BATTERY SIZING RECOMMENDATIONS

PRODUCT: SEAKEEPER 1, SEAKEEPER 2, SEAKEEPER 3, SEAKEEPER 4

DESCRIPTION

This Technical Bulletin gives an overview of different battery types, their characteristics, and how to size a battery bank for a given DC Seakeeper Installation. For more information on batteries, wiring, and overcurrent protections, please see the ABYC E-10 Storage Batteries, E-11 AC&DC Electrical Systems on Boats, and TE-13 Lithium-Ion Batteries.

GENERAL BATTERY OVERVIEW

Flooded Lead Acid ("Wet Cell"), Gel Cell, Absorbed Glass Mat (AGM), and Lithium-ion batteries are the most common battery chemistries in the marine market. Table 1 shows the typical specifications for each battery type.

Flooded Lead Acid batteries are a common and inexpensive battery found in marine applications. These batteries tend to be the least efficient, require more maintenance, and have a life span of a couple hundred cycles. Seakeeper does not recommend the use of Flooded Lead Acid Batteries due to their efficiency.

Sealed batteries (both Gel Cell and AGM) are more efficient than flooded, are less prone to leakage, and have a cycle span of around 500 cycles. Gel and AGM batteries do come at an increased cost, however, are recommended for use with DC Seakeeper units due to their efficiency and life span.

Lithium-ion batteries are growing in popularity for their power density but have not yet been widely adopted in marine applications. For safe operation, lithium-ion batteries require a battery management system to control their charge/discharge cycles. These batteries have a life span of around 2000 cycles before performance reductions are observed.

Table 1: Characteristics of Battery Chemistries (Information obtained from manufacturers public data).

Battery Metric	Flooded ("Wet Cell")	Gel Cell	AGM (Absorbed Glass Mat)	Lithium-Ion
	Average Ah	Average Ah	Average Ah	Average Ah
Group 27	105	90	97	80
Group 31	117	100	110	100
Group 8D	185	225	249	273
Battery Factor*	70%	80%	80%	80%

**Battery Factor is a measure of efficiency that includes "Deep Cycle" use, low power cutoff, and battery characteristics.*

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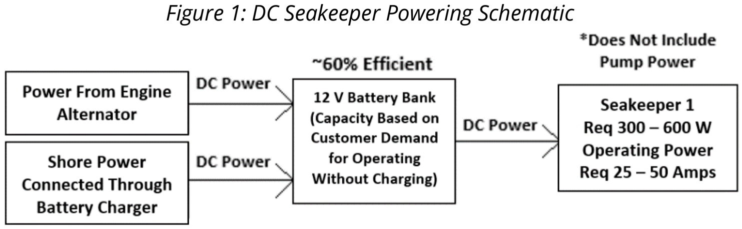
The following factors are to be considered when sizing a Seakeeper battery bank:

1. DC Seakeeper model installed and the associated spool-up and operating power requirements. (Shown in table 2)
2. Operation of the Seakeeper system
    a. Spool-up on shore power
    b. Spool-up on battery power
    c. Onboard charging capacity
3. Desired Seakeeper runtime
4. Battery Configuration
    a. Dedicated Seakeeper Battery Bank: Seakeeper high current, low current, and seawater are the only loads.
    b. Integrated House Battery Bank: Seakeeper is connected to a common bank with other non-Seakeeper house loads.
5. Desired battery group size and chemistry

These factors affect the power demand and battery capacity that is required for a given installation. Figure 1 illustrates the electrical path from either shore or engine power, through the battery bank, to the Seakeeper system.

Figure 1: DC Seakeeper Powering Schematic



Power consumption varies by Seakeeper model and is proportional to stabilization capacity and angular momentum. Table 2 outlines the different consumption figures to consider when sizing a battery bank for each model. The Seakeeper operating power consumption will vary based on the sea state.

Table 2: DC Seakeeper Power requirements (Amperage draw at 12 V)

	Spool-up		Operating	Control
Model	**Amps**	**Hours**	**Amps**	**Amps**
Seakeeper 1	50	0.5	25-50	N/A
Seakeeper 2	71	0.58	25-55	10
Seakeeper 3	75	0.83	33-63	10
Seakeeper 4	88	1	46-88	15

Battery configuration affects capacity requirements based on load and desired runtime. A dedicated Seakeeper battery bank can be installed that isolates the Seakeeper from other house loads. The alternative is an integrated house bank with the Seakeeper and house loads sharing a common source. With an integrated house battery bank, the installer should account for the power consumption of house systems (lighting, pumps, sanitation, instruments, stereo, communication equipment, refrigeration, air conditioning, etc.) to determine the combined house loads. The equations below show the relationship between power, voltage, and amperage:

$$Power = P\ (Watts) = V\ (Voltage) * I\ (Amperage)$$

$$Amperage = I = \frac{P}{V} \qquad I_{SK1} = \frac{P_{SK1}}{V_{SK1}} = \frac{600\ Watts}{12\ Volts} = 50\ Amps$$

The below equations show how to calculate the amp hours (capacity) and the usable Ah value from a battery based on its efficiency:

$$Amp\ Hours = Hours\ of\ Operation\ x\ Required\ Amps \qquad Ah = 4\ h\ x\ 50\ A = 200\ Ah$$

$$Usable\ Amp\ Hours = Battery\ Amp\ Hours\ x\ Battery\ Efficiency \qquad Usable\ Ah = 200\ Ah\ x\ 0.80 = 160\ Ah$$

The operational profile of the vessel, method of spool up (shore power vs battery), and alternator/generator input should also be considered when sizing the battery. “Deep Cycle” batteries are recommended by Seakeeper and can typically be discharged to 85 - 95% of its stated capacity however manufacturers do not recommend discharging batteries below a 20% state of charge (0.8 efficiency factor) to prolong battery life.

LOW POWER PROTECTION – VOLTAGE BASED

Seakeeper continually monitors battery voltage and will run at full power until 11.1 VDC is detected when operating with non-lithium batteries. If the measured voltage at the Seakeeper does not increase above 11.1 VDC, then the unit will continue to de-rate power consumption until it reaches 67% of its flywheel target speed. At this point, an alarm will trigger and the Seakeeper will power down. This is a safety feature to alert the user that their batteries are in a low charge state. The DC Input Voltage Low alarm (code: 111) is designed to alarm before any other system to maintain enough battery power to run navigation and other critical equipment.

LOW POWER PROTECTION – STATE OF CHARGE BASED

The 11.1 VDC protection is not compatible with lithium batteries due to high discharge voltage characteristics. When installing Lithium batteries, an external Battery Management System (BMS) or NMEA 2000 battery shunt will be required to provide low power protection. Seakeeper is equipped with a NMEA 2000 State of Charge (SOC) based logic that will automatically trigger low power mode when a 20% SOC is detected. A schematic of a generic BMS integration is shown in the figure below:

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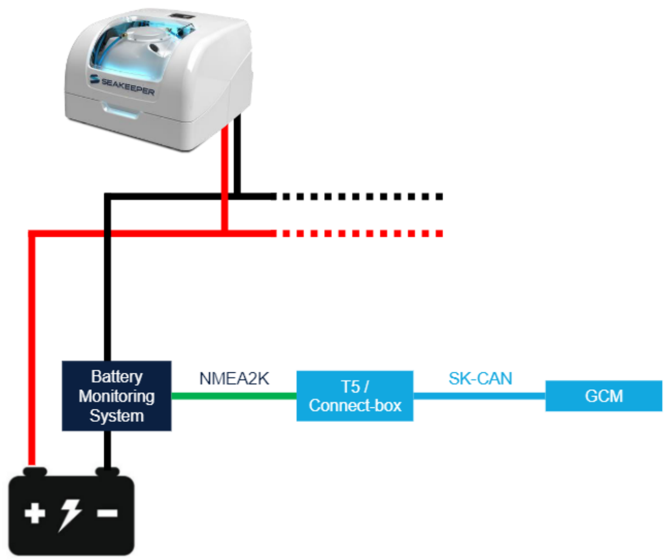
Figure 2: Lithium Battery SOC Monitoring



BATTERY AND RUNTIME CALCULATOR

Seakeeper has developed a simplified Battery & Runtime Calculator based on the information outlined in this Technical Bulletin. The calculator allows a user to determine the battery requirements for a desired runtime, or the expected runtime given a battery configuration, based on basic system information (Seakeeper model, battery type & size, spool-up power condition, integrated or independent bank, etc.). The minimum battery capacity recommended by Seakeeper for each model, based on the calculator, is outlined in Table 3.

Table 3: Outlines the minimum recommended battery bank capacity.

	Minimum Capacity	Expected Stabilization Time	
Model	**Amp Hours (Ah)**	**Spool-up: Shore Power (h)**	**Spool-up: Battery Power (h)**
Seakeeper 1	150	3.0	2.5
Seakeeper 2	200	2.6	2.1
Seakeeper 3	200	2.3	1.6
Seakeeper 4	220	2.2	1.4

The above configurations use an independent battery bank without an alternator input to show the minimum Ah capacity that should be considered for each Seakeeper model. If using an integrated battery bank, this minimum capacity should be increased based on the demands of the house loads. Additionally, if more runtime is desired without recharging, the total Ah capacity should be increased.