



Battery Technology Overview

SeaPower™ 57-Ah Battery Documentation

Document Version History

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Version	Date	Author	Reviewer	Change
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1 Introduction

1.1 Introduction

This document serves as a centralized technical overview for Kraken Robotics' SeaPower™ Battery System, offering a foundational platform for understanding its design, system architecture, features, and operational parameters. It is intended to serve as a launchpad for access to more detailed information across the broader SeaPower documentation suite in order to help users efficiently navigate the battery's design framework.

SeaPower Batteries address three key concerns for subsea applications: extending mission time, reducing charging turnaround, and increasing operational reliability. Built around a pressure-tolerant architecture, SeaPower combines advanced lithium-ion cells, an intelligent battery management system (BMS), and ruggedized modular construction to enable reliable deployment in demanding marine environments. The system is designed with scalability, serviceability, and safety in mind, supporting a wide range of use cases from autonomous underwater vehicles (AUVs) to subsea infrastructure.

1.2 Battery Model Key

Battery models in SeaPower documentation are identified using a structured alphanumeric naming convention that conveys its key specifications.

Typically, SeaPower battery models use the following format **BMXXXVYYY-Z**:

- **BM** stands for “Battery Module”
- **XXX** indicates the capacity (Ah) of the battery model.
- **V** stands for voltage.
- **YYY** denotes the nominal voltage value of the model.
- **Z** indicates the configuration version number.

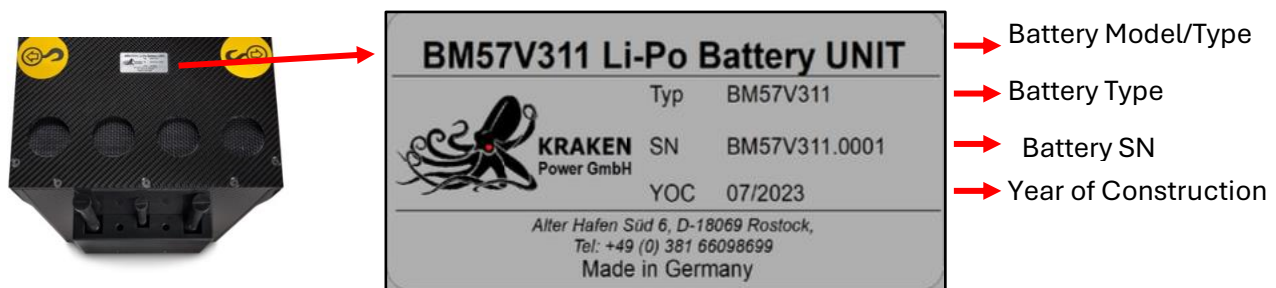


Figure 1 - Battery ID Plaque

2 Battery Design Overview

SeaPower Pressure-Tolerant Potted Batteries (PTPB) leverage a proprietary silicone-based potting to withstand full ocean depth without the need for rigid housings, pressure compensation oil, or mechanical seals. This eliminates weight, failure points, and maintenance overhead that is common in traditional subsea battery designs.

Traditional subsea batteries fall into two categories:

- I. **Pressure-Housed Batteries**, which use thick-walled metal housings to isolate electronics at 1 atm.
- II. **Pressure Balanced Oil-Filled (PBOF) Batteries**, which relies on thin-walled enclosures filled with dielectric oil that is then pressure-compensated via a bladder and spring assembly.

Both approaches introduce significant drawbacks: pressure-housed designs are bulky and heavy; PBOF systems are complex, maintenance-intensive, and prone to seal failures under repeated dives and high-pressure cycling.

Kraken PTPB technology replaces pressure-housed or oil-filled enclosures with a state-of-the-art, pressure-equalizing architecture. This fully solid-state approach enables compact, robust, and maintenance-free energy storage that is ideally suited to meet the demanding requirements of subsea energy storage where reliability, safety, and modular integration are essential.

The following sections outline all major hardware components of the battery—highlighting how each element of the battery’s design contributes to its overall reliability:

- a. Frame
- b. Potting
- c. Battery Cell Modules
- d. Battery Management System (BMS)
- e. Subsea Connectors



Figure 2 - SeaPower Battery Overview

2.1 Frame

The SeaPower carbon fiber frame provides lightweight structural support and mechanical protection for the battery module. It does not contribute to the environmental sealing or depth rating of the system; these functions are fully achieved through the encapsulating potting material.

The frame serves as the outermost structural layer and performs several critical functions:

- Maintains the dimensional integrity and alignment of the potted battery components
- Provides defined mechanical lift locations for handling and deployment
- Enables secure vertical stacking of up to two battery modules
- Enhances resistance to mechanical shock and impact during transport and operation

The frame is not a sealed enclosure. As shown in the accompanying image, the lateral sides are open, and additional through-holes are incorporated along the front of the lid. This design provides several functional advantages:

- **Hydrostatic pressure equalization** across potted surfaces during deep-sea operations.
- **Weight reduction** without compromising structural integrity.
- **Passive pressure** relief in the event of internal gas generation or overpressure.
- **Improved thermal management**, allowing ambient water to cool the battery when required.



Figure 3 - SeaPower Battery Carbon Fiber Frame

2.2 Potting

Kraken has developed a proprietary silicone-based potting process tailored for subsea battery systems. The compound is engineered to fulfill several critical performance functions:

- **Hydrostatic Pressure Equalization:** The potting material transmits external pressure uniformly throughout the encapsulated volume, allowing the battery to operate at depth without exposing internal components to differential stresses.
- **Vibration and Shock Dampening:** Its elastomeric properties stabilize all cells and electronics against mechanical shock and vibration, enhancing system reliability in dynamic environments.
- **Thermal Insulation and Propagation Delay:** With low thermal conductivity, the potting compound acts as a passive thermal barrier, reducing external heat transfer and contributing to internal temperature stability. In fault conditions, it also slows thermal propagation between components, buying critical time for system-level responses. Additional propagation control measures—including **fire-resistant barriers between cells and strategic spacing between cell packs**—are implemented at the module level.
- **Hermetic Environmental Protection:** Once cured, the compound forms a sealed internal structure that prevents any ingress of water or moisture, effectively isolating the electronics and cells from the subsea environment.
- **Buoyancy-Neutral Behavior:** The cured potting compound has a density of 1.1 to 1.2 g/cm³, making it approximately neutrally buoyant in seawater. Consequently, it adds minimal in-water weight to the battery system.
- **Electrical Isolation:** The cured silicone provides high dielectric strength, fully encapsulating internal conductors and preventing the formation of unintended conductive paths. This ensures insulation between high-voltage components, eliminates the risk of leakage currents in seawater, and maintains safe operation even under high external pressure.

The potting is applied as a liquid and fills the entire internal volume, flowing around all components. It then cures into a solid, flexible, form-fitting mass that conforms to the geometry of the internal frame, ensuring consistent structural and environmental protection.



Figure 4 - SeaPower Battery Potted

2.3 Cell Module

2.3.1 Cell

SeaPower batteries use lithium-ion pouch cells sourced from high-reliability suppliers with established deployment in the automotive industry. These cells deliver excellent energy density, long cycle life, and a strong safety record, forming the core building block of all SeaPower battery systems.

The cell type and supplier is qualified by Kraken for use in 6000-meter pressure-tolerant subsea environments, ensuring mechanical robustness and electrochemical stability under extreme external pressure. This qualification is essential for reliable long-term performance in deepwater applications.

2.3.2 Cell Modules

Cells are assembled into **cell modules**, which group individual cells in **series or parallel configurations** depending on the specific voltage and capacity requirements of the battery model. Each block integrates **fire-resistant spacers** between cells to mitigate thermal propagation risk. Electrical connections between battery tabs are made using either **laser welding** or **screw terminals**, depending on the generation of the block. This design ensures robust electrical integrity and mechanical stability.

Cell modules are combined into a **cell pack** by connecting them in **series or parallel**, depending on system-level requirements. Power is routed through **high-current copper busbars** to minimize electrical resistance, reduce cabling complexity, and improve thermal performance. Additional **fire-resistant barriers** are integrated between modules to further contain potential fault propagation.

A **SeaPower cell module** is configured to deliver a specific share of the system's total energy and voltage and acts as a **standardized electrical and structural unit** in the complete battery assembly composed of one with:

- A cell monitoring unit for monitoring voltage and temperature
- Redundant channel ISO SPI communication
- Balancing electronics to maintain cell voltage uniformity
- Heaters (in applicable models) to enable pre-heating of the cells for cold environment charging



Figure 5 - Cell Module

2.4 Battery Management System

Kraken’s advanced Battery Management System (BMS) is the central intelligence behind the SeaPower battery, providing comprehensive control, monitoring, and protection to ensure safe, reliable, and high-performance operation in demanding subsea environments.

The BMS governs all operational states of the battery—**OFF**, **STANDBY**, **ERROR**, **CHARGE**, and **DISCHARGE**—through a robust state machine embedded with safety logic. This autonomous architecture enables real-time response to fault conditions, minimizing risk and enhancing system resilience.

The BMS supports **passive cell balancing**, (via passive balancing board on each cell module) which can be manually initiated by the user through a command interface. This function helps equalize the state of charge across all cells and modules by dissipating excess energy as heat from higher-voltage cells. While not continuously active, periodic balancing improves overall capacity utilization, extends cycle life, and helps reduce long-term degradation.

Designed for scalability, the BMS allows **multiple battery modules to operate in parallel or series**, supporting megawatt-hour-scale energy systems. It seamlessly handles batteries at different states of charge without requiring external isolation or complex integration, enabling flexible deployment scenarios.

Communication is supported via **RS485 interfaces**, enabling integration with topside controllers, mission planning systems, and vehicle health monitoring platforms. This connectivity supports remote diagnostics, telemetry, and full external control.

2.4.1 Key Protection and Monitoring Features:

- Over-discharge protection
- Over-charge protection
- Over-current protection
- Thermal protection
- Short-circuit protection
- Real-time monitoring



Figure 6 - Battery Management System

2.5 Subsea Connectors

SeaPower batteries are equipped with **SubConn® connectors**, which are marine-grade, rubber-molded connectors specifically engineered for harsh subsea environments. These connectors are designed to ensure reliable electrical connections under extreme pressure, temperature, and vibration conditions commonly encountered in underwater operations.

Each battery features **two high-current power connectors** and **one communication connector**:

- The **power connectors** are fully redundant, each carrying both positive and negative terminals to support high-current delivery with built-in electrical failover.
- The **communication connector** provides an RS485 interface for BMS telemetry, control signals, and integration with topside or onboard systems.

All connectors feature a **9-pin layout** and are **IP-rated for continuous underwater operation**. They incorporate mechanical keying and pin configurations to prevent incorrect mating, reverse polarity, or accidental damage during connection.

For enhanced durability and operational integrity, SubConn connectors are **mechanically secured using locking collars or threaded couplings**, ensuring long-term performance in vibration-prone and high-pressure subsea environments. Once connected, a hard cover is screwed into place to prevent accidental disconnection or contact with the connectors.

Connector pin-out, type and orientation are customizable to suit specific integration needs. Please refer to the **model specific Interface Control Document (ICD)** for detailed connector specifications and configuration options.

This rugged connector architecture ensures seamless integration, operational safety, and long service life in demanding underwater applications.



Figure 7 - SeaPower Batteries Connectors

2.6 Shipment & Storage

SeaPower lithium-ion battery systems must be shipped and stored in accordance with international dangerous goods regulations due to their high energy density and chemical composition. Improper handling—such as non-compliant packaging, unprotected terminals, or exposure to unsuitable environments—can result in mechanical damage, electrolyte leakage, thermal runaway, or regulatory violations.

To ensure operational safety and regulatory compliance, the following technical protocols apply equally to shipping and storage:

- **State of Charge (SOC):** Batteries must be maintained at $\leq 20\%$ SOC during shipping and storage in order to mitigate thermal risk or fire during storage. To prevent over-discharge, the battery must be turned completely off and disconnected from any load in addition to meeting UN38.3 and IATA DGR requirements.
- **Terminal Isolation:** All connectors must be fitted with dummy plugs coated with dielectric grease to prevent corrosion, arcing, or accidental contact.
- **Environmental Conditions:** Batteries shall be stored and transported in a cool, dry, and ventilated environment, away from sources of heat, ignition, or corrosive atmospheres. Temperature excursions beyond recommended limits must be avoided.
- **Packaging & Containment:** SeaPower batteries uses **BAM-certified (German Federal Institute for Materials Research and Testing)** transport cases for shipping internationally. These enclosures incorporate shock absorption and non-conductive, non-combustible thermal insulation to protect against mechanical impact, propagation events, and external fire exposure.
- **Quiescent Current Monitoring:** In the powered-down state, batteries draw approximately 2.1 mA. SOC should be periodically verified during extended storage to prevent over-discharge.
- **Regulatory Classification:** SeaPower batteries are currently shipped under UN38.3 or UN38.3 Prototype Provision (≤ 100 units/year), which mandates specific labeling, documentation, and handling by trained personnel under DGR 3.9.2.6.



Figure 8 - Battery Shipping and Storage

3 Charging

SeaPower batteries are engineered for high-performance energy delivery and safe, controlled charging in demanding operational environments. Charging is managed externally and requires the battery to be placed into a designated “charge state” before it can accept current. This charging state is initiated via the RS485 communication interface.

Each battery is equipped with an integrated Battery Management System (BMS) that continuously monitors critical parameters such as voltage, current, temperature, and state of charge (SoC). These metrics are transmitted to the external charge controller or host system over the RS485 bus. The external charger, informed by this data and predefined battery specifications, determines the appropriate power output—namely, the target voltage and current levels.

It is important to note that the battery does not compute or dictate charger output values, as it lacks system-wide awareness of the broader power configuration (e.g., parallel battery arrays or shared power buses). Instead, the BMS exercises autonomous oversight over its own cell stack during charging: it issues warnings, actively monitors health indicators, and exits the charge state as necessary to ensure operational safety and prevent damage.

To ensure safe and effective charging:

- The battery must be explicitly commanded into *charge state* via the designated protocol.
- Use Kraken-approved chargers.
- Charging must occur within the specified voltage, current, and temperature ranges provided in the product datasheet.
- Charger-to-battery communication must be established and maintained to allow real-time monitoring and charge state control.

Charging outside of defined parameters can lead to thermal protection triggers, degraded battery performance, or damage.



Figure 9 - SeaPower Battery Charging Set-up

4 Battery System Integration

Kraken batteries are engineered for seamless scalability into larger battery systems of exceeding 1 MWh. Each unit features an integrated BMS with a directional diode that prevents in-rush current when connecting batteries at different states of charge—enabling safe parallel or series configurations without pre-balancing.

To support modular system integration, Kraken offers subsea-rated, potted junction boxes known as Power-Communication Rails (PCRs). PCRs consolidate both power and communication lines and support connection of up to six batteries per unit—either for charging or for interfacing with the host system. Multiple PCRs can be interconnected to expand system capacity.



Figure 10 - Power Communication Rail (PCR)

For higher-power applications, Kraken provides an advanced power management bottle capable of consolidating up to 32 batteries.

These units support:

- Bank-level on/off switching
- Fuse protection per sub-bank
- No-voltage interlock safety features
- Independent isolation and control of sub-battery groups



Figure 11 - XL-PCR

5 Handling & Installation

Kraken batteries must be handled using designated lifting locations or certified lifting clamps aligned with the structural load paths of the battery frame. Under no circumstances should lifting be performed via cables, connectors, or non-load-bearing components.



Figure 12 - Lifting location

Batteries may be stacked up to two units high without additional structural support, provided they are placed on a stable, level surface and secured to prevent movement during transport or operation.

Installation methods are application-specific and typically defined by the system integrator. A common approach involves frame-mounted clamps or brackets that interface with the battery's structural features.

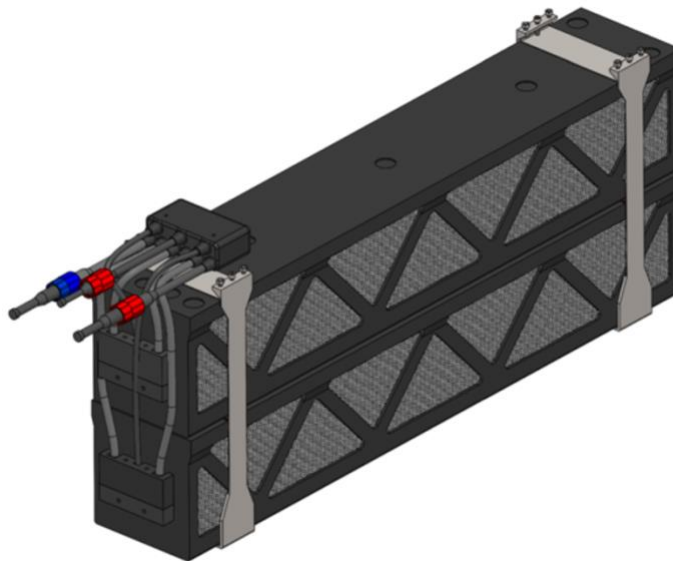


Figure 13 - Battery System Assembly

For detailed mounting dimensions and load data, refer to the model specific battery ICD for Handling & Installation.

6 Manufacturing & Testing

SeaPower batteries are manufactured through a tightly controlled, proprietary process designed for maximum performance, safety, and reliability in demanding subsea environments. Robust quality protocols are applied throughout - from component-level verification to final system assembly. All Kraken batteries follow ISO-certified quality standards. Depth-rated models are pressure-tested to their maximum design rating of up to 660 bar for 6000 m variants. Every unit undergoes both a **Factory Acceptance Test (FAT)** and **System Integration Test (SIT)** in order to confirm electrical performance, communication, and system integrity before shipment.

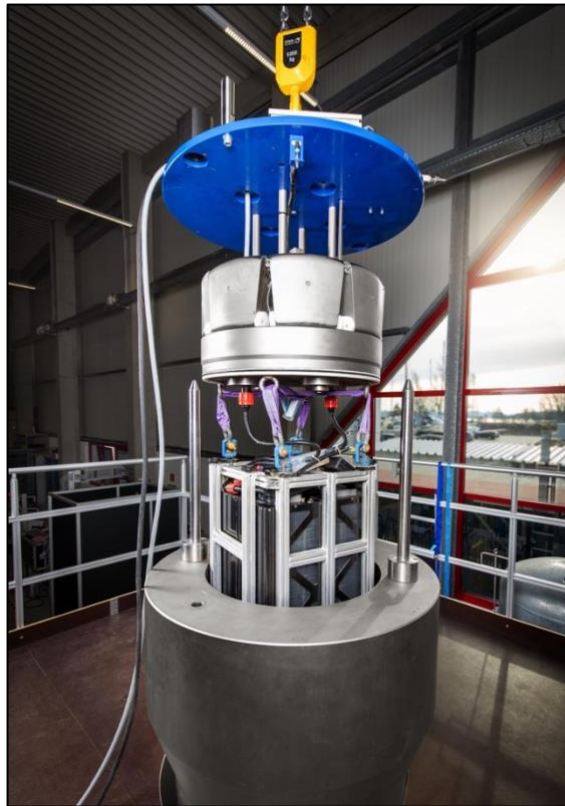


Figure 14 - SeaPower Battery Pressure Testing

7 Safety & Handling

7.1 Safe Handling Principles

All SeaPower batteries must be treated with care, as improper handling, electrical misuse, or mechanical abuse can lead to serious hazards. General users must:

- Follow all guidance found in the interface control document (ICD) and manuals.
- Use only approved chargers and connections.
- Monitor the battery for signs of swelling, unusual heat, discoloration, or odor.
- Avoid any physical shock (e.g., dropping the battery) or exposure to water without protection.
- Never open the battery housing or bypass the BMS.

7.2 Chemical Risks & Off-Gassing

Under normal operating conditions, lithium-ion batteries function safely and do not release harmful substances. However, if the battery is misused or damaged, harmful gasses could be released. These gases can be corrosive and hazardous even at low concentrations. In such cases, personnel should avoid inhaling fumes and wear appropriate personal protective equipment (PPE) including gloves, respirators rated for chemical exposure, and protective under-clothing. Proper ventilation and cohesive emergency response procedures are essential when a battery is damaged or compromised.

7.3 Fire and Thermal Risk

SeaPower batteries are not inherently flammable but can ignite if exposed to abuse or sustained electrical faults. In the event of a fire, the batteries may emit toxic gases. Fire response protocols emphasize:

- Preserving life and protecting property first.
- Using water to cool the battery and surrounding equipment.
- Avoiding direct firefighting on cells once ignited and allow them to burn in a safe area.
- Wearing appropriate fire-rated PPE and breathing apparatus when responding.

7.4 Operation and Storage Guidelines

Overcharging, undercharging, or operating outside the safe thermal envelope can cause permanent damage or dangerous conditions. Key guidelines include:

- Charging only within the prescribed temperature and voltage range.
- Preventing reverse polarity connections.
- Discharging within safe current and temperature limits.
- Monitoring for abnormal heating or system alerts.

7.5 Emergency Response Overview

In the event of a battery failures such as smoke or overheating, the unit must be allowed to self-extinguish. **DO NOT** attempt to open or handle a compromised battery without full PPE. Perform immediate steps such as:

- Evacuating the area
- Ventilating the space
- Monitoring temperature and structural integrity
- Submerging the battery if safe to do so
- Following Kraken's detailed emergency procedures, especially for failed cells during charging or after vehicle deployment.

SeaPower batteries offer advanced energy capabilities for underwater systems but require an informed and careful emergency response protocol. This overview provides a baseline understanding of best practices and potential hazards, while encouraging users to reference ICD guides for configuration, maintenance, and emergency action. Compliance with Kraken Power's instructions is critical to the safe operation and lifecycle of the entire SeaPower battery system.

8 Next Steps

By summarizing the most critical technical elements, this document serves as a starting point for safe, efficient integration and operation of SeaPower batteries for a wide range of subsea systems.

Next Steps After Reading This Document

After reviewing this overview, users are encouraged to consult the model-specific Interface Control Documents (ICDs), installation guides, and safety manuals referenced throughout. These supporting documents contain detailed specifications, procedures, and compliance requirements needed for implementation, testing, and maintenance. For additional support, contact Kraken Robotics or your designated systems engineer for technical assistance and integration planning.

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9.2 Disclaimer

- Kraken must be consulted regarding the proper **integration, calibration, and configuration** of any Kraken-designed system.
- This document is intended as **supplementary information only**. Any modifications to system integration or configuration must be discussed with Kraken Robotics.
- Failure to operate the product in a **safe and responsible manner** may result in injury, property damage, or product failure.
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