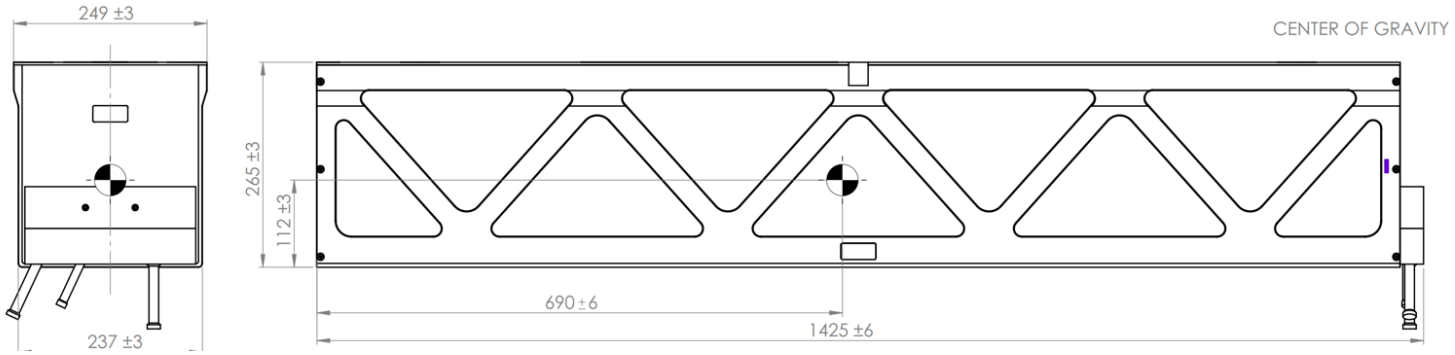


Figure 2: Characteristic Dimension of BM513V45-2 Battery Unit

3 Common Firmware Specifications

Communication with the battery can be done with a serial terminal program using the settings shown in **Table 2**. See document *FW-ICD-001 Interface Control Document* document for full information.

Table 2: Serial Settings

Setting	Value
Serial Com	RS485
Baud Rate	9600
Data Bits	8
Parity	none
Stop Bits	1

4 Voltage Specifications

Follow the electrical limits to avoid damage or reduced performance of a battery unit or the battery system.

4.1 Minimum and Maximum Voltage Levels

The batteries are equipped with multiple protective devices, such as firmware restrictions that cause an error, and inhibited discharge. Additionally, there is hardware-implemented deep discharge protection (DDP) that switches the battery off at low level voltage to extend the duration before the battery reaches a critical cell voltage level. Battery-related voltage parameters are listed in **Table 3**.

Table 3: Battery Related Voltage Parameters

Specification	Voltage (V)
Minimum cell voltage firmware determined	3.0
Maximum cell voltage firmware determined	4.16
Critical minimum cell voltage	2.7
Critical maximum cell voltage	4.2
Minimum battery voltage without DDP	≈36
Maximum battery voltage without DDP	≈49.9
Minimum battery voltage with DDP	≈37.5
Maximum battery voltage with DDP	≈49.9
Nominal battery voltage	≈45

4.2 Deep Discharge Protection (DDP) Related Functions

Deep discharge protection (DDP) delays the deep discharge process of the battery by safety circuitry.

When the battery has reached the DDP-VOLTAGE level it will switch off automatically. However, the following functions enable the user to switch the battery on and charge it to exceed the DDP-VOLTAGE level.

4.2.1 OneShot Function

The OneShot function switches the battery on for approximately 30 seconds to initiate additional actions to keep the battery alive. OneShot is always triggered when switching the battery on and can be interrupted immediately by switching the battery off.

4.2.2 KeepAlive Function

The KeepAlive function is a firmware feature that enables the battery to operate by bypassing the DDP circuit. This feature becomes active only when the battery is powered up. The KeepAlive function works in conjunction with the OneShot function, allowing the user to power up the battery for charging after it reaches the DDP threshold.

4.2.3 Recovery Function

The Recovery function is only available via a determined/assembled cable that supplies the BMS with voltage to recover the battery. If the recovery voltage is removed when the battery voltage level is still below the DDP voltage, the battery switches off immediately.

4.3 Relationship between DDP and State of Charge (SOC)

The DDP is designed to switch the battery off at low State of Charge (SOC). This expands the time when the critical cell voltage level is reached. The DDP has a negligible effect on the total capacity of the battery. This ensures that the specifications will still be met.

4.4 Cell Balancing Specifications

Balancing is an action that brings the cells to the same voltage level. Each cell behaves differently and the cell voltages will eventually drift apart. This spread can cause a reduction in capacity, as it is not possible to charge single cells.

If the highest cell reaches its maximum (firmware determined) voltage, the charge process must be stopped to prevent this cell from being damaged. as a result, the lower cells do not reach their maximum voltage.

Balancing equalizes the voltage levels such that the voltage spread is reduced, and all cells are chargeable for longer. The spread between the highest cell voltage and the lowest cell voltage is called cell difference.

Balancing the batteries is required when, in the cell voltage range between 3.7 and 4.0 V, the cell difference exceeds 30 mV.

Batteries should be balanced when the lowest cell voltage surpasses at least 3.7 V and the highest voltage is below 4.0 V.

It is mandatory to balance the battery in water and for the water temperature to not exceed 25 °C or the heat dissipation during balancing can cause critical damage to the battery.

5 Current Specifications

Follow the electrical limits to avoid damage to or reduced performance of a battery unit or the battery system.

Table 4 shows the maximum current ratings in water and in air per battery. The water temperature must not exceed 25 °C. Otherwise the environmental situation has to be assumed as “in air”.

Table 4: Battery-Related Current Values

Specification	Current [A]
Maximum discharge current in water	28
Maximum charge current in water	28
Maximum discharge current in air	5
Maximum charge current in air	5
Maximum charge current in air BMS current consumption (Hotel Load)	0.09
Current Consumption in Off State	2.12 mA See table 7.

6 Power and Energy Specifications

Follow the electrical limits to avoid damage to or reduced performance of a battery unit or the battery system.

Table 5 shows the battery related power and energy values.

Table 5: Battery Related Power/Energy Values

Specification	Value
Min. Power (@V_min, @I_max)	1008 W
Nom. Power (@V_nom, @I_max)	1260 W
Max. Power (@V_max, @I_max)	1390 W
Hotel Load	≈2.3 W
Total Energy	23 kWh
Capacity[1]	513 Ah
Charge/Discharge Duration @ maximum Current	18h 15 min

[1]Test conditions: 25±3 °C; 5A Load Current; 20 mV Cell Difference @ SoC 50%

6.1 Capacity Impacts

Unbalanced battery cells have an enormous impact on the capacity of a battery, as well as aging and the charge state itself.

To reach the highest possible capacity refer to the balance conditions in **4.4 Cell Balancing Specifications** and charge the batteries completely.

7 Temperature Criteria

Table 6 shows the temperature criteria of the battery.

Table 6: Temperature Criteria

Specification	Value
Minimum Device Temperature	Refer to Table 8
Maximum Device Temperature	Refer to Table 8
Max Battery Temperature for Heater	30 °C
Battery Temperature Range Charge	[10 … 45] °C
Battery Temperature Range Discharge	[-10 … 45] °C

7.1 Heater

If the battery temperature becomes too low it will not charge, and will require a heater to raise the temperature of the battery. The heater requires the use of an external power supply, such as the Kraken charger, to operate.

8 Storage Specifications

This section describes general storage conditions. Storage conditions for battery transit are stricter than those described here, especially regarding the State of Charge. Please refer to the document *SeaPower-D004 Battery Shipment and Storage Guide* for information on storage conditions required for battery transit.

8.1 Applications of Dummy Plugs

It is always necessary to cover the bulkhead connectors with dummy plugs to avoid corrosion and ensure safe use. This prevents the battery from damage and inhibits injuries. The bulkheads should be covered with grease for better connectivity and to detain water intrusion. See document *SeaPower D002 Connector and Cable Handling Guide*.

For **in-water** applications, use only **dummy plugs or wet connectors** from PowerCommRail. For **transit in transport case** use the connector cover shown in **Figure 3**.

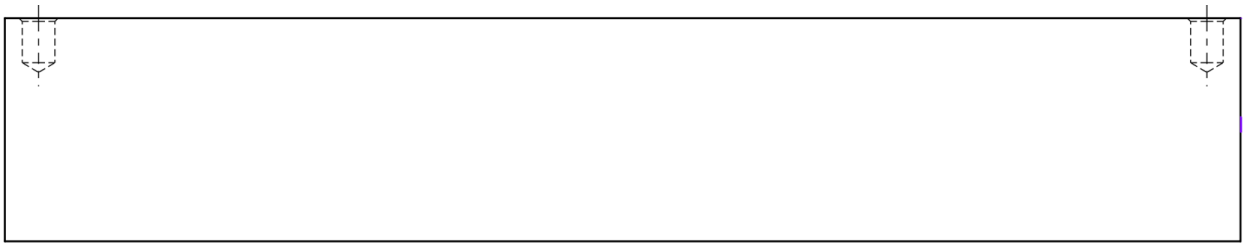


Figure 3: Connector Block SYN_0103

8.2 Battery Storage Life Cycle

Table 7 describes the storage and transport specifications for the battery/battery systems. “SOC” stands for “state of charge” of the battery. Follow the limits to prevent deep discharge.

Table 7: Storage Specifications

Description	Value
Current Consumption in Off State	2.12 mA
Total Capacity (100% SOC)	513 Ah
Capacity per 1% SOC	5.13 Ah
Maximum SOC in shipment	20%

Description	Value
Battery selfdischarge (off state): SOC loss per day	0.01 %/day
Battery selfdischarge (off state): Amount of time to lose 1% SOC	100 days

8.3 Environmental Specifications

Table 8 describes the environmental specifications for the battery/battery system. Follow the limits for the best battery performance.

Table 8: BM513V45-2 Environmental Specifications

Specification	Value	Comment
Ambient Pressure	[0.5…600] bar	N/A
Storage	[-20…25] °C	Refer to Table 7
	[25…40] °C	Continuous 3 month and refer to Table 7
	[40…60] °C	Continuous 1 week

9 Electrical Interface

The electrical interface is accessed through three SubConn rubber molded connectors, as demonstrated in **Figure 4**.

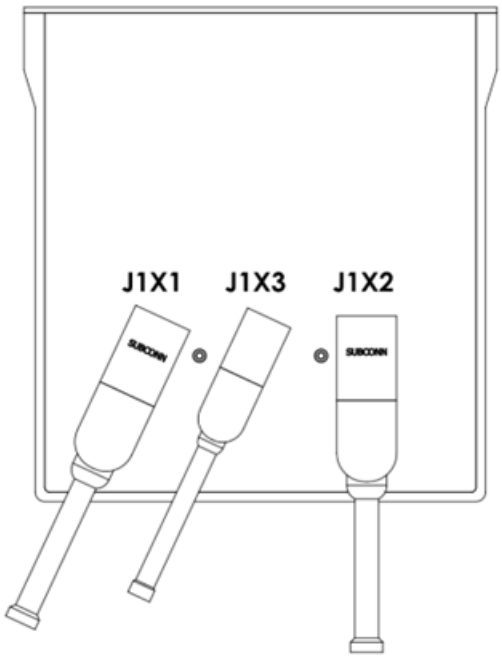


Figure 4: Connector Front View

Use **Table 9**, **Table 10**, and **Table 11** as references for the power connector pinouts.

Table 9: Power Connector Pinout J1X1

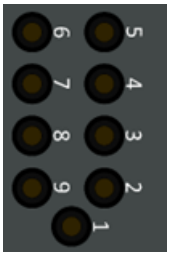
Connector Label	Connector Part Number/Diagram	Description	Pin	Signal
J1X1	LPBH9F 	POWER 1	1	V+
			2	V+
			3	V+
			4	V+
			5	V-
			6	V-
			7	V-
			8	V-
			9	RESERVED

Table 10: Power Connector Pinout J1X2

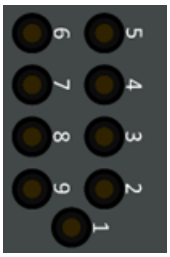
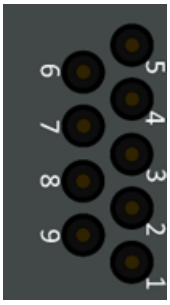
Connector Label	Connector Part Number/Diagram	Description	Pin	Signal
J1X2	LPBH9F 	POWER 2	1	V+
			2	V+
			3	V+
			4	V+
			5	V-
			6	V-
			7	V-
			8	V-
			9	RESERVED

Table 11: Communication Connector J1X3

Connector Label	Connector Part Number/Diagram	Description	Pin	Signal
J1X3	MCLPBH9F 	COM	1	RS485-
			2	RS485+
			3	BMU ON
			4	LOAD ON
			5	MAIN_SW_RET
			6	RESERVED
			7	RESERVED
			8	RESERVED
			9	RESERVED

10 Mechanical Interface

Install the battery units so they are not subject to excessive movement or damage. The carbon fiber housing can be used to locate the battery unit within the host system.

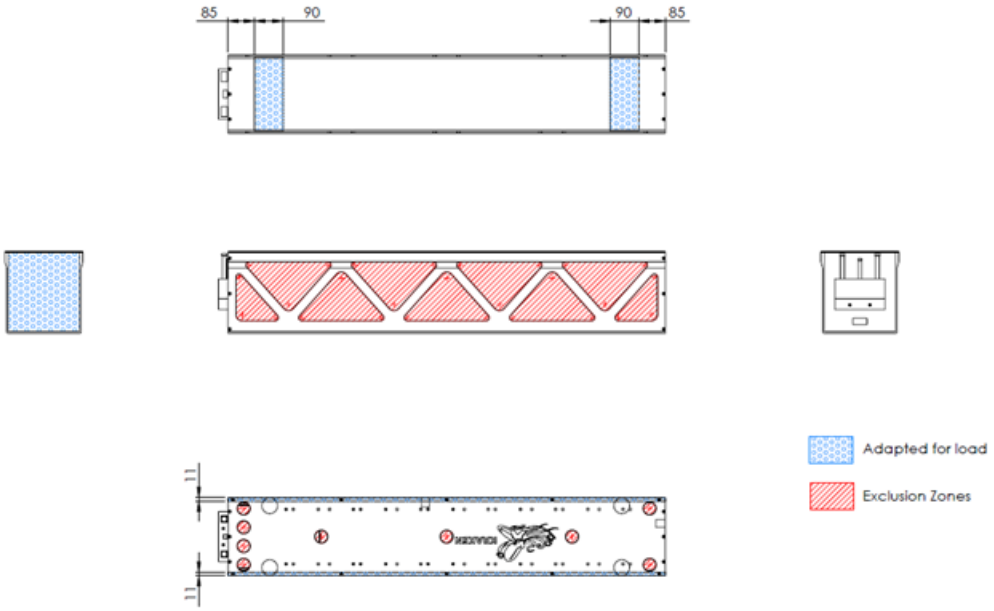


Figure 5: Mechanical Zones

- Use the blue (adapted for load) areas for mechanical location and fixation.
- Protect the red (exclusion zone) areas from impact by foreign objects. These areas include a reinforced screening to help prevent puncture of the integral silicone skin, but they should still be protected during the installation.

11 Arrangement of Equipment

Use the battery units independently or in parallel/series with other battery units of the same kind.

If used independently, mount the battery in the vehicle and connect directly to the host system via wet connectors. Typically, water-blocked underwater cables are used to connect the battery unit and the host system. This allows an efficient placement of the battery unit within the host system.

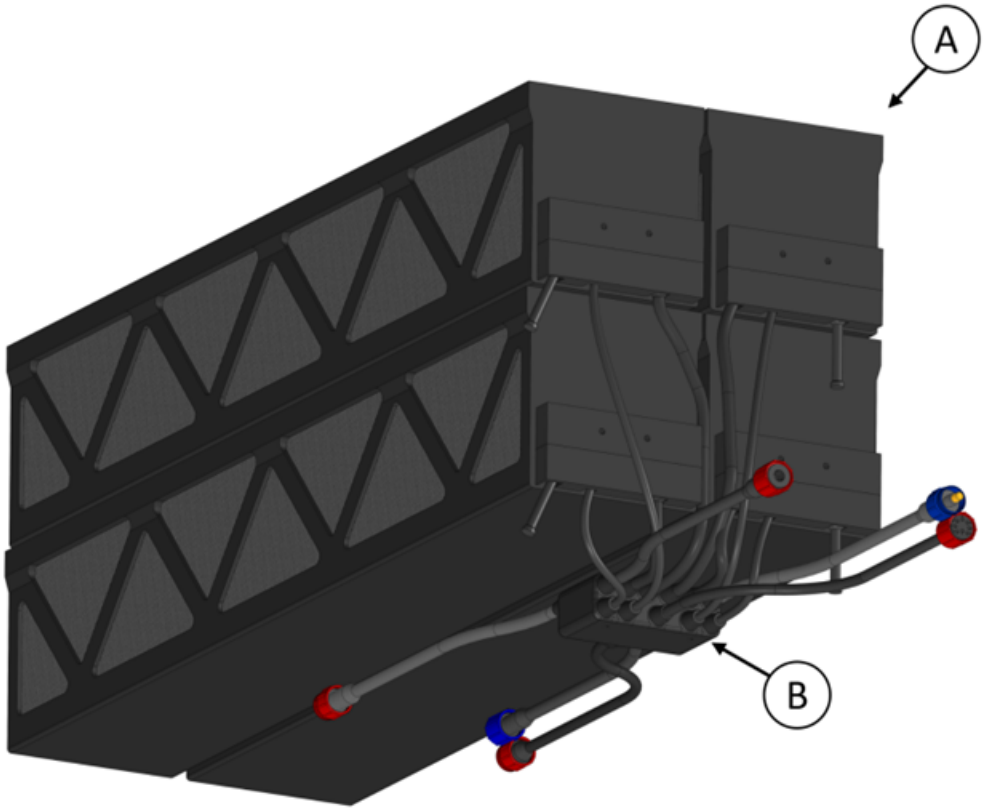


Figure 6: Multiple Battery Unit System Components

The following items are labeled in **Figure 6** above:

A) BM513V45-2 battery unit

B) Customer-specific power-com rail junction assembly

Up to two battery units may be stacked on top of each other as shown in **Figure 7**.

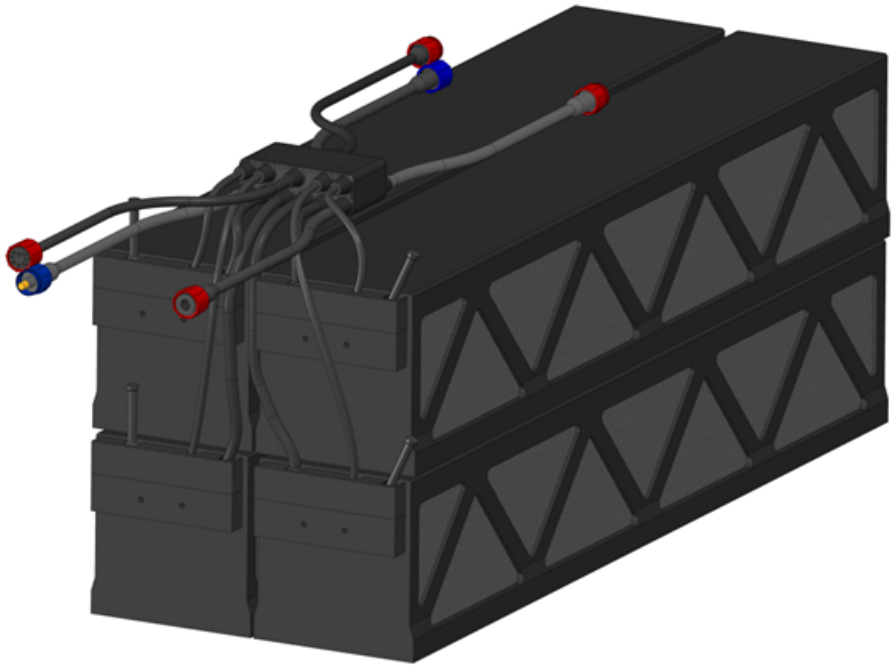


Figure 7: Multiple Unit Installation

In this arrangement, the battery units must be stacked with one unit's bottom surface resting on the other unit's lid. This arrangement ensures that both battery units are adequately supported. To ensure the security of the arrangement, install a minimum of 3 mm NBR rubber stripping between the units at the location of the clamping belts.

Any arrangement outside of this specification must be agreed to in writing with Kraken.

Do not stack more than two units vertically. For specific details on multi-unit installation, see the relevant system manual.

12 Miscellaneous

12.1 Miscellaneous Specifications

12.1.1 Cell Specifications

Table 12: Miscellaneous Cell Specifications

Specification	Value
Base Cell Chemistry	Lithium Cobalt Manganese Nickel Oxide
Battery Unit ELC (Equivalent Lithium Content)	1523 g
Cell Arrangement	9P 12S
Cycle Life @ 90% DOD[1]	≥6000 Cycles

[1]Test conditions: 25±3 °C, 70% remaining capacity.

Table 13: Miscellaneous Unit Specifications

Specification	Value
Number of Cells in Battery Unit	108
Safety Device (Fuse)	50 A

12.2 Swollen Batteries in Charge

It is possible that the batteries swell when being charged. This is a physical effect and not critical behavior.

12.3 Battery Behaviour in Battery System

When batteries are used in a system certain side effects are possible which won't occur in single unit application. Causes and results are:

12.3.1 Different Voltage Level

The greater the voltage difference the more unequal the current distribution becomes. This can result in the error described in **section 12.3.2 One Battery Stops Power Consumption**.

12.3.2 One Battery Stops Power Consumption

A battery can stop power consumption unexpectedly if it reaches the voltage target, detects an error current, or if other errors are detected. When this occurs, the current consumed by the stopped battery is distributed to the remaining batteries in the system. For this reason, it is recommended to choose the maximum current of a system based on the maximum current that can be supplied by **one less** than the total number of batteries in the system.

Example:

A system consists of 4 batteries, all in discharge mode and connected to a load that consumes 100 A. The load will now pull approximately **25 A** from every battery when all batteries have the same voltage level.

One of the batteries in the system stops discharging (for example the critical cell voltage is reached). This will cause the 100 to distribute to the three remaining batteries in the system causing each battery to now supply approximately **34 A** which exceeds the maximum battery current of 28 A, and resulting in the remaining three batteries switching off consecutively.