Operations Manual

Battery Stack Models S20-008F, S20-0080

Distributed by:

SOLAR PANELS PLUS

P: (757) 549-1494

AQUION ENERGY

Table of Contents

1. General Information

1.1 About This Manual

This manual is intended to provide technical information and safe practices regarding receiving, installing, operating, and servicing the Aquion Energy S20-0080 and S20-008F Battery Stacks. For complete safety information, refer to the Safety Data Sheet (SDS) included with your product shipment.

NOTICE: Failure to follow the instructions in this document could result in fire, electric shock, and/or other injury or damage.

1.2 Contact Information

Authorized Distributor

Solar Panels Plus, LLC.
2133 Smith Avenue
Chesapeake, VA 23320
(757) 549-1494
www.solarpanelsplus.com

2. Product Information

2.1 AHI™ Battery Technology

Aquion Energy's Aqueous Hybrid Ion (AHI™) batteries are optimized for stationary applications with charge/discharge rates greater than 4 hours. The batteries are designed to have extremely long cycle life at full depth of discharge with minimal degradation, the ability to stand at partial state of charge with minimal self-discharge or loss in function, and extensive fault tolerance.

2.2 S20-0080 Battery Stack Overview

The S20-0080 and S20-008F Battery Stack (hereafter "Battery Stack") is the base component of Aquion Energy's scalable energy solutions. The Battery Stack is composed of eight B20 batteries connected in series, built to be voltage-optimized for safety and system architecture. The S20-008F includes an in-line 15-ampere (A) fuse. Battery Stacks can be scaled in series or parallel for a wide range of stationary system requirements. For detailed specifications, please see the latest Product Specification Sheet, available on the Aquion Energy Customer Portal or from your distributor.

2.3 Physical Characteristics

For product physical characteristics and measurements, please see the latest Product Specification Sheet.

2.4 Terminal Overview

The terminal of each Battery Stack uses standard Amphenol Helios H4 connectors (male/positive, Part No. H4CMC4DI, female/negative, Part No. H4CFC4DI, and available as a mated pair, Part No. H4CPC4DI) and 12 AWG wire.

3. Safety Information

3.1 General Safety Information

- **Only qualified individuals are to service battery systems.**
- **The Battery Stack is designed to be UL recognized.**
  The UL recognition is in progress. Certification tests include:
  - UL 1973-23 Vibration
  - UL 1973-24 Shock
  - UL 1973-25 Crush
  - UL 1973-26 Static Force
  - UL 1973-27 Impact
  - UL 1973-35 Salt Fog
  - UL 1973-36 External Fire Exposure

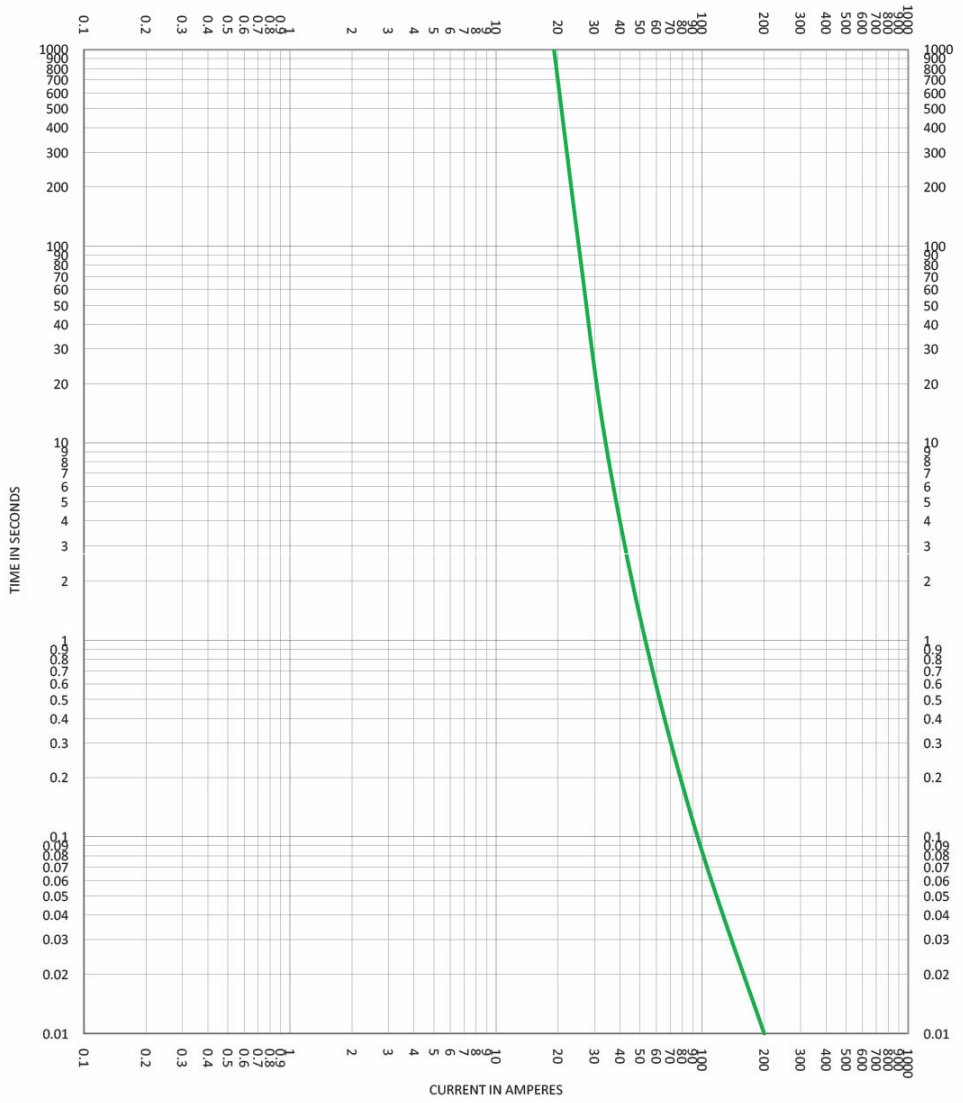
3.2 Electrical Hazards

- **Never place foreign objects or tools in or on the unit as the metal parts of the battery terminals are always live.**
  Electrical hazards exist in the voltage and current ranges that are found in battery systems and associated electronics.
- **WARNING: Connecting Battery Stacks in series can lead to dangerously high voltages.**
  When connecting S20-0080 Stacks in parallel, 15 A branch fuses are recommended and should be placed as close to the Battery Stack positive (recommended) or negative terminal as possible.

3.3 Electrical Safety

- **Aquion recommends fusing S20-0080 strings with a 1,000 V, 15 A fuse at the positive (+) lead of each string of Battery Stacks (or on each individual Battery Stack if they are all connected in parallel).**
  The S20-008F already contains an in-line fuse, and additional fusing at each Stack is not necessary.
- **In the series configuration, the Battery Stacks should be grounded by using a tie rod.**
  The following parts and tools are required:
  - Ring Terminal (Morris Products 11072)
  - Nut (McMaster 93839A835)
  - 12 AWG wire
  - standard wire crimper

  Attach the ring terminals to the Battery Stacks, and then ground the Battery Stacks.



Time Current Curve (15–30 A) for Littelfuse SPF Series Solar Fuses[1]

3.4 Chemical Hazards

- **AHI battery materials are non-toxic and contain no chemical hazards.**
  Electrolyte spillage is not a concern with AHI batteries. The electrolyte is sodium-sulfate-based saltwater with a neutral pH. In the unlikely event that electrolyte comes in contact with eyes or skin, thoroughly wash out with water. Electrolyte residue on the battery terminal can be wiped away with a cloth. A collection pan under the Stack is not needed as the electrolyte will not leak during normal operation, and any leaked electrolyte will not damage battery surfaces or equipment. Refer to the SDS for additional information.

[1] Image adapted from Littelfuse®, POWR-GARD® Fuse Datasheet: SPF Series Solar Fuses. See http://www.littelfuse.com/~/media/electrical/datasheets/fuses/solar-fuses/littelfuse_fuse_solar_spf_datasheet.pdf.

3.4.1 Gas Emissions

- **The battery may emit trace amounts of gas H_2, O_2, CO_2, and CO during normal operation.**
  These gasses are not accumulated in hazardous quantities if the batteries are ventilated according to the ventilation guidelines stipulated in this manual (see Section 5.5). The battery has passed UL overcharge testing, which includes monitoring for toxic vapors and combustible vapor concentrations.

  Overcharging the battery will result in venting of non-hazardous gas, primarily composed of H_2, O_2, CO_2, and CO, through the pressure relief valve.

3.5 Mechanical Hazards

- **AHI Battery Stacks are compressed and designed never to be dismantled.**
  WARNING: Do NOT attempt to disassemble Battery Stacks. Do NOT remove the nut on the compression fixture on top of the Stack. Battery Stacks have been compressed to optimize battery performance. Releasing this load could result in poor battery performance, permanent damage to Stack components, and/or injury.

- **The Battery Stack cases are intentionally flexible to accommodate compression of the electrode stack and normal variations in internal pressure during operation.**
  A slight concave deformation in the sidewall of the Battery Stack case is not unusual, especially in new batteries, and does not present an unsafe condition. A convex deformation, or bulge, projecting no more than 10 mm from the sidewall of the battery is also not unusual and does not present an unsafe condition. If a bulge projects more than 10 mm, the affected Battery Stack should be removed from service, and Aquion Energy's technical support should be contacted.

3.6 Transportation Hazards

- **AHI battery products have no hazardous classifications and can be shipped as standard goods.**
  The AHI battery has also undergone International Safe Transit Association Testing for shock, vibration, thermal shock, and altitude.

- **Battery Stacks shall not exceed fifteen (15) degrees of tilt angle during transportation and placement.**

3.7 Weight Hazards

- **The Battery Stack weighs 113 kg (249 lbs) and must be transported and handled with appropriate precautions.**
  A furniture dolly with an appropriate weight rating may be useful for transporting the Stack, though care should be taken not to tilt the Stack more than fifteen (15) degrees.

3.8 Environmental Considerations

- **Under normal conditions, AHI materials are contained and pose no known risk to persons or the surrounding environment.**
  The product is not classified as environmentally hazardous.

3.9 Recycling and Disposal

- **AHI batteries are non-toxic, non-corrosive, and can be disposed of as ordinary trash or through proper recycling channels.**
  Follow all local laws and regulations regarding disposal.

4. Receipt of Equipment

4.1 Delivery Inspection

- **Immediately upon delivery, inspect all hard goods for signs of damage or tipping during transit.**
  This may be evidenced by damaged pallets or packaging. Immediately check the Tip-N-Tell indicator, if one is included on the shipping container, and alert the carrier if the indicator has registered tip. Thoroughly document all instances of product damage or tipping, and make a claim with the carrier as soon as possible. Contact Aquion Energy for further support.

4.2 Hidden Damage

- **Within 10 days of receipt, a visual inspection must be performed.**
  If any damage is found, request an inspection by the carrier and file a hidden damage claim. Do not delay visual inspection. Delaying this step may result in a loss of right of reimbursement for hidden damages.

4.3 Actions

- **If, upon delivery, equipment appears to have been damaged or tipped, do not accept the shipment.**
  If you have accepted shipment and equipment in the shipment appears to have been tipped or damaged, please contact your appropriate support representative. For technical support contact information, please see Section 8, Technical Support and Troubleshooting.

5. Installation Procedures

5.1 Unpacking

- **Unpack all items carefully and note quantities received.**
  Battery Stacks are shipped on pallets. All accessories needed for installation and use are packed in boxes and secured to the pallet. Contact Aquion Energy if any items are missing or damaged.

5.2 Installation

- **Ensure that the installation location is level before moving and installing any S-Line product.**
  The S-Line product has been designed to be moved and installed in an upright position (less than fifteen (15) degrees of tilt).
- **Use proper lifting procedures and personal protective equipment when moving the S-Line product.**
  The S-Line product is heavy. Failure to follow appropriate lifting procedures or use personal protective equipment may cause serious injury.

The S-Line product has been designed to be moved using the lifting eye and metal tie-rod that runs vertically through the center of the Stack. Each shipment of six S-line Stacks includes one lifting eye. The lifting eye screws onto the tie rod and can be used to move one Stack at a time.

A crane, hoist, or similar device of appropriate load-bearing capacity can be used to lift the S-Line product vertically by the lifting eye threaded onto the tie-rod. NEVER LIFT S-LINE PRODUCTS BY THE TERMINALS OR ANY PART OTHER THAN THE SUPPLIED LIFTING EYE THREADED ONTO THE TIE-ROD AS THIS WILL VOID THE WARRANTY AND MAY CAUSE DAMAGE TO THE PRODUCT AND/OR SIGNIFICANT INJURY. No other component of the S-Line product is designed to support the weight of the product. Alternatively, an appropriately sized hand truck can be used to move S-Line product(s), so long as the product is not tilted more than fifteen (15) degrees.

- **Battery Stacks should be positioned on flat, level surfaces appropriately rated for the weight of the Stacks.**
- **Do not stack Battery Stacks on top of each other.**

5.3 Electrical Interfaces and Connections

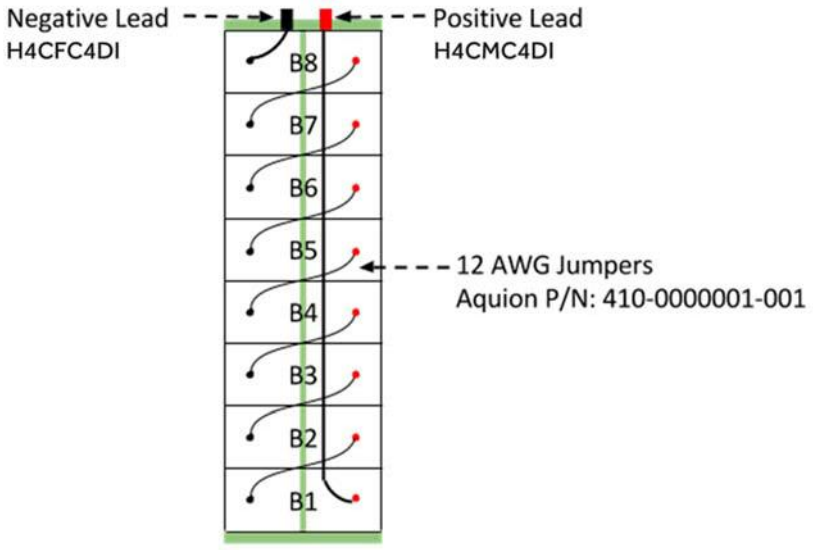
- **The connectors, found at the top of the Battery Stack, are as follows:**
  - Negative (Black): Female Helios H4 Connector (H4CFC4DI)
  - Positive (Red): Male Helios H4 Connector (H4CMC4DI)

The mating connectors (not supplied by Aquion) can be ordered as a mated pair (H4CPC4DI).

The battery-to-battery jumpers use 12 AWG wire.

Crimping the Helios H4 connectors requires the H4 Crimp Tool, if crimping the connectors yourself, and the H4 Universal Unlocking Tool to disconnect the connectors.

5.4 Wiring Diagrams



The 12 AWG jumpers are 180 mm cables with AEH4 connectors ordered from Aquion Energy (P/N: 410-0000001-001).

5.5 Ventilation Guidelines

- **Per IBC and NFPA 1 guidelines, installations in enclosed spaces require ventilation equal to either six (6) air changes per hour or ventilation at 1 cubic foot per minute (CFM) per square foot of room size.**

6. Operation

6.1 Configuration and Operation Requirements

The following system design configurations must be followed. Contact Aquion before attempting to install a system outside of these parameters.

- **Battery Stacks must be installed in a dry environment.**
  The S20-0080 and S20-008F Stacks are IP22 rated. Direct exposure to water may cause shorting.
- **The unit may be installed in coastal regions with atmospheric salt.**
- **Battery Stacks must not be operated or stored under direct exposure to sunlight.**
  Prolonged exposure to ultraviolet light may damage the battery casing and reduce product lifetime.
- **Battery Stacks may be stored at 0%–100% state of charge (SOC) without significant performance loss.**
  For best results over long-term storage, Aquion recommends keeping the battery at ≤50% SOC (<48 V) and ≤40°C.
- **Battery Stacks must be operated in temperatures between -5°C and 40°C on a 24-hour average.**
  Operation above or below these limits will cause advanced degradation of the battery chemistry.
- **Battery Stacks must be stored in temperatures between -10°C and 40°C.**
  Storage above or below these limits may cause permanent damage to the Battery Stacks.
- **Battery Stacks must be kept between 30 and 59 Vdc after initial charge.**
  Operation or storage above or below these voltage limits will cause damage to the battery chemistry.
- **Battery Stacks must be charged or discharged with less than or equal to 15 A of current.**
  There is a 15 A fuse connected in-line in the S20-008F Stack.
- **Battery Stacks may be operated in systems up to 1,000 Vdc.**
- **Battery Stacks may be wired together in PARALLEL configurations of up to 144 Stacks per inverter or power control system.**
  When connecting together S-Line products in parallel, it is important to design the system so that the maximum current per Stack is lower than the fused limit of 15 A. Aquion recommends that in systems with 12 or more S-Line products connected together in parallel, the overall system be designed for no more than 12 A per Stack as the maximum expected charge or discharge current. The buffer of 3 A per Stack will allow for system balancing to occur over the product's life. Aquion also recommends that for systems with 12 or more S-Line Stacks connected together in parallel, the system be sized to account for a small, yet conservative, energy derating factor of 5%. Derating the overall expected

energy from the system by this amount will account for the losses that will occur in the system's multiple connections.

- **If wiring Battery Stacks in series, the voltage of each Stack must be monitored to ensure that voltage limitations are followed.**

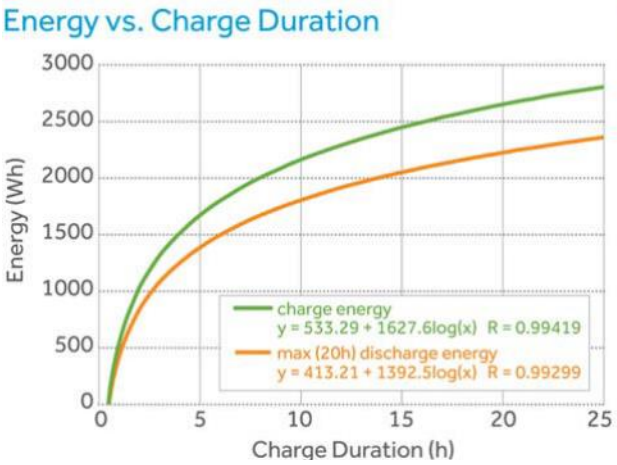
6.2 Initial Charge

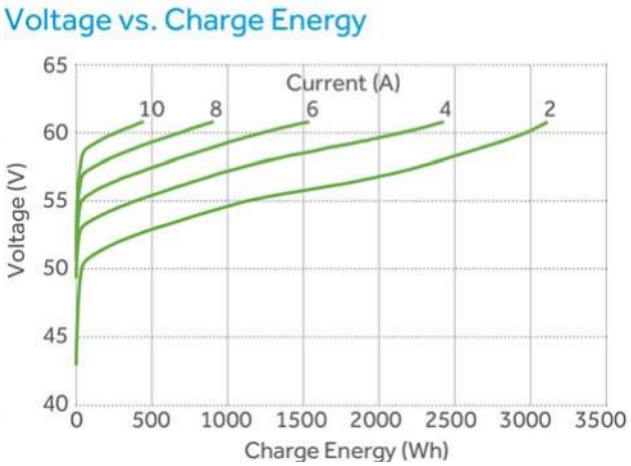
- **The Battery Stack should arrive with an initial voltage greater than 32 Vdc.**
  If the initial voltage is insufficient for charging power electronics, the Battery Stack can be charged using a battery charging device set to the operating limits of the Stacks as defined the latest Product Specification Sheet, available on the Aquion Energy Customer Portal or from your distributor.
- **Use only power supplies designed to charge batteries.**
  Most DC power supplies are not designed to charge batteries and lack sufficient reverse current protection.
- **If the Stacks are to be installed in a series configuration, it is important to match their states of charge to be within 5% of each other.**
  Ideally, before Stacks are connected in series they should be taken to full discharge, 40 ±1 V at open circuit.
- **If Stacks or series strings of Stacks are to be wired in parallel, it is important to match the string voltages to within 5 Vdc.**
- **The high impedance of the AHI battery limits the short-circuit current of the battery.**
  Care must still be taken, however, when "live parallel bussing" batteries with unequal open circuit voltages. The current created in this situation may still be sufficient to cause an arc or cause a fuse to blow.
- **During its initial charge cycles, it is normal for the battery to accept more energy before it reaches its max voltage.**
  This is the normal conditioning process that occurs in the battery. A specific conditioning procedure does not need to be used.

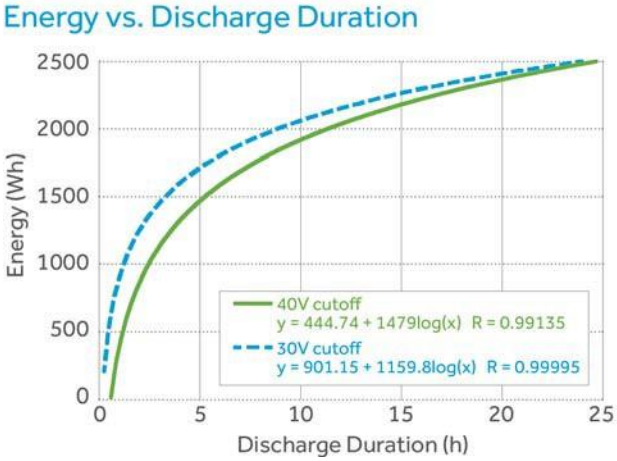
6.3 Discharge/Charge Cycles

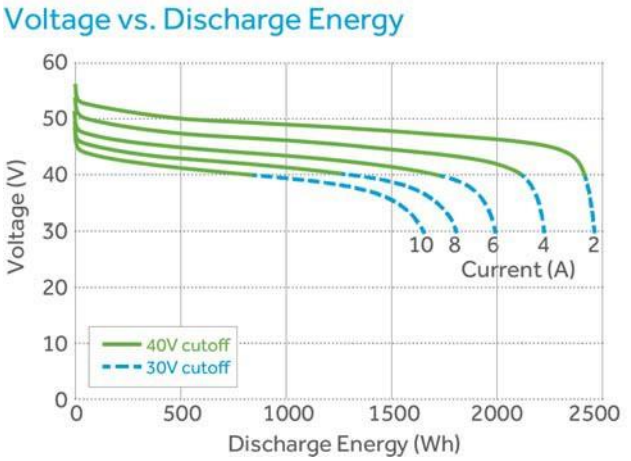
- **The AHI battery chemistry allows for long cycle life at high depth of discharge.**
  Based on the current results of Aquion's ongoing, real-time test of production batteries, Aquion is targeting a cycle life of 3,000 cycles at 100% depth of discharge to 80% retained capacity on all commercial battery products.

  The AHI battery chemistry can accept any charge or discharge profile or algorithm that respects the operating limits defined in the Product Specification Sheet, available on the Aquion Energy Customer Portal or from your distributor. For example, the battery can accept charging up to the recommended current limit as long as the upper voltage limit is not exceeded.







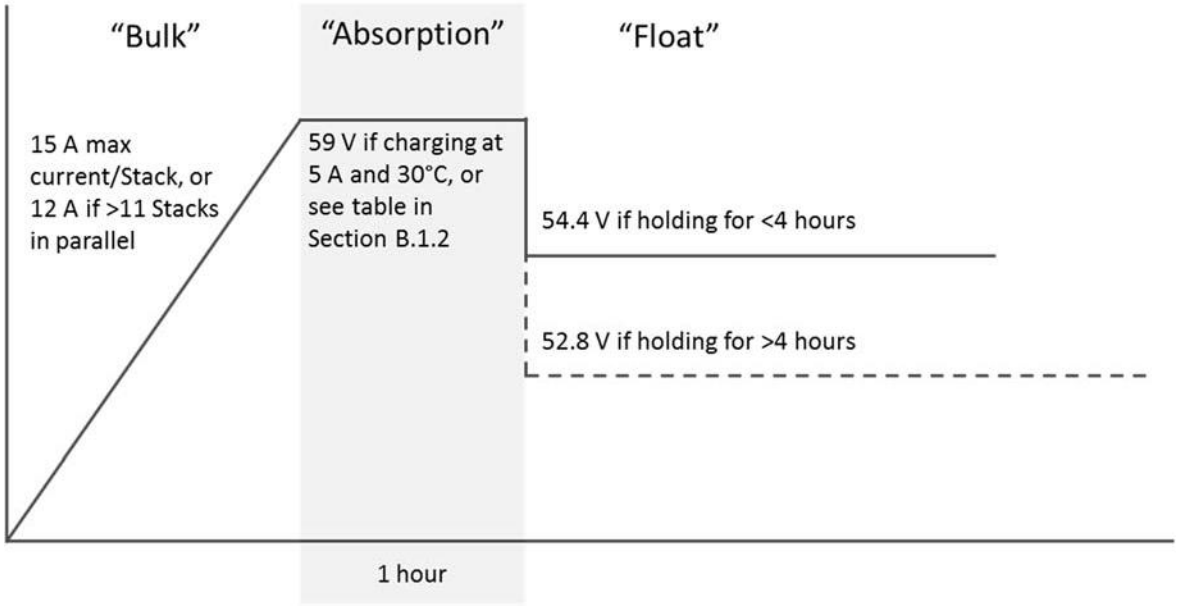


- **Aquion batteries can be charged using the same type of three-stage profile used for lead acid batteries.**

  Though not strictly correct for the AHI chemistry, the lead acid terminology (bulk, absorption, float) is included for clarity. Unlike lead acid, AHI batteries do not require a float voltage, but one is included to maintain a full state of charge.

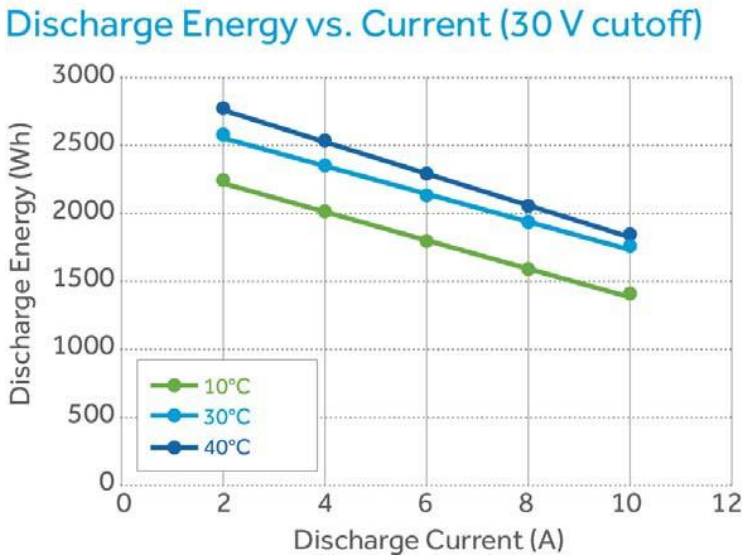
  Aquion batteries should be charged using the following set points:

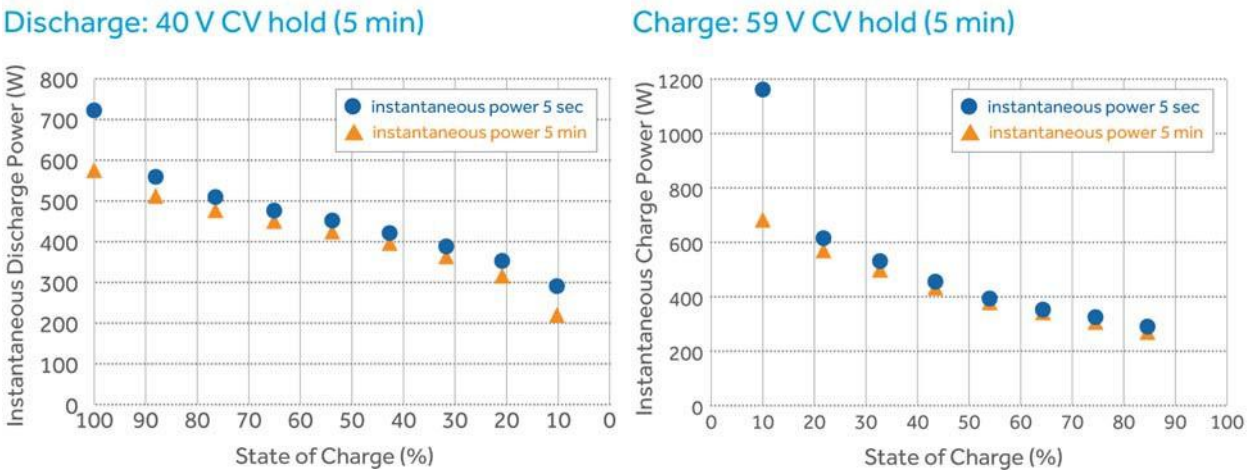
Max Current	12 A/Stack for Stacks in parallel, 15 A for individual Stacks
Max (Absorption) Voltage	59 V at 5 A and 30°C average charge, or use table in Section B.1.2
(Absorption) Time at Max V	1 hour
Float Voltage	54.4 V, or 52.8 V if holding for >4 hours (UPS/grid-tied)



Recommended charge profile

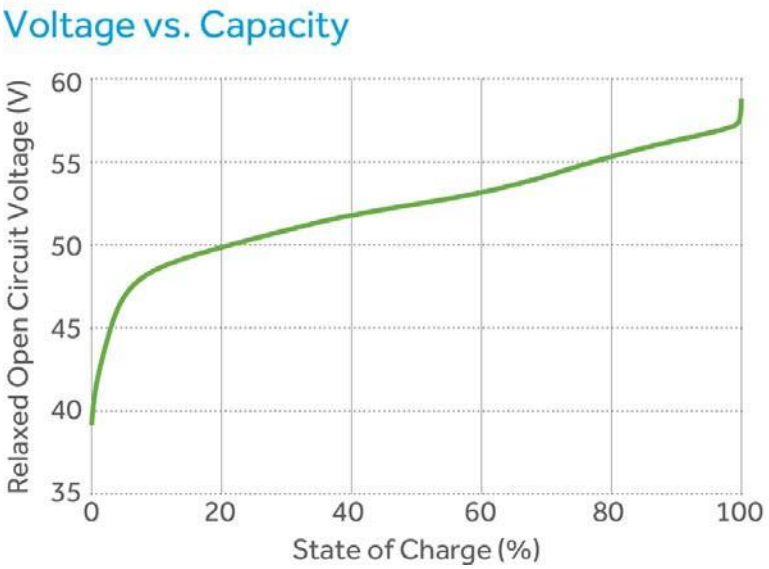
- **Charging the battery to 100% SOC daily or periodically is not required to maintain battery life.** The AHI battery chemistry can be maintained at a partial or low state of charge indefinitely.
- **The Stack can be discharged within its operating limits as well, as defined in the Product Specification Sheet, available on the Aquion Energy Customer Portal or from your distributor.**
  The AHI battery is designed for long duration charge and discharge. The battery's high impedance causes its voltage response to high current levels to be higher than lead acid or lithium ion battery solutions of equivalent capacity. The supplemental charger settings (i.e., generator- or grid-tie) may need to be adjusted so that at low battery state of charge, high inrush loads will not trigger a low battery fault condition in the power electronics.





Peak Power

6.4 State of Charge



6.5 Record Keeping

- **Aquion Energy recommends maintaining proper system documentation records.**
  These include a single line diagram of the complete system and a log documenting system settings (inverter, charge controller, charge voltages, etc.).

Record	Description	Frequency
single line system diagram	complete AC and DC system diagram	at installation or upon change
system component settings	charge voltage and current settings	at installation or upon change

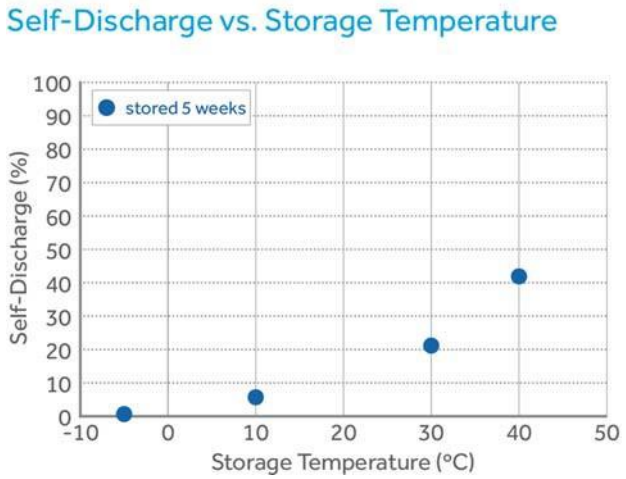
6.6 Operational Records

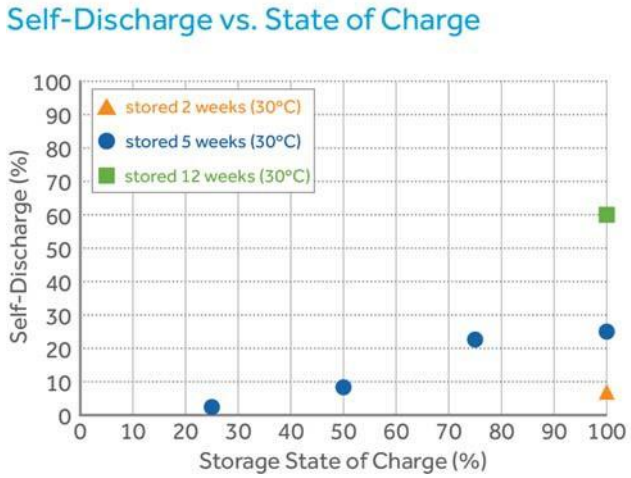
- **Aquion Energy recommends maintaining proper and regular operating records.**
  These include battery temperatures, maximum and minimum operating voltages, and maximum currents. Module-based systems that include the optional Aquion Energy Battery Monitoring System (BMS) log this data automatically.

Measurement	Description	Frequency
average battery temperature	daily average temperature	logged every 24 hours
minimum battery voltage	daily minimum voltage	logged every 24 hours
maximum battery voltage	daily maximum voltage	logged every 24 hours
maximum battery current	daily maximum current	logged every 24 hours

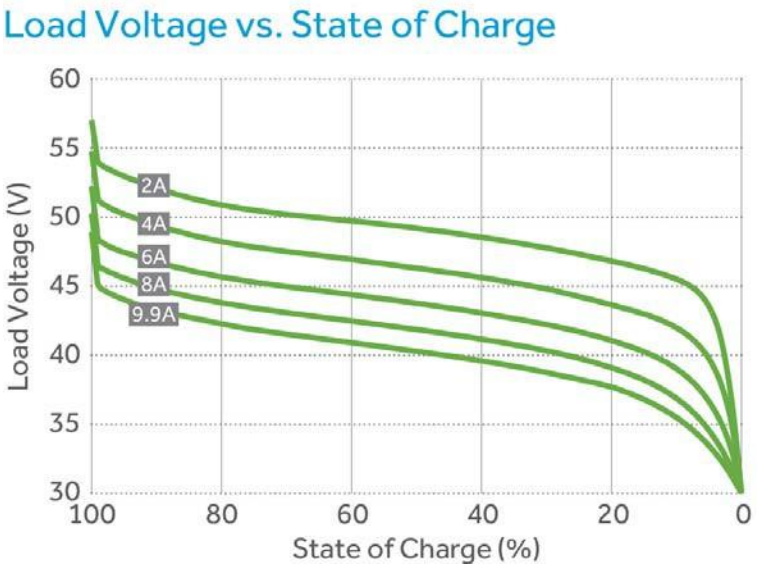
6.7 Long-Term Storage

- **If the Battery Stack is to be stored for an extended period of time, remove all signal and power connections to prevent unintended self-discharge and undetected ground faults.**
  Keep any grounding in place.





6.8 Discharge Load Voltage from 100% SOC



Load Voltage vs. State of Charge

	Discharge Current				
SOC (%)	**2 A**	**4 A**	**6 A**	**8 A**	**9.9 A**
0	30.00 V	30.00 V	30.00 V	30.00 V	30.00 V
5	43.04 V	39.40 V	36.42 V	34.40 V	33.28 V
10	44.92 V	41.52 V	38.67 V	36.61 V	35.28 V
15	45.64 V	42.50 V	39.85 V	37.89 V	36.54 V
20	46.19 V	43.16 V	40.64 V	38.74 V	37.41 V
25	46.66 V	43.67 V	41.24 V	39.38 V	38.04 V
30	47.10 V	44.23 V	41.73 V	39.91 V	38.40 V
35	47.49 V	44.65 V	42.17 V	40.35 V	38.85 V
40	47.85 V	45.03 V	42.56 V	40.74 V	39.22 V
45	48.17 V	45.38 V	42.90 V	41.08 V	39.57 V
50	48.47 V	45.70 V	43.24 V	41.41 V	39.89 V
55	48.74 V	46.01 V	43.55 V	41.70 V	40.20 V
60	48.99 V	46.30 V	43.83 V	42.00 V	40.49 V
65	49.22 V	46.58 V	44.12 V	42.29 V	40.78 V
70	49.46 V	46.86 V	44.42 V	42.60 V	41.10 V
75	49.73 V	47.18 V	44.73 V	42.92 V	41.41 V
80	50.09 V	47.54 V	45.08 V	43.28 V	41.81 V
85	50.60 V	48.03 V	45.53 V	43.72 V	42.27 V
90	51.27 V	48.67 V	46.08 V	44.28 V	42.81 V
95	52.11 V	49.46 V	46.81 V	45.00 V	43.48 V
100	55.99 V	53.85 V	51.40 V	49.50 V	48.22 V

6.9 Energy Efficiency

- **Energy efficiency is determined by running a symmetric charge-discharge cycle, bounded by time or voltage, and using the equation**

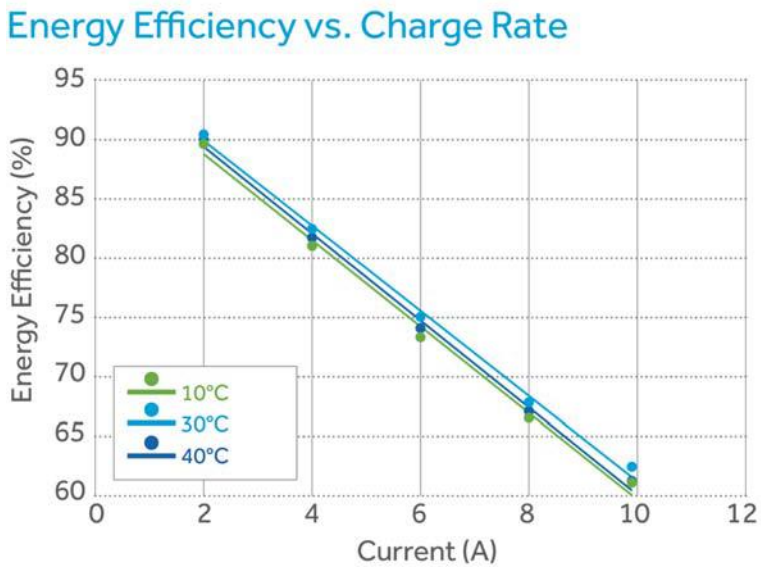
$$\text{Energy Efficiency} = \text{Discharge Energy} / \text{Charge Energy} * 100\%$$

Thus, for a given rate and temperature:

$$\text{Discharge Energy} = \text{Energy Efficiency} * \text{Charge Energy}$$

or

$$\text{Charge Energy} = \text{Discharge Energy} / \text{Energy Efficiency}$$



Energy Efficiency vs. Charge Rate

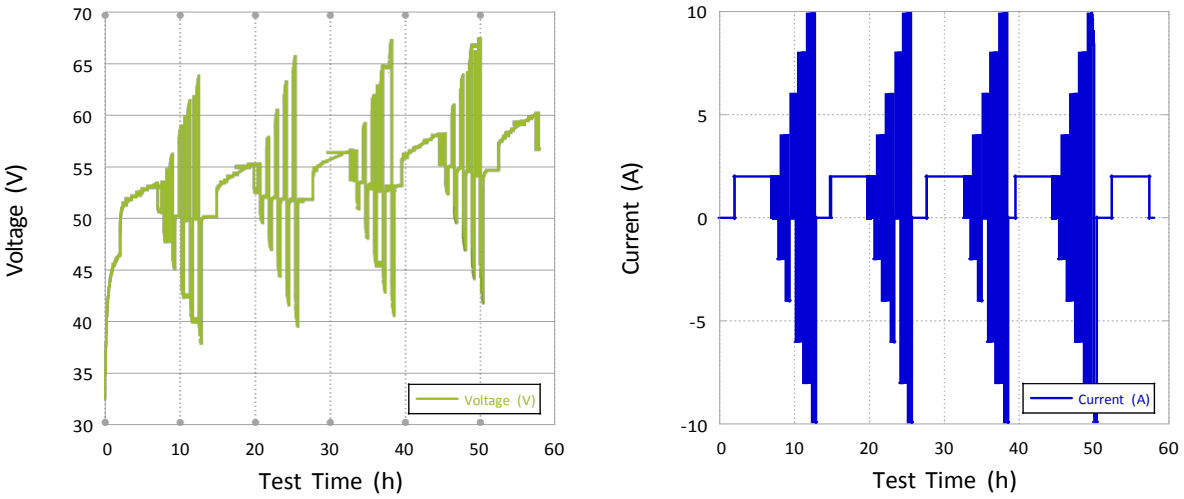
Ambient Temperature	Current				
	2 A	**4 A**	**6 A**	**8 A**	**9.9 A**
10°C	89.70%	81.04%	73.30%	66.46%	61.00%
30°C	90.50%	82.48%	75.02%	67.78%	62.35%
40°C	90.06%	81.74%	74.06%	67.03%	61.15%

- **The energy efficiency of Aquion Energy's AHI battery does not significantly change with state of charge.**

Energy Efficiency vs. Condition

	Current				
Condition	**2 A**	**4 A**	**6 A**	**8 A**	**9.9 A**
10°C, 20% SOC	89%	80%	73%	66%	60%
10°C, 40% SOC	90%	81%	73%	66%	61%
10°C, 60% SOC	90%	81%	74%	67%	--
10°C, 80% SOC	89%	80%	72%	--	--
30°C, 20% SOC	90%	82%	74%	67%	62%
30°C, 40% SOC	91%	82%	75%	68%	62%
30°C, 60% SOC	91%	83%	75%	68%	63%
30°C, 80% SOC	91%	83%	75%	69%	--
40°C, 20% SOC	90%	81%	74%	67%	60%
40°C, 40% SOC	90%	82%	74%	67%	61%
40°C, 60% SOC	91%	82%	74%	67%	--
40°C, 80% SOC	91%	82%	75%	68%	--

- **A pulse test as defined below can also provide a reliable approximation of round trip efficiency from Vmin to Vmax at each rate.**



In the energy efficiency test shown above, state of charge is set by a fixed ampere-hour (Ah) charge determined as a specified percentage of the battery's nominal capacity. A symmetric charge and discharge pulse was then run for a fixed time (20 minutes) at each rate. At higher state of charge, the pulse time may be limited by Vmax.

7. Warranty

Please see the Terms and Conditions and/or separate warranty documentation for warranty information.

8. Technical Support and Troubleshooting

For technical support and troubleshooting, contact your dealer or authorized distributor.

9. Disclaimers

The information in this document is subject to periodic updates and changes. Upon any updates or changes to the above-described material, Aquion Energy will provide new drawings and/or associated documentation that will supersede those contained in this document. Contents are subject to change without notice.

Appendix A: Frequently Asked Questions

What connectors are needed for the S20 Battery Stack?

The following standard solar connectors are required to make connections to the S20 Battery Stack. Aquion Energy does not supply these parts.

Quantity	Part Name	Part Number
1	Solar Connector, Male	H4CMC4DI
1	Solar Connector, Female	H4CFC4DI
	OR	
1	Solar Connector, Mated Pair	H4CPC4DI

The negative (black) and positive (red) leads on the top of the Battery Stack are the Amphenol H4CPC4DI (Helios H4), 12 AWG, male (positive) and female (negative) connectors.

Mating connectors can be purchased through Amphenol distributors worldwide. Find your nearest authorized distributor here: http://www.sineco.com/Distributors_ep_255.html

Full details regarding electrical connections are listed in Sections 2.4 and 5.3 of this manual.

What sub-string balancing issues, if any, must be managed when using AHI batteries? Because other battery chemistries require battery equalization, they need a BMS or string size limitations. The AHI chemistry does not require balancing and is considered to be self-balancing. Though Aquion Energy offers a BMS for certain applications, AHI batteries do not require a traditional BMS. There are no passive or active balancing electronics in the Aquion Energy equipment. In products that do employ a BMS, Aquion Energy's BMS serves as a monitoring and communication device.

What do we require for conditioning-based monitoring to ensure that the individual cells, batteries, Stacks, and Modules are functioning properly?

Due to the nature of their chemistry, AHI batteries do not require maintenance cycling or conditioning. The best way to verify proper functionality is to monitor the battery capacity during operation. Please refer to the Product Specification Sheet, available on the Aquion Energy Customer Portal or from your distributor, for expected energy based on the charge and discharge duration.

At high voltages, what operational issues can be expected with regard to the proper functioning of cells and batteries? Can you destroy an individual cell or battery? If so, what is the effect on the string?

The amount of voltage is not an issue as long as the system is sized properly. With respect to voltage, the failure mode to be mindful of is overcharge. The voltage range of your product is specified in the Product Specification Sheet, available on the Aquion Energy Customer Portal or from your distributor. AHI batteries can be sized to meet most voltage needs as long as the provided voltage window is followed. Excessive overcharge can destroy a battery and invalidate its warranty. Depending on the system configuration, doing so could either result in the loss of a portion of the complete system's capacity or even render the entire system useless.

What are the concerns involving degradation?
Overcharge will lead to early degradation problems. Loss of electrolyte from overcharge or from exposing the batteries to temperatures outside of the range specified in the Product Specification Sheet, available on the Aquion Energy Customer Portal or from your distributor, will degrade performance.

Will the batteries be "dead" after they have been used more than the specified number of cycles in your Product Specification Sheet?
No. End of life is considered a loss of 20% of a battery's original capacity. However, the batteries do not experience "death" at that point and can be cycled further with a reduction of capacity.

Will the batteries be "dead" after freezing?
The aqueous electrolyte in the battery will freeze at temperatures below -10°C. Aquion Energy does not recommend allowing AHI batteries to freeze. However, testing has shown that upon thawing, the battery will continue to charge and discharge. After this freeze/thaw cycle, the battery may deliver less energy than if it had not frozen.

Are there any rules, like UN38.3, for the transportation of your batteries?
No. AHI batteries can be shipped as standard goods.

How much do the batteries self-discharge?
The self-discharge of the Aquion AHI battery chemistry is closely related to the ambient temperature at which the battery is being held. Aquion batteries should be held within the temperature range outlined in the Product Specification Sheet (available on the Aquion Energy Customer Portal or from your distributor. Aquion batteries exhibit the following capacity losses due to self-discharge over the course of one (1) month:

- at -5°C: <2%
- at 10°C: 5%
- at 30°C: 25%
- at 40°C: > 35%

For the AHI battery chemistry, the capacity loss due to self-discharge is not irreversible. Capacity lost over a month can be recovered simply by recharging the battery to 100% SOC.

Appendix B: Operational Settings for Off-Grid Power Control Electronics

B.1 Operational Settings for Off-Grid Power Control Electronics

The 48 V Battery Stack is designed to be compatible with the majority of charge controllers and inverters that are compatible with lead acid batteries. With the appropriate voltage, time, and temperature compensation settings, the Aquion Energy battery can use the common lead acid charge profile of Bulk, Absorb, Float. The Aquion Energy battery does not require a float current, as lead acid batteries do, but there is a regulation voltage at which the battery can be held following its absorption charge cycle.

The inverter settings in this appendix are recommendations only. They are intended to keep the batteries within their operational limits (maximum voltage, maximum current, etc.). These settings can be changed to optimize the performance of your particular system. Please contact Aquion Energy support for any further assistance.

B.1.1 Definitions

- Bulk current – Maximum current at which the battery can be charged.
- Absorption voltage – Voltage at which the battery can be maintained in the constant voltage "absorption" stage of the charge profile. This condition allows the battery to charge at a faster rate.
- Absorption time – Length of time that the battery should be held at absorption voltage.
- Hold (float) voltage – Voltage at which the battery can be held following the absorption stage. The hold stage allows the battery to maintain a full state of charge when the system is generating more power than is required by the system loads.

B.1.2 Voltage Limits vs. Temperature

The table below shows the maximum voltage (absorption voltage) as a function of average charge current per stack and temperature.

	Ambient Temperature (°C)						
Current (A)	**>=5**	**10**	**15**	**20**	**25**	**30**	**35**
2	62.8	62.8	61.2	59.6	58	56.4	54.8
4	64.8	64.8	63.2	61.6	60	58.4	56.8
6	66.8	66.8	65.2	63.6	62	60.4	58.8
8	68.8	68.8	67.2	65.6	64	62.4	60.8
10	70.8	70.8	69.2	67.6	66	64.4	62.8
>12	72.8	72.8	71.2	69.6	68	66.4	64.8

B.1.3 How to Charge Aquion Batteries

All off-grid power control devices that have temperature compensation have a battery temperature sensor accessory. Affix the battery temperature sensor to the side of the topmost battery in the eight-battery stack. For groups of stacks, install the battery temperature sensor on the most central stack.

Aquion recommends that the sensor be attached with high-quality tape, in addition to any self-adhesive included with the sensor.

The AHI chemistry can be rapidly charged such that more than 90% of the nameplate (20-hour) capacity can be input into the battery in approximately 4 hours. This is accomplished by using IR-compensated charging, which permits the allowable Vmax to exceed the specified (non-IR-corrected) Vmax, and setting the charge current to the highest allowable value (13 A for S20 Battery Stacks). Under these conditions, the IR-corrected Vmax becomes approximately 66 V (for an 8-Stack configuration). When this IR-corrected Vmax is reached during charging, the current applied to the Stack should be reduced, and Vmax should be lowered in concert during the current taper phase of the charge. Cycle life testing using this charge regime indicates that this is a safe and reliable use case, and we do not expect any unusual loss in function as a result of fast charging. However, the efficiency of this fast-charge step will be significantly lower than that achievable using lower power and current charge conditions.

B.1.4 Temperature Compensation

The Aquion AHI battery is capable of operating at higher ambient temperatures than lead acid batteries can. The reference temperature for the AHI battery is 30°C, rather than the 25°C typical of lead acid technologies. Because most off-grid power electronics are designed to use 25°C as the reference temperature and have varying temperature compensation functions, care must be taken when selecting the appropriate charge settings for an AHI battery. For your convenience, the following sections list the appropriate settings for several devices. If your device is not shown, please derive the settings from the "Voltage Limits vs. Temperature" table above (Section B.1.2) or contact Aquion Energy applications engineering for assistance.

B.2 Off-Grid Device-Specific Settings by Manufacturer

B.2.1 Morningstar

Several Morningstar charge controllers can be configured using their serial/Modbus adapter and the MSView software. The charge controllers operate at different voltages (12, 24, or 48 V) depending on the initial battery voltage when power is connected.

Sunsaver MPPT

Charge Settings

Absorption Voltage	14.85 V*
Float Voltage	13.6 V
Disable Float	unchecked
Float – Low Battery Threshold	12.0 V
Float – Cancel Threshold	9 V
Time Before Float	60 min
Time Before Float – Low Battery	60 min
Time Unit Float Exit	360 min
Equalize Voltage	14 (default)
Disable Equalize	checked

* At 5 A charge rate; otherwise, refer to Section B.3.5.

Shared Settings

Temperature Compensation	-0.080
Battery High Voltage Disconnect	16.0 V
Battery High Voltage Reconnect	15.8 V
Max. Regulation Voltage Limit	16.0 V
Max. Temp Compensation Limit	80°C
Min. Temp Compensation Limit	16°C

Tristar TS-60 MPPT

Charge Mode – PWM, Temp Comp, & Reminder

Absorption Voltage	14.85 V*
Absorption Time	60 min
Enable Absorption Extension	disable
Battery Temperature Compensation	-0.080
Maximum Compensation Temp.	80°C
Minimum Compensation Temp	16°C
Enable Maximum Regulation Limit	checked
Maximum Regulation Limit	16.0
Enable Battery Current Limit	enable
Battery Current Limit	12 A/Stack
Enable Battery Service Reminder	unchecked

* At 5 A charge rate; otherwise, refer to Section B.3.5.

Charge Mode – Float Settings

Enable Float	checked
Float Voltage	13.6 V
Float Timeout	360 min
Enable Float Cancel	disable

Charge Mode – Equalize & HVD Settings

Enable Equalize ..... unchecked
Enable Battery HVD..... checked
High Voltage Disconnect..... 16.0 V
High Voltage Reconnect..... 15.8 V

B.2.2 Midnite Classic

T-Comp.....-0.008
Equalization..... equalization is not needed; verify that CHARGE>EQ>AUTOEQ>AUTO = 0
Current Limit – CHARGE>LIMITS>Out Amps ..... 15 A/Stack (12 A if in parallel)
Absorb Voltage – CHARGE>VOLTS>Absorb Volts ..... 59.4 V*
Equalize Voltage – CHARGE>VOLTS>Equalize Volts..... 54.4 V
Float Voltage – CHARGE>VOLTS>Float Volts ..... 54.4 V
Absorb Time ..... 60 min

* At 5 A charge rate; otherwise, refer to Section B.3.5.

B.2.3 Outback

Charge Controller Menu

Absorb Voltage..... 59.4 V*
Absorb Time ..... 1 hr
Float Voltage ..... 54.4 V
ReBulk Voltage ..... 50 V
Output Current Limit..... 12 A/Stack
Absorb End Amps..... 2 A/Stack

* At 5 A charge rate; otherwise, refer to Section B.3.5.

FX Class Inverter Menu

Low Battery Cut-Out Voltage ..... 36 V
Low Battery Cut-In Voltage ..... 40 V
Absorb Voltage..... 59.4 V*
Absorb Time ..... 1 hr
Float Voltage ..... 54.4 V
Float Time ..... 4 hr
Re-Float Voltage..... 52 V
Equalize Voltage..... 54.4 V
Equalize Time ..... 0 hr

* At 5 A charge rate; otherwise, refer to Section B.3.5.

Radian Class Inverter Menu

Low Battery Cut-Out Voltage	36 V
Low Battery Cut-In Voltage	40 V
Absorb Voltage	59.4 V*
Absorb Time	1 hr
Float Voltage	54.4 V
Float Time	4 hr
Re-Float Voltage	52 V
Equalize Voltage	54.4 V
Equalize Time	0 hr
Grid-Tie Sell Voltage	52.8 V

* At 5 A charge rate; otherwise, refer to Section B.3.5.

FLEXnet DC Menu

Battery Ah	51 Ah/stack
Charged Voltage	56 V
Charged Time	1 hr
Charged Return Amps	2 A
Charge Factor	99

B.2.4 SMA Sunny Island

221.02	BatCpyNom	51 Ah/Stack
221.03	BatVtgNom	48 V
222.01	BatChrgCurMax	15 A/Stack (12 A if in parallel)
222.02	AptTmBoost	60 min
222.03	AptTmFul	1 hr
222.04	AptTmEqu	1 hr
222.05	CycTmFul	180 days
222.06	CyCTmEqu	180 days
222.07	ChrgVtgBoost	2.45 V*
222.08	ChrgVtgFul	2.45 V*
222.09	ChrgVtgEqu	2.45 V*
222.10	ChrgVtgFlo	2.25 V
222.11	BatTmpCps	10 mV/°C
223.05	BatPro1Soc	25%
223.06	BatPro2Soc	30%
223.07	BatPro3Soc	25%
224.01	SilentEna	enable
224.02	SilentTmFlo	4 hr
224.03	SilentTmMax	48 hr

Parameter nubmers are for model Si*xx*48-US. Parameters 224.01–224.03 not applicable to non-U.S. models.

* At 5 A charge rate; otherwise, refer to Section B.3.5.

B.2.5 Schneider Conext XW+

Batt Type ..... custom
Batt Capacity ..... 51 Ah/Stack
Max Charge Rate .....15 A/Stack (12 A if in parallel)
Charge Cycle..... 3 stage
Float Voltage ..... 54.4 V
Absorb Time ..... 1 min
Bulk Voltage ..... 59.4 V*
Absorption Voltage ..... 59.4 V*
Equalize ..... disable
Batt Temp Comp ..... -0.180

* At 5 A charge rate; otherwise, refer to Section B.3.5.

B.3 Grid-Tied/UPS Device-Specific Settings by Manufacturer

Different settings apply if the battery is to be used primarily in a grid-tied, UPS-type application. The goal of off-grid, solar/battery charged applications is to charge the battery as fast as possible when power is available. The grid-tied or UPS use case emphasizes providing voltage settings that ensure the long-term life of the battery and maximum available energy when required. To achieve this goal, the battery will use a lower float voltage or utilize silent mode settings.

B.3.1 Midnite Classic

T-Comp.....-0.008
Equalization ..... equalization is not needed; verify that CHARGE>EQ>AUTOEQ>AUTO = 0
Current Limit – CHARGE>LIMITS>Out Amps ..... 15 A/stack (12 A if in parallel)
Absorb Voltage – CHARGE> VOLTS>Absorb Volts..... 59.4 V*
Equalize Voltage – CHARGE> VOLTS>Equalize Volts..... 52.8 V
Float Voltage – CHARGE> VOLTS>Float Volts ..... 52.8 V
Absorb Time ..... 60 min

* At 5 A charge rate; otherwise, refer to Section B.3.5.

B.3.2 Outback

Charge Controller Menu

Absorb Voltage..... 59.4 V*
Absorb Time ..... 1 hr
Float Voltage ..... 52.8 V
ReBulk Voltage ..... 50 V
Output Current Limit.....15 A/Stack (12 A if in parallel)
Absorb End Amps..... 2 A/Stack

* At 5 A charge rate; otherwise, refer to Section B.3.5.

FX Class Inverter Menu

Low Battery Cut-Out Voltage	9 V
Low Battery Cut-In Voltage	11 V
Absorb Voltage	59.4 V*
Absorb Time	1 hr
Float Voltage	52.8 V
Float Time	4 hr
Re-Float Voltage	52 V
Equalize Voltage	54.4 V
Equalize Time	0 hr

* At 5 A charge rate; otherwise, refer to Section B.3.5.

Radian Class Inverter Menu

Low Battery Cut-Out Voltage	36 V
Low Battery Cut-In Voltage	44 V
Absorb Voltage	59.4 V*
Absorb Time	1 hr
Float Voltage	52.8 V
Float Time	4 hr
Re-Float Voltage	52.0 V
Equalize Voltage	52.8 V
Equalize Time	0 hr
Grid-Tie Sell Voltage	52.8 V

* At 5 A charge rate; otherwise, refer to Section B.3.5.

FLEXnet DC Menu

Battery Ah	51 Ah/Stack
Charged Voltage	56 V
Charged Time	1 hr
Charged Return Amps	2 A
Charge Factor	99

B.3.3 SMA Sunny Island

221.02	BatCpyNom	51 Ah/stack
221.03	BatVtgNom	48 V
222.01	BatChrgCurMax	15 A/Stack (12 A if in parallel)
222.02	AptTmBoost	60 min
222.03	AptTmFul	1 hr
222.04	AptTmEqu	1 hr
222.05	CycTmFul	180
222.06	CyCTmEqu	180 days
222.07	ChrgVtgBoost	2.45 V*
222.08	ChrgVtgFul	2.45 V*
222.09	ChrgVtgEqu	2.45 V*
222.10	ChrgVtgFlo	2.20 V
222.11	BatTmpCps	10 mV/°C
223.05	BatPro1Soc	25%
223.06	BatPro2Soc	30%
223.07	BatPro3Soc	25%
224.01	SilentEna	enable
224.02	SilentTmFlo	1 hr
224.03	SilentTmMax	48 hr

Parameter nubmers are for model Si*xx*48-US. Parameters 224.01–224.03 not applicable to non-U.S. models.

* At 5 A charge rate; otherwise, refer to Section B.3.5.

B.3.4 Schneider Conext XW+

Batt Type	custom
Batt Capacity	51 Ah/Stack
Max Charge Rate	15 A/Stack (12 A if in parallel)
Charge Cycle	2 stage
ReCharge Volts	52 V
Absorb Time	1 min
Bulk Voltage	59.4 V*
Absorption Voltage	59.4 V*
Equalize	disable
Batt Temp Comp	-0.180
Grid Supp Volts	52.8 V

* At 5 A charge rate; otherwise, refer to Section B.3.5.

B.3.5 Absorption Voltage vs. Charge Current, 30°C

Minimum Charge Current (A)	Absorption Voltage		
	Schneider Outback Midnite	SMA	Morningstar
0	54.4	2.26	13.60
1	55.4	2.31	13.85
2	56.4	2.35	14.10
3	57.4	2.39	14.35
4	58.4	2.43	14.60
5	59.4	2.48	14.85
6	60.4	2.52	15.10
7	61.4	2.56	15.35
8	62.4	2.60	15.60
9	63.4	2.64	15.85
10	64.4	2.68	16.00
11	65.4	2.73	16.00
12	66.4	2.77	16.00
13	67.4	2.80	16.00
14	68.4	2.85	16.00
15	69.4	2.89	16.00

B.4 Reference Cycles for Lab Use

It is common to perform reference cycles to verify the capacity of the battery in a lab environment. Due to the unique characteristics of the Aquion Battery, it is important to use a standard test plan in order to ensure the results can be compared to the manufacturer specifications. Please use the following parameters when performing reference cycles:

Step	Mode	Value	End Type
1	Constant Current Charge	2 A	60.8 V
2	Constant Voltage Charge	60.8 V	1 A
3	Constant Current Discharge	2 A	30.4 V
4	Rest	0 A	2 hours