# SeaBattery

# User's Guide

# P/N  730-001-601

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Rev. 5/6/04

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# GENERAL DESCRIPTION

Each orange molded polyethylene box contains a single or multiple battery configuration; standard configurations are:

1. A single 12V-65AH battery (SB12-65).
2. Two 12V-38AH batteries connected in series or in parallel to provide either 24V-38AH (SB24-38) or 12V-76AH (SB12-76).
3. Three 6V-50AH batteries connected in parallel to provide 6V-150AH (SB6-150).

All batteries are maintenance-free rechargeable lead-acid type which utilize a non-liquid electrolyte. The non-liquid "suspended electrolyte" permits the batteries to be operated in any orientation without spillage or loss of capacity, and prevents electrolyte stratification which greatly reduces capacity when normal liquid electrolyte batteries are charged under pressure. The battery boxes are filled with a high purity mineral oil which provides pressure compensation and also isolates the batteries from the surrounding seawater.

The batteries have low self-discharge characteristics, and produce a minimal gas buildup during normal charge and discharge cycles, which eliminates the need for complicated venting systems. Gas can be manually vented through the valve molded in the diaphragm. The flexible polyether urethane diaphragm is transparent, which allows the battery to be visually inspected without disassembly.

**IMPORTANT:**

1. A gas bubble under the diaphragm valve is normal. Manual venting is recommended when the bubble diameter exceeds about 6 in. (15 cm).
2. To ensure long life at rated capacity:
   a) Do NOT overcharge.
   b) Store in charged condition at reduced temperature (-40 deg to 50 deg F).
   c) Do not discharge battery below 75% of rated voltage.

**CAUTION:** These batteries can deliver very high currents if shorted. Exposed male connector pins with applied power should be handled with extreme care; they can be easily shorted against any metal surface. If a short circuit persists for more than about a second, connectors and cabling may be destroyed and fire may result. ALWAYS verify polarity. Many devices can be damaged by reverse polarity.

# CHARGING

The battery should always be fully charged before use, and should be stored in a fully charged state (see STORAGE).

The battery cells are of starved electrolyte construction, and produce very little, if any gas while charging. However, when fully charged, a cell will start to produce gas. IT IS EXTREMELY IMPORTANT NOT TO OVERCHARGE THE BATTERY. The evolution of gas that results from overcharging will slowly reduce the capacity of the cells by drying out the electrolyte. In an extreme case the diaphragm can be damaged by the pressure load caused by the trapped gas bubble.

To ensure many recharging cycles over the life of the cells, it is preferable to slightly undercharge them on each cycle. Usually, one cell will achieve full charge before the others and a stream of gas bubbles will rise from that cell. If the battery is charged beyond this point, there may be some slow bubble formation after it is disconnected from the charger. This gas formation should stop within about an hour.

Excess gas that accumulates can be vented easily by carefully loosening the chromed valve cap and releasing the gas. Be careful to minimize loss of compensating oil.

Batteries should always be charged in an upright position. Charging in an inverted position may result in gas being trapped inside the cells. Keep a close watch on batteries during their first charge cycle after shipment or storage, or after a significant temperature change.

Do not exceed .25 x $C_a$ amps charging current, where $C_a$ is the amperage capacity of the battery. For example, to charge a 12v-65 amp hr battery, the maximum charging current should be less than .25 x 65 = 16.25 amps. Charge until a single cell starts venting and measure the battery voltage at that point. This is the reference battery voltage value for the fully charged state. This value will decrease over the life of the battery, and is also a function of temperature and of time after charge (voltage settling will occur shortly after disconnecting from charge).

**WARNING:** SEVERE OVERCHARGING CAN RESULT IN FORMATION OF A LARGE AMOUNT OF EXPLOSIVE GAS WHICH MAY RESULT IN MECHANICAL RUPTURE OF THE DIAPHRAGM AND/OR FIRE AND/OR EXPLOSION.

**NOTE:** The SeaBattery should be charged with a constant voltage, current limiting charger. A bench power source with current limited to .25$C_a$ can be used. DO NOT USE AN AUTOMOTIVE TYPE BATTERY CHARGER. THIS TYPE OF CHARGER WILL OVERCHARGE THE BATTERY.

## CHARGERS

Specially designed battery chargers are available from DSP&L for each SeaBattery configuration. Contact DSP&L for further battery charger information. The following instructions apply to these chargers.

Once powered up and connected to the battery, the two red charger lights will turn on. The lower light indicates "power on" and "low rate" while the upper light indicates "high rate". When the battery reaches full charge the "high rate" light will go out. The "high rate" set point voltage will vary as a function of temperature and battery condition. It may have to be re-tuned as the battery ages, due to a natural decrease in battery capacity. Charging time depends on battery and charger capacity and on the initial state of charge.

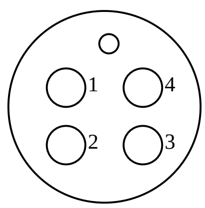
If the charger is well-tuned, the battery should not produce gas during the charging cycle and the diaphragm valve may remain closed. The battery should be checked for gas production, especially toward the end of the charging cycle. If there is a stream of bubbles rising from one or more of the cells and the charger "high rate" light is still on, then the battery is being overcharged and the charger is incorrectly tuned (Contact DSP&L for charger tuning information).

Batteries may be charged either inside or outdoors. If a battery is being charged outdoors great care must be taken to protect the charger rain or sea spray--the chargers are not weatherproof. Prolonged unprotected exposure to salt spray may damage the charger electronics. A large, clear, heavy plastic bag can be used to cover and protect the charger.

## STANDARD CONNECTORS

A right angle diaphragm penetrator is installed in the SeaBattery diaphragm, and is molded to an SO 16/4 4-conductor power cable terminated with an Impulse IL4FS female 4-pin connector. The connector polarity is shown below.

**FEMALE CONNECTOR PINOUT DIAGRAM (for 12V SeaBattery)**




| | |
|---|---|
| #1 | Ground (black) |
| #2 | +12 volts (white) |
| #3 | +12 volts (red) |
| #4 | Ground (green) |

## DISCHARGING

For optimal results, the SeaBattery should not be overly discharged. Do not reduce the voltage below the minimum values shown.

| Nominal Voltage | Minimal Voltage |
|---|---|
| 24 | 18 |
| 12 | 9 |
| 6 | 4.5 |

Complete discharge is not advised, but batteries can usually be recovered by using a special charging procedure. If the battery is completely discharged and will not accept a charge, try initializing the charge with a higher voltage to induce current flow. When current is flowing, reduce the voltage. Refer to the "Recharge Methods" technical notes located in Appendix B.

The SeaBattery might produce significant amounts of gas in the discharge cycle, especially during rapid discharge. Before use, purge any significant bubbles from the SeaBattery case. A small amount of gas trapped under the diaphragm will not cause a problem; it will go into solution under pressure, and the flexibility of the diaphragm allows for limited expansion and contraction of volume. When the SeaBattery is brought to the surface, the depressurization will cause the compensating oil to foam. This is normal, and will form into a single bubble within about an hour, after which it should be purged.

**CAUTION:** The SeaBattery is capable of discharging very high currents and must not be shorted. Cables and connectors can quickly be destroyed by the high current resulting from a short circuit.

## INSPECTION

The diaphragm should be filled so that the top of the valve cap is approximately one half inch below the top of the box. In an emergency almost any type of oil can be used; oils that will not damage rubber are best, such as mineral oil (high viscosity is best), white oils, silicon oil, cooking oils, or any oil that will not solidify at low temperatures.

Unless completely flooded, water inside the case should not cause battery failure. A non-hardening gasket sealer (e.g. Permatex #2) is used between the case and the diaphragm to help prevent flooding, and it is also important that the bolts that secure the top to the case are tightened to the correct torque specifications.

The bolts around the perimeter of the box may loosen over time. Check the torques periodically. Tighten the center bolts on each side until the edge of the diaphragm begins to bulge at that point. Tighten the bolts down less and less as they approach the corners of the box, thus maintaining a uniform bulge of approximately 1 mm between the top and the case. The factory torque settings are:

| | |
|---|---|
| Center bolt on each side | 50 in-lb (35 cm-kg) |
| Surrounding bolts | 35 in-lb (23 cm-kg) |
| Corner bolts | 20 in-lb (11 cm-kg) |

If the bolts are too loose, the box will slowly leak oil. Over-tightening will cause deformation of the diaphragm; extreme over-tightening can cause the diaphragm to tear.

Inspect the SeaBattery after the first deployment, and after submersion to a significantly greater depth. Check for water leakage by inverting the box and looking for water bubbles. Water can be drained from the case when in this position. Water leakage has not been a problem, however. Always check for damage and for rocks trapped between the top and the diaphragm.

## MOUNTING

The SeaBattery case is very durable, but it must be well secured. Do not mount the SeaBattery so that it is suspended from the top flange. The weight of the battery may cause cold flow deformation of the plastic flange which can result in leakage.

If the SeaBattery is likely to experience shock loading (e.g. during launch or recovery) a tray should be constructed to support and retain the case. For extremely rough usage (e.g. towed systems that might "crash" into the bottom), a frame that supports and retains the top of the case should be added. There may be threaded mounting inserts in the bottom of some older model cases. These mounting inserts should not be used--the inserts may tear out of the plastic case under severe loading.

## BATTERY STORAGE

Recommended Storage Temperature: -40C (-40F) to 10C (50F)

**NOTE:** The SeaBattery should be recharged at least once every 6 months while in storage at room temperature. More frequent recharging is required at storage temperatures higher than recommended.

**WARNING:** When completely discharged, the electrolyte is reduced nearly to water. Freezer storage can freeze the electrolyte and damage the SeaBattery.

After the last deployment or battery use, fully recharge the SeaBattery before storing. Although the battery can be used in any position, it should be stored upright. The battery case does not need to be disassembled for storage.

Check the battery periodically for excess gas production, and release any accumulated gas bubble. During extended storage at elevated temperatures, gas production is more significant; in these conditions, the SeaBattery should be stored with the fill valve cap removed. Some oil may be lost, but can be replaced prior to actual use. To minimize oil loss during storage attach a length of tubing to the fill valve.

Storage at a low ambient temperature reduces the self-discharge rate. Higher temperatures will cause the battery to self-discharge more rapidly and produce excess gas, which should be vented.

Long term exposure to sunlight (UV radiation) can eventually cause some degradation in the mechanical properties of the urethane diaphragm. Avoid storing the SeaBattery in full sunlight for extended periods. Cover the battery for periods of exposure of longer than a week or two.

The plastic case is made of polyethylene which is impervious to most oils and solvents. The connectors are molded neoprene; contact with damaging oils or solvents (e.g. diesel oil or organic solvents) should be avoided. Similarly, do not use any organic solvent on the urethane diaphragm.

## LIFE EXPECTANCY

The SeaBattery life expectancy is approximately three years under normal use. Intermittent use combined with cold storage can increase battery life, while abuse can significantly shorten life expectancy. Contact DSP&L for applications that require continuous use and in situ recharging.

There are two options for battery replacement:

1. Ship the SeaBattery back to DeepSea Power & Light where the batteries will be replaced and refurbished.
2. Order a new, pressure-modified battery from DSP&L and install them in-house.
3. While not recommended, emergency field replacement is possible; see Field Replacement Procedure for instructions.

## SHIPPING

The SeaBattery is classified as a dry cell type battery and can be shipped by air freight.

## CUSTOMER MODIFICATIONS

It is recommended that electrical penetrations be made through the diaphragm, although successful penetrations have been made through the case. Holes cut through the diaphragm should be **cut** with a boring tool (circular knife) rather than being drilled. Drilling causes ragged hole edges which have a tendency to encourage tearing. Also, holes must be cut significantly undersize to maintain a tight seal during diaphragm stretch.

Any customer modification such as installing a penetrator, or field battery replacement voids the SeaBattery warranty.

## PRESSURE COMPENSATION OIL WARNING

The pressure compensation oil will also soften the insulation of any internal wiring. This softening will cause the insulation to swell, and reduces resistance to tearing. When opening up the battery case, handle the wires gently to avoid damage to the insulation. CONTACT BETWEEN DAMAGED WIRES MAY RESULT IN A SHORT CIRCUIT.

When replacing the pressure compensating oil, note that low viscosity oil will have a greater softening effect on the wiring insulation than high viscosity oil.

## SEABATTERY WARRANTY

DeepSea Power & Light (DSPL) will replace any SeaBattery that is found to be defective in manufacture during a period of sixty days after receipt of delivery. Except for such replacement, the sale or any subsequent use of the SeaBattery is without warranty or liability.

## BATTERY REPLACEMENT

### Field Replacement Procedure (recommended as an emergency procedure only)

NOTE: The removal procedure is reversed for replacement.

1. Drain approximately 1/2 of the oil out of the SeaBattery. Remove the valve cap, invert box and slightly inflate with compressed air. The heavy mineral oil can be reused; keep it clean!

2. Remove the bolts securing the top to the battery box. Note the tightness of each bolt before removal. The bolts are tightest toward the middle of the frame and looser toward the corners. Bolt torques are: Center bolt = 50 in-lb; Surrounding bolts = 35 in-lb; Corner bolts = 20 in-lb.

3. Remove the top of the battery box and the diaphragm. Note the dark brown sealant present on the diaphragm and the battery box surfaces.

4. Pour out the remaining heavy mineral oil.

5. Disconnect the wires from the battery terminals. Be careful not to short circuit the terminals during this process. A short circuit can be VERY dangerous.

6. Remove old battery from box.

7. Prepare new batteries for installation. The new batteries must be modified to allow oil to freely enter the individual cells. The following is our recommended field modification which offers satisfactory results while differing from the factory procedure.

    a) Pry off top plastic plate that covers cell vents.

    b) Remove individual rubber vent caps.

    c) COMPLETELY fill each individual cell with oil.

8. Install new modified battery in box. Reconnect terminals to diaphragm feedthrough connector.

9. Clean the old sealant off the urethane diaphragm with Isopropyl alcohol. A stronger solvent such as MEK can be used to clean the old sealant off the battery box.

10. Partially fill box with oil before final assembly.

11. Make sure the sealing surfaces are clean and oil free, and apply a bead of non-hardening automotive gasket sealer (e.g. Permatex no. 2) to the box surface, just outside the sealing ridge.

12. Reassemble diaphragm and box top, being careful not to pinch any wires.

13. Retighten frame bolts to previous torque specifications as noted in instruction 2. Diaphragm should not protrude beyond box edges more than 2-3 mm.

14. Fill box with oil until the top of the valve stem is approximately 1 cm below the bottom surface of the box top.

# APPENDIX A

PS-12400 PowerSonic Rechargeable Battery Application Manual


# SEALED LEAD-ACID BATTERIES

TECHNICAL HANDBOOK

# FEATURES

## Sealed/Maintenance-Free
The valve regulated, spill-proof construction of the Power-Sonic battery allows trouble-free, safe operation in any position. There is no need to add electrolyte, as gases generated during over-charge are recombined in a unique "oxygen cycle."

## Long Shelf Life
A low self-discharge rate permits storage of fully charged batteries for up to a year at room temperature before charging is required. Lower storage temperatures enhance shelf life characteristics even further.

## Design Flexibility
Batteries may be used in series and/or parallel to obtain choice of voltage and capacity. Due to recent design breakthroughs, the same battery may be used in either cyclic or standby applications. Over 50 models are available to choose from.

## Deep Discharge Recovery
Special separators, advanced plate composition, and a carefully balanced electrolyte system have greatly improved the ability of recovering from excessively deep discharge.

## Economical
The high watt-hour per dollar value is made possible by the materials used in a sealed lead-acid battery: they are readily available and low in cost.

## Easy Handling
No special handling precautions or shipping containers — surface or air — are required due to the leak-proof construction. Classified as non-hazardous commodity.

## Compact
Power-Sonic batteries use state of the art design, high grade materials, and a carefully controlled plate-making process to provide excellent output per cell. The high energy density results in superior power/volume and power/weight ratios.

## High Discharge Rate
Low internal resistance allows discharge currents of up to ten times the rated capacity of the battery. Relatively small batteries may thus be specified in applications requiring high peak currents.

## Wide Operating Temperature Range
Power-Sonic batteries may be discharged over a temperature range of -40°C to +60°C (-40°F to +140°F) and charged at temperatures ranging from -20°C to +50°C (4°F to +122°F).

## Rugged Construction
The high impact resistant battery case is made either of non-conductive ABS plastic or styrene. Large capacity batteries frequently have polypropylene cases. All of these case materials impart great resistance to shock, vibration, chemicals and heat.

## Long Service Life
Under normal operating conditions, four or five years of dependable service life can be expected in stand-by applications, or between 200-1000 charge/discharge cycles depending on average depth of discharge.

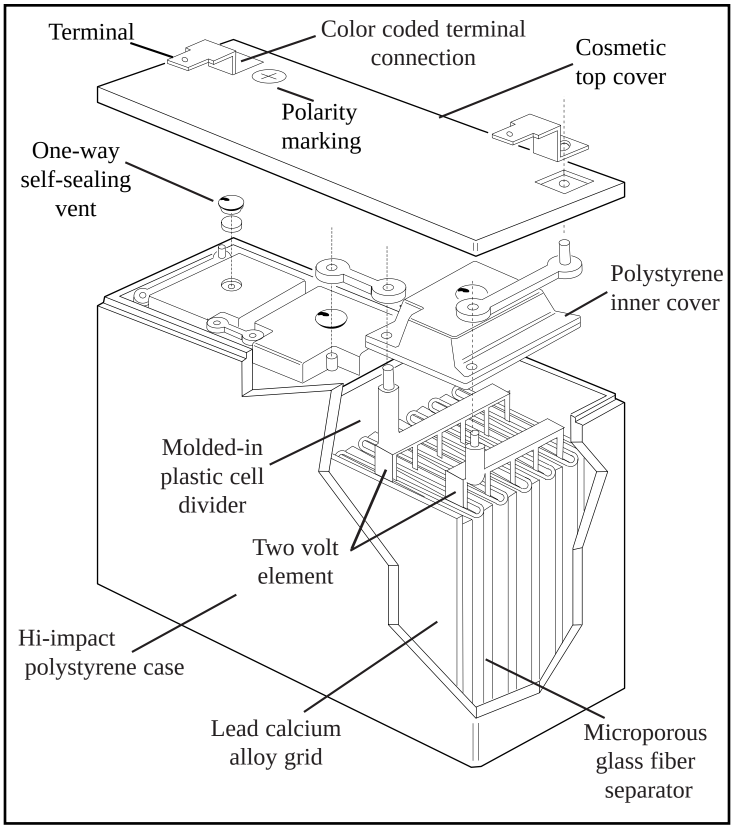



*Figure 1*

## Plates (Electrodes)

Plate construction is the key to producing a good battery. Recognizing this, Power-Sonic utilizes the latest technology and equipment to cast grids from a lead-calcium alloy free of antimony. The small amount of calcium and tin in the grid alloy imparts strength to the plate and guarantees durability even in extensive cycle service. Lead oxide paste is added to the grid to form the electrically active material. In the charged state, the negative plate paste is pure lead and that of the positive lead oxide. Both of these are in a porous or spongy form to optimize surface area and thereby maximize capacity.

## Separators

Power-Sonic separators are made of woven glass fiber cloth with high heat and oxidation resistance. The material further offers superior electrolyte absorption and retaining ability, as well as excellent ion conductivity.

## Electrolyte

Immobilized dilute sulfuric acid: $H_2SO_4$.

## Container

Case material is either ABS, a high-impact proof plastic resin, styrene, or a polypropylene-polyethylene copolymer with resistance to chemicals and flammability.

## Leakproof Design & Operational Safety

Power-Sonic batteries have been approved for shipment by air, both by D.O.T. and I.A.T.A.. U.L.'s component recognition program for emergency lighting and power batteries lists Power-Sonic under file number MH 20845.

## Terminals

Depending on the model, batteries come either with AMP Faston type terminals made of tin plated brass, post type terminals of the same composition with threaded nut and bolt hardware, or heavy duty flag terminals made of lead alloy. A special epoxy is used as sealing material surrounding the terminals.

## Relief Valve

In case of excessive gas pressure build-up inside the battery (usually caused by abnormal charging) the relief valve will open and relieve the pressure. The one-way valve not only ensures that no air gets into the battery where the oxygen would react with the plates causing internal discharge, but also represents an important safety device in the event of excessive overcharge. Vent release pressure is between 2-6 psi; the seal ring material is neoprene rubber.

## Case Sealing

Depending on model, the case sealing is tongue and groove with polyurethane, epoxy, or heat seal.

# THEORY OF OPERATION

The basic electrochemical reaction equation in a lead-acid battery can be written as follows:

| $Pb$ | $2H_2SO_4$ | $PbO_2$ | Discharging ⇌ Charging | $PbSO_4$ | $2H_2O$ | $PbSO_4$ |
|---|---|---|---|---|---|---|
| (porous lead) active material of negative plate | (sulfuric acid) electrolyte | (porous lead dioxide) active material of positive plate | | (lead sulfate) active material of negative plate | (water) electrolyte | (lead sulfate) active material of positive plate |

## Discharge

During the discharge portion of the reaction, lead dioxide (positive plate) and lead (negative plate) react with sulfuric acid to create lead sulfate, water and energy.

## Charge

During the recharge phase of the reaction, the cycle is reversed: the lead sulfate and water are electro-chemically converted to lead, lead oxide and sulfuric acid by an external electrical charging source.

## Oxygen Recombination

To produce a truly maintenance-free battery, it is necessary that gases generated during overcharge are recombined in a so-called “oxygen cycle”. Should oxygen and hydrogen escape, a gradual drying out would occur, eventually affecting capacity and battery life. During charge, oxygen is generated at the positive and reacts with and partially discharges the sponge lead of the negative. As charging continues, this oxygen recombines with the hydrogen being generated by the negative, forming water. The water content of the electrolyte thus remains unchanged unless the charging rate is too high.

In case of rapid generation of oxygen gas exceeding the absorbing capacity of the negative plate, the pressure relief valve will open to release excessive gas.

## Deep Discharge

The Power-Sonic battery is protected against cell shorting by the addition of a buffering agent that insures the presence of acid ions even in a fully discharged state. The need for expensive circuitry in the design of a system to prevent deep discharge and possible cell shorting is thereby reduced considerably.

Power-Sonic defines “deep discharge” as one that allows the battery voltage under load to go below the cut-off (or “final”) voltage of a full discharge. The recommended cutoff voltage varies with the discharge rate for a 6 volt battery, for example, it is 5.25V at the 20-hour (0.05C) rate, 5.10V at the 4-hour (0.2C) rate, and 4.5V at the 1/2- hour(1.0C) rate.

It is important to note that deep discharging a battery at high rates for short periods is not nearly as severe as discharging a battery at low rates for long periods of time. To clarify, let’s, analyze two examples:

- Battery A is discharged at the 1C rate to zero volts. “C” for a 4 AH battery, for example, is 4 amps. Full discharge is reached after about 30 minutes when the battery voltage drops to 1.5V/cell. At this point, only 50% of rated capacity has been discharged (1C amps x 0.5 hrs = 0.5C Amp. Hrs.) Continuing the discharge to zero volts will bring the total amount of discharged ampere-hours to approximately 75% because the rapidly declining voltage quickly reduces current flow to a trickle. The battery will recover easily from this type of deep discharge.

- Battery B is discharged at the 0.01C rate to zero volts. 0.01C for a 4 AH battery is 40mA. Full discharge is reached after 100+ hours when the terminal voltage drops to 1.75 V/cell. At this point, the battery has already delivered 100% of its rated capacity (0.01 x 100 hrs = 1C Amp. Hrs.). Continuing the discharge to zero volts will keep the battery under load for another 4-5 days(!), squeezing out every bit of stored energy.

This type of “deep” discharge is severe and is likely to damage the battery. The sooner a severely discharged battery is recharged, the better its chances to fully recover.

# CAPACITY

The capacity of a battery is the total amount of electrical energy available from a fully charged cell or cells. Its value depends on the discharge current, the temperature during discharge, the final (cut-off) voltage and the general history of the battery.

Capacity, expressed in ampere-hours (AH) is the product of the current discharged and the length of discharge time. The rated capacity (C) of a Power-Sonic battery is measured by its performance over 20 hours of constant current discharge at a temperature of 68°F (20°C) to a cutoff voltage of 1.75 volts.

As an example, Model PS-610, with a rated capacity of 1AH will deliver 50 mA (1/20 of 1AH, or 0.05C ) for 20 hours before the voltage drops from 6.45 to 5.25 volts.

By cycling the battery a few times or float charging it for a month or two, the highest level of capacity development is achieved. Power-Sonic batteries are fully charged before leaving the factory, but full capacity is realized only after the battery has been cycled a few times or been on float charge for some time.

The table in *Figure 2* shows capacities for various multiples of the 20-hour discharge current.

| Rated Capacity | @ 0.05C rate (20 Hr. Rate.) | | @0.1C rate (9 Hr. Rate) | | @0.2C rate (4 Hr. Rate) | | @0.5C rate (1.3 Hr. Rate) | | @1C rate (33 Min. Rate) | | @2C rate (12 Min. Rate) | | @3C rate (7.2 Min. Rate) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Current Amps. | Capacity Amp. Hrs | Current Amps. | Capacity Amp. hrs. | Current Amps. | Capacity Amp.Hrs | Current Amps. | Capacity Amp. Hrs. | Current Amps. | Capacity Amp. hrs. | Current Amps. | Capacity Amp. Hrs. | Current Amps. | Capacity Amp. Hrs. |
| 0.5AH | 0.025 | 0.50 | 0.05 | 0.45 | 0.10 | 0.40 | 0.25 | 0.325 | 0.50 | 0.28 | 1.00 | 0.20 | 1.50 | 0.18 |
| 0.8AH | 0.04 | 0.80 | 0.08 | 0.72 | 0.16 | 0.64 | 0.40 | 0.52 | 0.80 | 0.44 | 1.60 | 0.32 | 2.40 | 0.29 |
| 1.0AH | 0.05 | 1.00 | 0.10 | 0.90 | 0.20 | 0.80 | 0.50 | 0.65 | 1.00 | 0.56 | 2.00 | 0.40 | 3.00 | 0.36 |
| 1.3AH | 0.065 | 1.30 | 0.13 | 1.17 | 0.26 | 1.04 | 0.65 | 0.845 | 1.30 | 0.715 | 2.60 | 0.52 | 3.90 | 0.47 |
| 2.3AH | 0.115 | 2.30 | 0.23 | 2.07 | 0.46 | 1.84 | 1.15 | 1.495 | 2.30 | 1.288 | 4.60 | 0.92 | 6.90 | 0.83 |
| 3.0AH | 0.15 | 3.00 | 0.30 | 2.70 | 0.60 | 2.40 | 1.50 | 1.95 | 3.00 | 1.65 | 6.00 | 1.20 | 9.00 | 1.08 |
| 3.2AH | 0.16 | 3.20 | 0.32 | 2.88 | 0.64 | 2.56 | 1.60 | 2.08 | 3.20 | 1.76 | 6.40 | 1.28 | 9.60 | 1.15 |
| 4.5AH | 0.22 | 4.40 | 0.45 | 4.05 | 0.90 | 3.60 | 2.25 | 2.92 | 4.5 | 2.47 | 9.00 | 1.80 | 13.50 | 1.62 |
| 5.0AH | 0.25 | 5.00 | 0.50 | 4.50 | 1.00 | 4.00 | 2.50 | 3.25 | 5.00 | 2.80 | 10.00 | 2.00 | 15.00 | 1.80 |
| 6.5AH | 0.325 | 6.50 | 0.65 | 5.85 | 1.30 | 5.20 | 3.25 | 4.23 | 6.50 | 3.64 | 13.00 | 2.60 | 19.50 | 2.34 |
| 7.0AH | 0.35 | 7.00 | 0.70 | 6.30 | 1.40 | 5.60 | 3.50 | 4.55 | 7.00 | 3.85 | 14.00 | 2.80 | 21.00 | 2.52 |
| 8.0AH | 0.40 | 8.00 | 0.80 | 7.20 | 1.60 | 6.40 | 4.00 | 5.20 | 8.00 | 4.48 | 16.00 | 3.20 | 24.00 | 2.88 |
| 9.0AH | 0.45 | 9.00 | 0.90 | 8.10 | 1.80 | 7.20 | 4.50 | 5.85 | 9.00 | 5.04 | 18.00 | 3.60 | 27.00 | 3.24 |
| 10.0AH | 0.50 | 10.00 | 1.00 | 9.00 | 2.00 | 8.00 | 5.00 | 6.50 | 10.00 | 5.60 | 20.00 | 4.00 | 30.00 | 3.60 |
| 12.0AH | 0.60 | 12.00 | 1.20 | 10.80 | 2.40 | 9.60 | 6.00 | 7.80 | 12.00 | 6.72 | 24.00 | 4.80 | 36.00 | 4.32 |
| 18.0AH | 0.90 | 18.00 | 1.80 | 16.20 | 3.06 | 14.40 | 9.00 | 11.70 | 18.00 | 9.90 | 36.00 | 7.20 | 54.00 | 6.48 |
| 20.0AH | 1.00 | 20.00 | 2.00 | 18.00 | 4.00 | 16.00 | 10.00 | 13.00 | 20.00 | 11.20 | 40.00 | 8.00 | 60.00 | 7.20 |
| 26.0AH | 1.30 | 26.00 | 2.60 | 23.40 | 5.20 | 20.80 | 13.00 | 16.90 | 26.00 | 14.30 | 52.00 | 10.40 | 78.00 | 9.36 |
| 28.0AH | 1.40 | 28.00 | 2.80 | 25.20 | 5.40 | 21.60 | 14.00 | 18.20 | 28.00 | 15.40 | 54.00 | 10.88 | 84.00 | 10.08 |
| 33.0AH | 1.65 | 33.00 | 3.30 | 29.70 | 6.60 | 26.40 | 16.50 | 21.45 | 33.00 | 18.15 | 66.00 | 13.20 | 99.00 | 11.88 |
| 40.0AH | 2.00 | 40.00 | 4.00 | 36.00 | 8.00 | 32.00 | 20.00 | 26.00 | 40.00 | 22.40 | 80.00 | 16.00 | 120.00 | 14.40 |
| 55.0AH | 2.75 | 55.00 | 5.50 | 49.50 | 11.00 | 44.00 | 27.50 | 35.75 | 55.00 | 30.25 | 110.00 | 22.00 | 165.00 | 19.80 |
| 60.0AH | 3.00 | 60.00 | 6.00 | 54.00 | 12.00 | 48.00 | 30.00 | 39.00 | 60.00 | 33.60 | 120.00 | 24.00 | 180.00 | 21.60 |
| 75.0AH | 3.75 | 75.00 | 7.50 | 67.50 | 15.00 | 60.00 | 37.50 | 48.75 | 75.00 | 41.25 | 150.00 | 30.00 | 225.00 | 27.00 |
| 80.0AH | 4.00 | 80.00 | 8.00 | 72.00 | 16.00 | 64.00 | 40.00 | 52.00 | 80.00 | 44.80 | 160.00 | 32.00 | 240.00 | 28.80 |
| 100.0 AH | 5.00 | 100.00 | 10.00 | 90.00 | 20.00 | 80.00 | 50.00 | 65.00 | 100.00 | 55.00 | 200.00 | 40.00 | 300.00 | 36.00 |

*Figure 2*

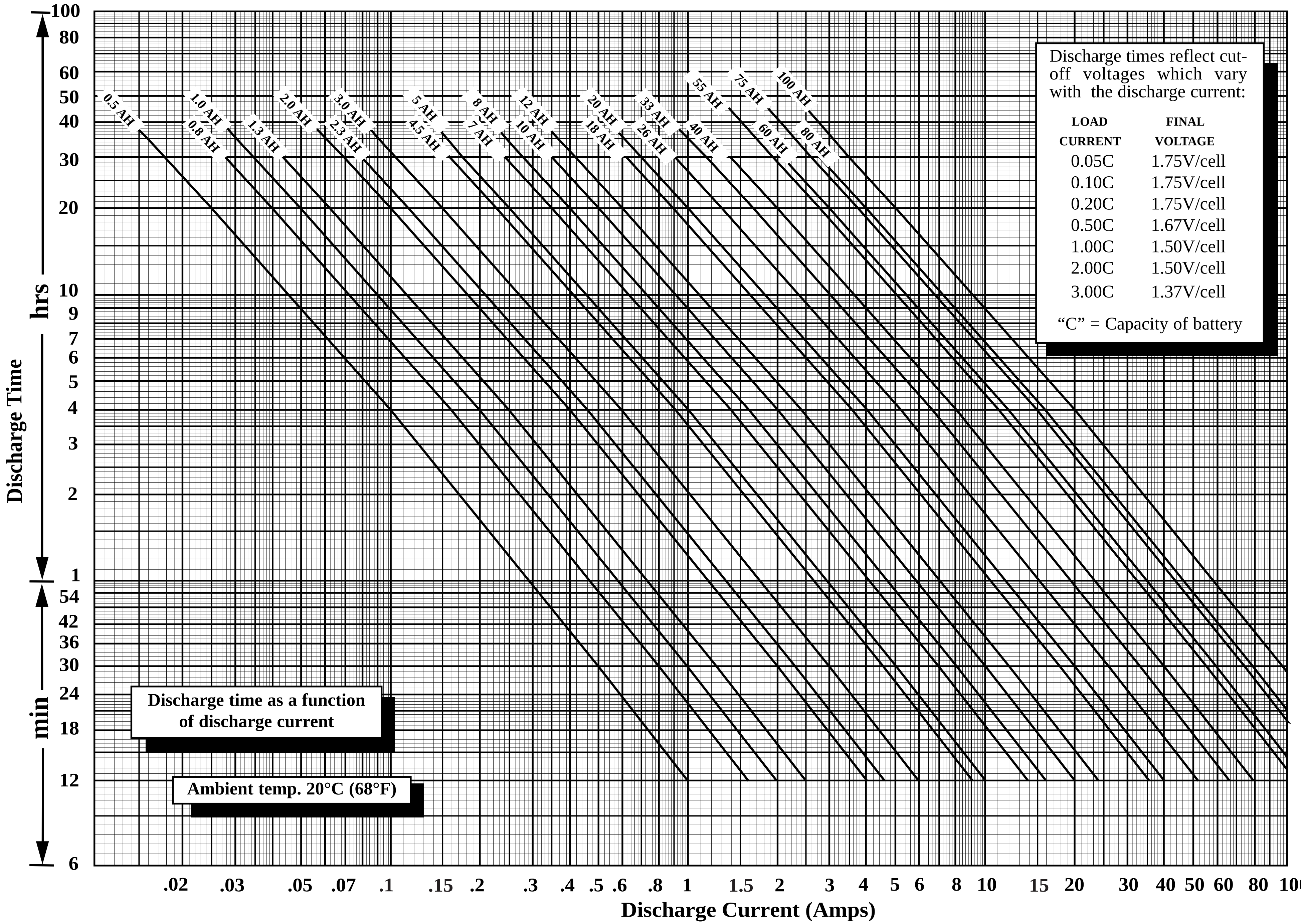
When a battery discharges at a constant rate, its capacity changes according to the amperage load. Capacity increases when the discharge current is less than the 20-hour rate and decreases when the current is higher.

*Figure 3* shows capacity curves for major Power-Sonic battery models with different ampere-hour ratings. Amperage is on the horizontal scale and the time elapsed is on the vertical scale; the product of these values is the capacity.

Proper battery selection for a specific application can be made from this graph if the required time and current are known. For example, to determine the proper capacity of a battery providing 3 amps for 20 minutes, locate the intersection of these values on the graph. The curve immediately above that point represents the battery which will meet the requirement.

# CAPACITY VARIATION BY CURRENT LOAD

*Figure 3*



## Discharge

During discharge the voltage will decrease. The graphs in *Figure 4* illustrate this for different discharge rates and ambient temperatures. "C" is the rated capacity of a battery: "C" for Model PS-610 (6V - 1AH) is 1AH. By convention, rating of nearly all sealed-lead acid batteries, including Power-Sonic, is based on a 20-hour (0.05C) discharge rate .

An important feature of Power-Sonic batteries is shown in the discharge curves; namely, the voltage tends to remain high and almost constant for a relatively long period before declining to an end voltage.

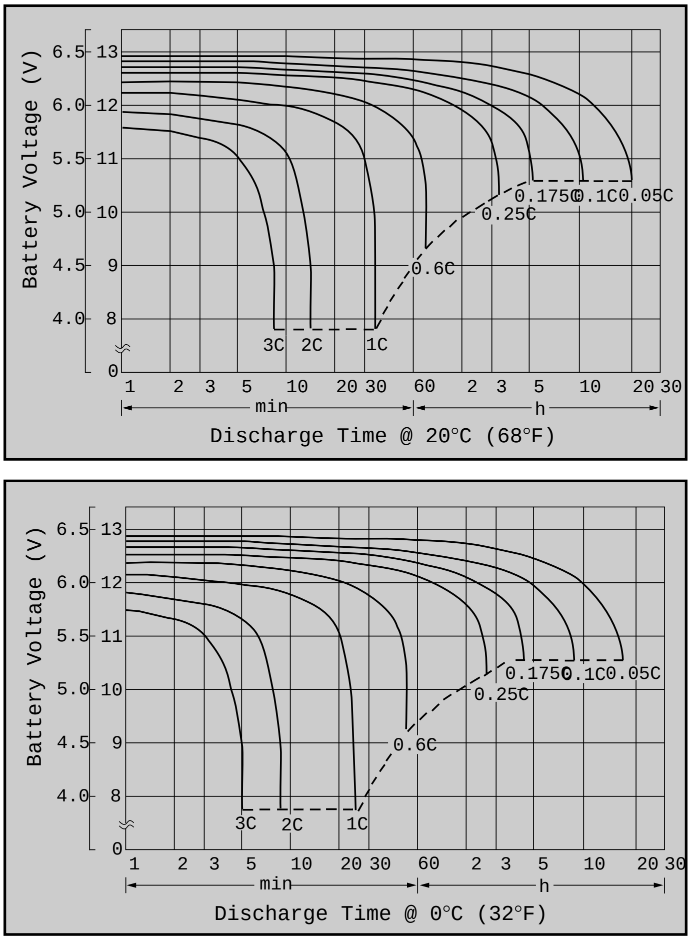



*Figure 4: Characteristic Discharge Curves*

## Open-Circuit Voltage

Open circuit voltage varies according to ambient temperature and the remaining capacity of the battery. Generally, open circuit voltage is determined by the specific gravity of the electrolyte. Discharging a battery lowers the specific gravity. Consequently, it is possible to determine the approximate remaining capacity of a battery from the terminal voltage.

The open circuit voltage of a Power-Sonic battery is 2.15 V/cell when fully charged and 1.94 V/cell when completely discharged.

As seen in *Figure 4,* under load, the battery can deliver useful energy at less than 1.94 V/cell, but after the load is removed the open circuit voltage will "bounce back" to voltages shown in *Figure 5*, dependent upon residual capacity.

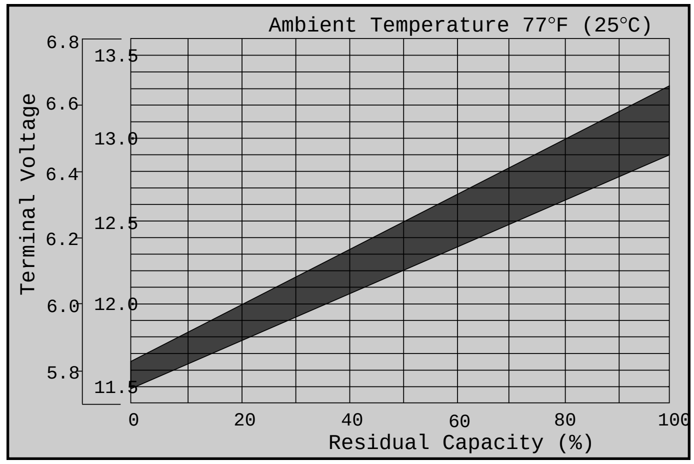



*Figure 5: Open-Circuit Voltage Characteristics*

## Temperature

Actual capacity is a function of ambient temperature and rate of discharge. At 68°F (20°C) rated capacity is 100%. The capacity increases slowly above this temperature and decreases as the temperature falls. Even at -40°F (-40°C), however , the Power-Sonic battery will still function at better than 30% of its rated capacity when discharged at the 20-hour rate (0.05C). At any ambient temperature, the higher the rate of discharge, the lower the available capacity. This relationship is shown in *Figure 6*.

Power-Sonic batteries may be discharged at temperatures ranging from -40°F to 140°F (-40°C to 60°C) and charged at temperatures from -4°F to 122°F (-20°C to 50°C).

While raising ambient temperature increases capacity, it also decreases useful service life. It is estimated that battery life is halved for each 10°C above normal room temperature.

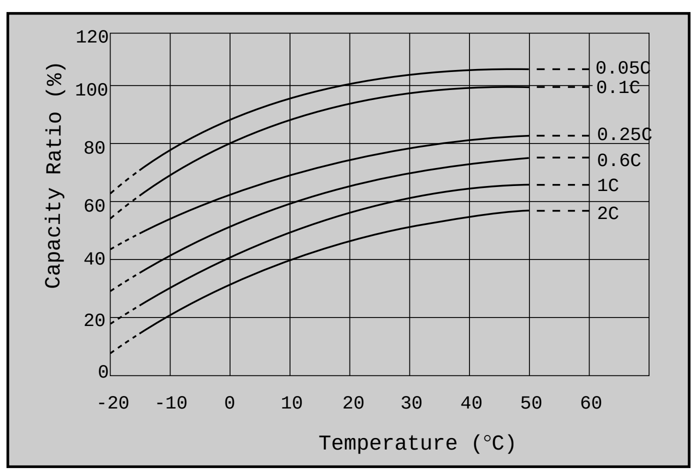



*Figure 6: Effect of Temperature on Capacity*

*Figure 7* shows the relationship between current and discharge time for different ambient temperatures.

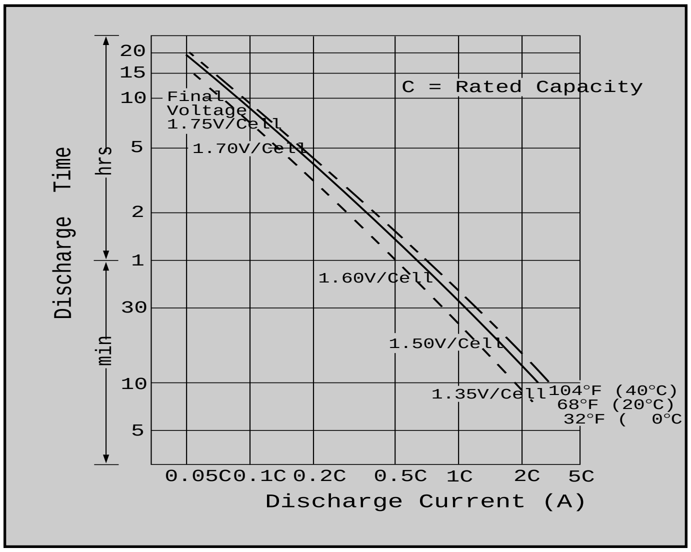



*Figure 7: Discharge Time vs. Discharge Current*

## Shelf Life & Storage

Low internal resistance and special alloys in the electrodes assure a low self discharge rate and, consequently, a long shelf life. If kept at 68°F (20°C), about 60-70% of the nominal capacity remains after one year of storage. One recharge per year is sufficient to maintain the original capacity of a battery not in use.

The rate of self discharge varies with the ambient temperature. At room temperature it is about 3% per month. At low temperatures it is nearly negligible, at higher ambient temperatures self discharge increases.

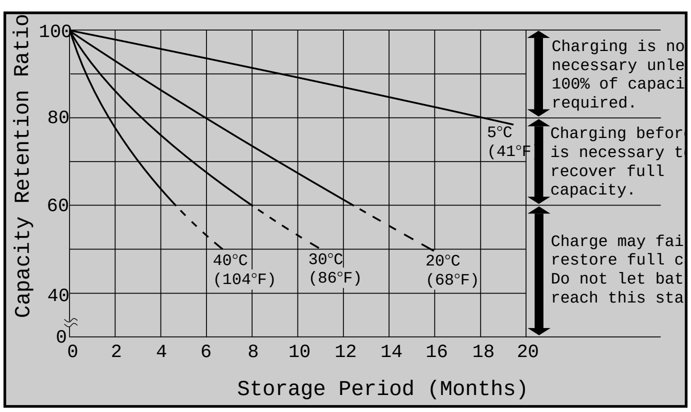



*Figure 8: Self Discharge Characteristics*

To obtain maximum battery life and performance, batteries should be:

- recharged as soon as possible after each use and not stored in a discharged state;
- stored at 68°F (20°C) or lower, if possible, and
- recharged annually when not used.

## Battery Life

**Cyclic Use:** The number of charge/discharge cycles depends on the capacity taken from the battery (a function of discharge rate and depth of discharge), operating temperature and the charging method.

*Figure 9* shows the relationship between depth of discharge and number of cycles as well as increases of capacity during the early cycles.

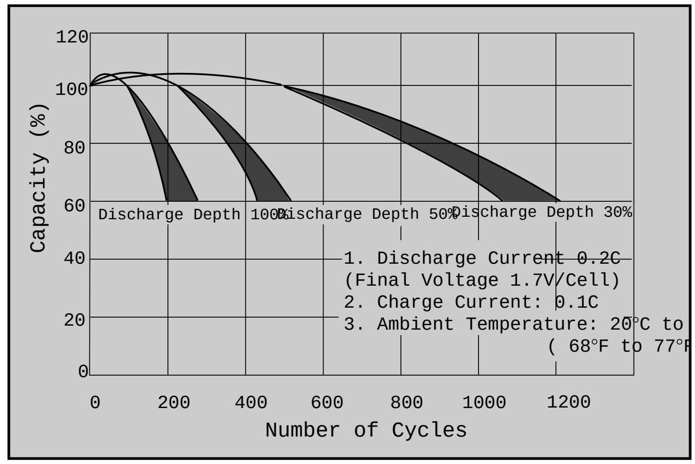



*Figure 9: Depth of Discharge vs. Number of Cycles*

**Standby Use:** The float service life, or life expectancy under continuous charge, depends on the frequency and depth of discharge, the charge voltage, and the ambient temperature. At a float voltage of 2.25V to 2.30V/cell and an ambient temperature of 60°F to 77°F (20°C to 25°C) Power-Sonic batteries should last four to five years before the capacity drops to 60% of its original rating.

*Figure 10* indicates how capacity changes over time.

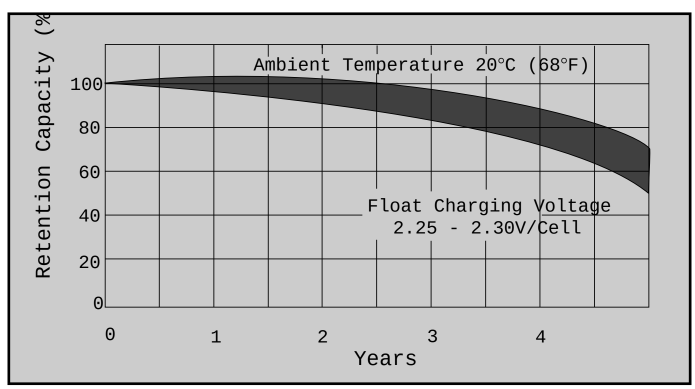



*Figure 10: Life Characteristics in Standby Use*

# PERFORMANCE DATA

The graph in *Figure 11* shows life characteristics in float (standby) service for ambient temperatures ranging from 15°C to 55°C

If prevailing ambient temperatures are well above 20-25°C the life expectancy of this type of battery in float service depends greatly on temperature compensated charging. The typical temperature coefficient is -2mV/cell/°C. The graph shown along side is based on temperature compensated charging.

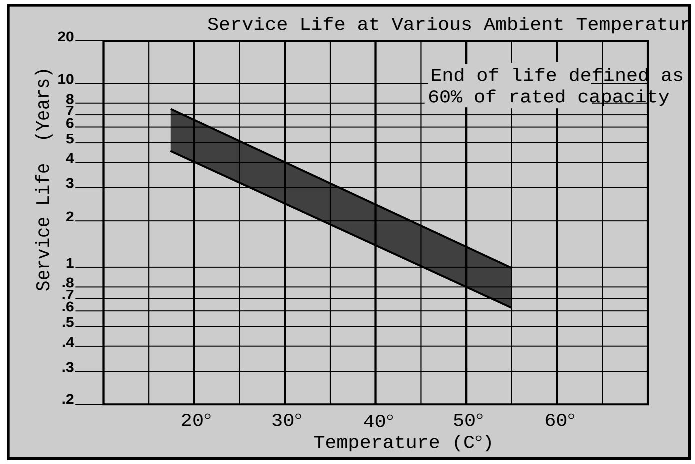



*Figure 11: Service Life at Various Ambient Temperatures*

# OVER-DISCHARGE PROTEC-

To optimize battery life, it is recommended that the battery be disconnected from the load when the end voltage – a function of the discharge rate – is reached. It is the voltage point at which 100% of the usable capacity of the battery has been consumed or continuation of the discharge is useless because of the voltage dropping below useful levels. (see section on Deep Discharge on page 3)

Discharging a sealed lead-acid battery below this voltage or leaving a battery connected to a load will impair the battery's ability to accept a charge. To prevent potential over-discharge problems, voltage cut-off circuits as shown in *Figure 12* may be used.

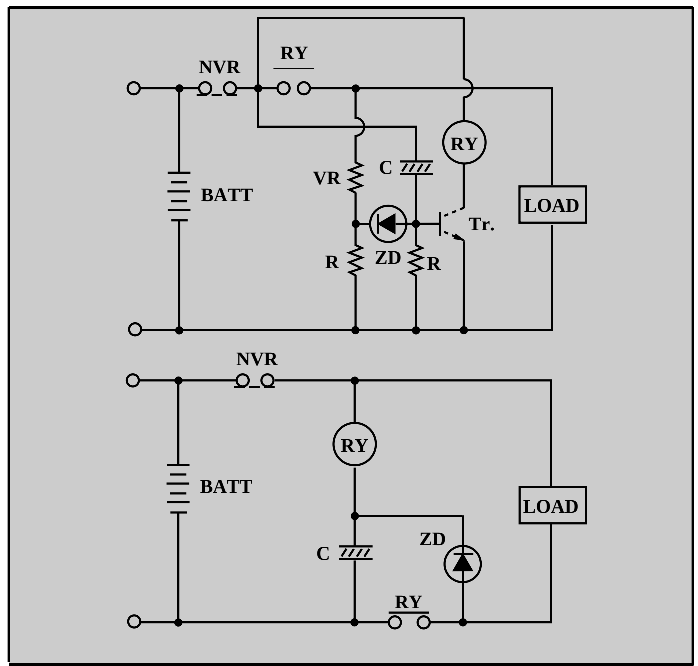



*Figure 12: Circuits of Over-Discharge Preventive Device*

# CHARGING

Dependable performance and long service life depend upon correct charging. Faulty procedures or inadequate charging equipment result in decreased battery life and/or unsatisfactory performance. The selection of suitable charging circuits and methods is as important as choosing the right battery for the application.

## General

To charge a Power-Sonic battery, a DC voltage higher than the open-circuit voltage of 2.15 is applied to the terminals of the battery. Depending on the state of charge, the cell may temporarily be lower (after discharge) or higher (right after charging) than 2.15 volts. After some time, however, it should level off at about 2.15 volts per cell.

Power-Sonic batteries may be charged by using any of the conventional charging techniques. To obtain maximum service life and capacity, along with acceptable recharge time and economy, constant voltage-current limited charging is recommended.

During charge, the lead sulfate of the positive plate becomes lead dioxide. As the battery reaches full charge, the positive plate begins generating dioxide causing a sudden rise in voltage. A constant voltage charge, therefore, allows detection of this voltage increase and thus control of the charge amount.

**Overcharging:** As a result of too high a charge voltage excessive current will flow into the battery after reaching full charge causing decomposition of water in the electrolyte and, hence, premature aging.

At high rates of overcharge a battery will progressively heat up. As it gets hotter, it will accept more current, heating up even further. This is called thermal runaway, and can destroy a battery in as little as a few hours.

**Undercharging:** If too low a charge voltage is applied, the current flow will essentially stop before the battery is fully charged. This allows some of the lead sulfate to remain on the electrodes which will eventually reduce capacity.

Batteries which are stored in a discharged state, or left on the shelf for too long, may initially appear to be "open circuited" or will accept far less current than normal. This is caused by a phenomenon called "sulfation". When this occurs, leave the charger connected to the battery. Usually, the battery will start to accept increasing amounts of current until a normal current level is reached. If there is no response, even to charge voltages above recommended levels, the battery may have been in a discharged state for too long to recover.

## Charging Characteristics

During constant voltage or taper charging, the battery's current acceptance decreases as voltage and state of charge increase. The battery is fully charged once the current stabilizes at a low level for a few hours.

**Caution:** Never charge or discharge a battery in a hermetically sealed enclosure. Batteries generate a mixture of gases internally. Given the right set of circumstances, such as extreme overcharging or shorting of the battery, these gases might vent into the enclosure and create the potential for an explosion when ignited by a spark.

If in doubt, or concepts of proper use and care are unclear, contact Power-Sonic's department for application engineering at 619-661-2020.

Please note that there are two criteria for determining when a battery is fully charged: (1) the final current level and (2) the peak charging voltage while this current flows.

*Figure 13* depicts an example of typical charge characteristics for cycle service where charging is non-continuous and peak voltage can, therefore, be higher.

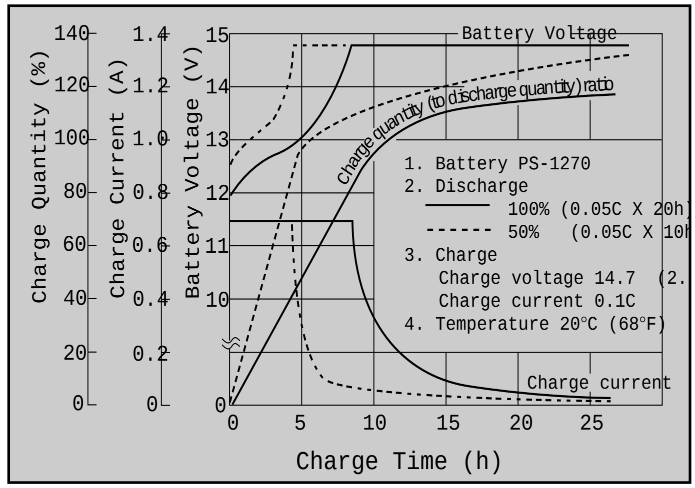



*Figure 13: Charge characteristics for 14.7V Constant Voltage*

*Figure 14* illustrates typical characteristics for standby service type charge. Here, charging is continuous and the peak charge voltage must, therefore, be lower.

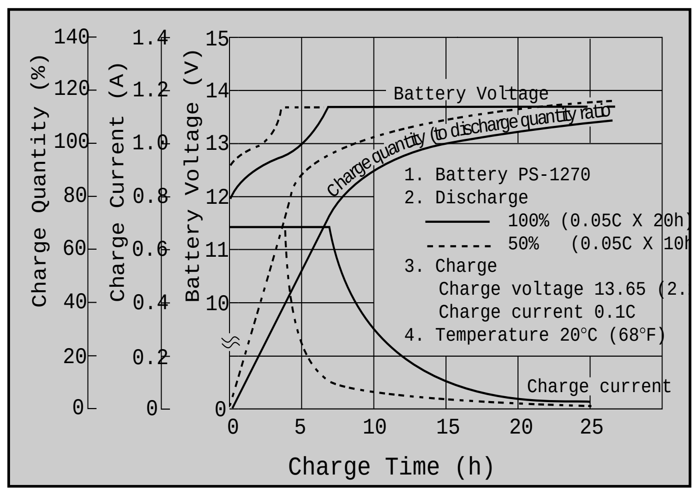



*Figure 14: Charge Characteristics for 13.65V Constant Voltage*

## Charging Methods

Selecting the appropriate charging method depends on the intended use (cyclic or float service), economic considerations, recharge time, anticipated frequency and depth of discharge, and expected service life. The key goal of any charging method is to control the charge current at the end of the charge.

**Taper Charging:** This is the simplest, least expensive charging method. Either quasi-constant voltage or quasi-constant current characteristics can be built into the charger through combination of transformer, diode and resistance. Of the two, constant potential charging is preferable.

Typical taper chargers are comprised of small transformer-rectifier circuits wherein the transformer is so designed that the current is limited to the maximum initial charge current for the battery. This current is held constant until the terminal voltage and resultant current demand reach a point at which the charge current begins to fall. Although this type of charger can provide a relatively fast recharge, it is basically a constant current device and the charge voltage may be driven too high. Therefore, it must be disconnected, usually within 12-24 hours, or after 100-120% of the preceding discharge has been returned. It is also sensitive to line voltage variations which can cause over- or under-charging. Consequently, this charging method can only be used in cyclic applications

*Figure 15* shows an example of a typical diagram and *Figure 16* the resultant charge characteristics for this type of basically unregulated charger.

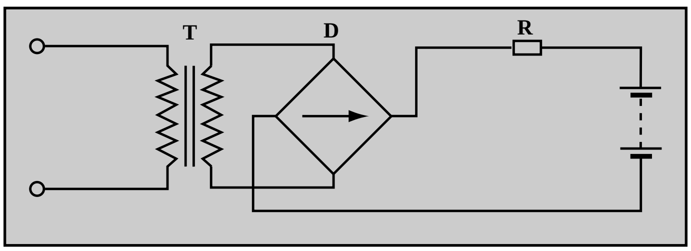



*Figure 15: Semi-Constant Current Charging Circuit*

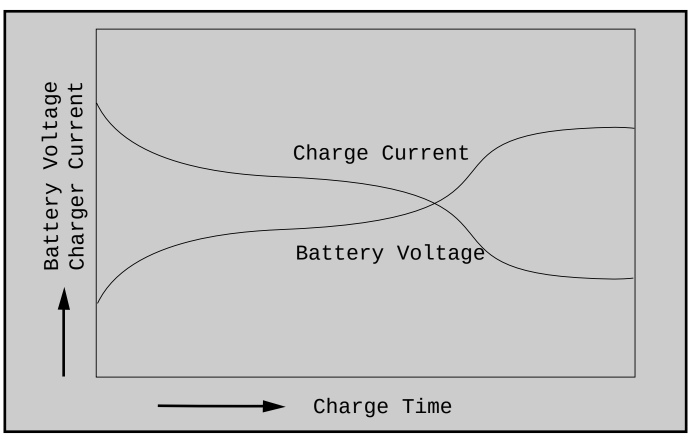


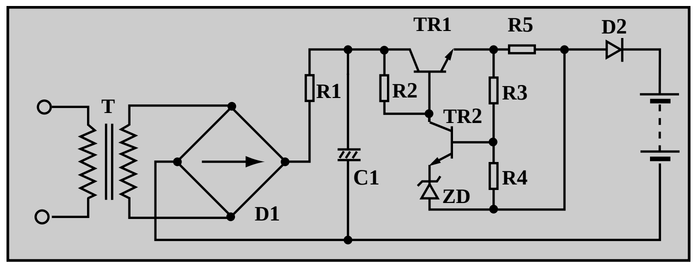

*Figure 16: Semi-Constant Current Charge Characteristics*

**Constant Current Charging:** Constant current charging is suited for applications where discharged ampere-hours of the preceding discharge cycle are known. Charge time and charge quantity can easily be calculated, however an expensive circuit is necessary to obtain a highly accurate constant current. Monitoring of charge voltage or limiting of charge time is necessary to avoid excessive overcharge.

While this charging method is very effective for recovering the capacity of a battery that has been stored for an extended period of time, or for occasional overcharging to equalize cell capacities, it lacks specific properties required in today's electronic environment.

An example of a constant current charge circuit is shown in *Figure 17* and the charge characteristics for this type of charger in *Figure 18*.

*Figure 17: Constant Current Charging Circuit*



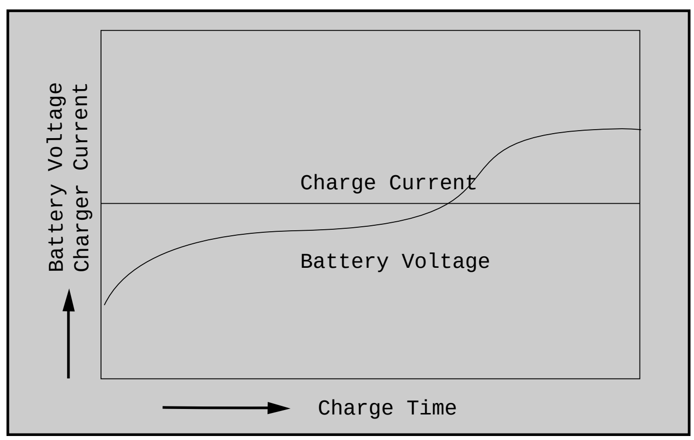




*Figure 18: Constant Current Charge Characteristics*

**Constant Voltage Charging:** Constant current/constant voltage charging is the best method to charge Power-Sonic batteries. Depending on the application, batteries may be charged either on a continuous or non-continuous basis. In applications where standby power is required to operate when the AC power has been interrupted, continuous float charging is recommended. Non-continuous cyclic charging is used primarily with portable equipment where charging on an intermittent basis is appropriate.

The constant current/constant voltage charge method applies a constant voltage to the battery and limits the initial charge current. It is necessary to set the charge voltage according to specified charge and temperature characteristics. Inaccurate voltage settings cause over- or under-charge. This charging method can be used for both cyclic and standby applications.

*Figures 19* and *20* illustrate examples of a constant current/constant voltage charging circuit and charging characteristics, respectively. The circuit diagram includes a temperature compensation feature for charge voltage to ensure optimum charging conditions regardless of changes in ambient temperature.

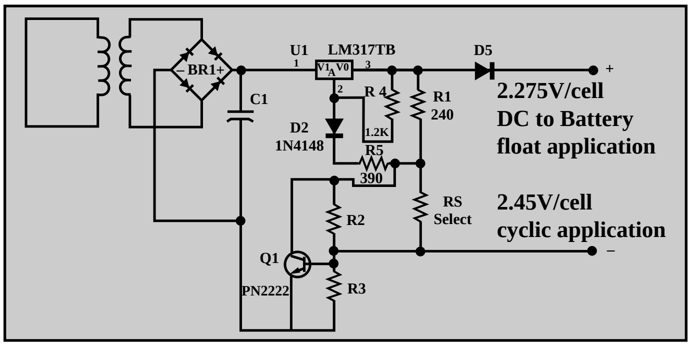



*Figure 19: Constant Current/Constant Voltage Charge Circuit*

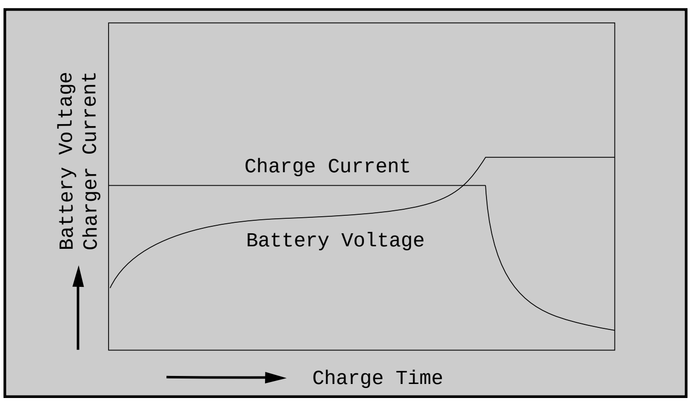



*Figure 20: Constant Current/Constant Voltage Charge Characteristics*

## Charging for Cycle Operation

Cyclic applications generally require that recharging be done in a relatively short time. The initial charge current, however, must not exceed 0.20 x C amps. Just as battery voltage drops during discharge, it slowly rises during charge. Full charge is determined by voltage and inflowing current. When, at a charge voltage of 2.45 ±0.05 volts/cell, the current accepted by the battery drops to less than 0.01 x C amps (1% of rated capacity), the battery is fully charged and the charger should be disconnected or switched to a float voltage of 2.25 to 2.30 volts/cell. The voltage should not be allowed to rise above 2.45 ±0.05 volts/cell.

## Charging for Standby Operation

Standby applications generally do not require that the battery be charged as fast or as frequently as in cycle operation. However, the battery must be kept constantly charged to replace the energy that is expended due to internal loss and deterioration of the battery itself. Although these losses are very low in Power-Sonic batteries, they must be replaced at the rate the battery self-discharges; at the same time the battery must not be given more than these losses or it will be overcharged. To accomplish this, a constant voltage method of charging called "float charging" is used.

The recommended constant float voltage is 2.25-2.30 volts per cell. Maintaining this float voltage will allow the battery to define its own current level and remain fully charged without having to disconnect the charger from the battery. The trickle current for a fully charged battery floating at the recommended charge voltage will typically hover around the 0.001C rate (10mA for a 10AH battery, for example.)

The float charger is basically a constant voltage power supply. As in cycle chargers, however, care must be exercised not to exceed the initial charge current of 0.20 x C amperes.

## Two-Step Constant Voltage Charging

This method uses two constant voltage devices. In the initial charge phase the high voltage setting is used. When charging is nearly complete and the charge voltage has risen to a specified value (with the charge current decreased), the charger switches the voltage to the lower setting. This method allows rapid charging in cycle or float service without the possibility of overcharging even after extended charging periods.

The graph in *Figure 21* shows charging characteristics, and the diagram in *Figure 22* an example of a charging circuit for this type of charger.

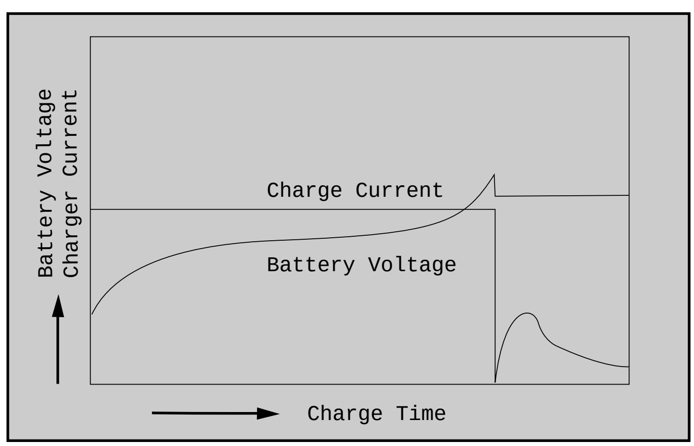



*Figure 21: Two-Step Constant Voltage Charge Characteristics*

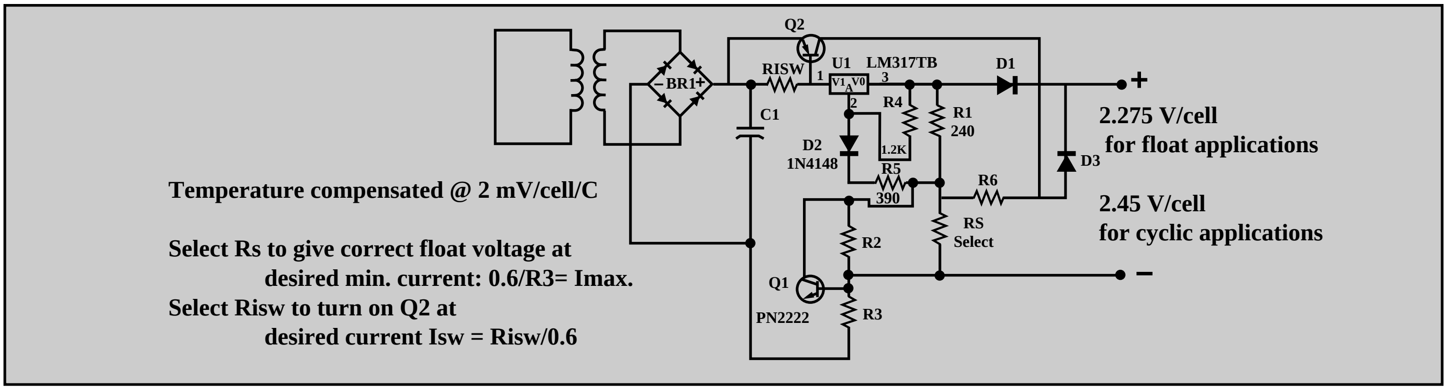



*Figure 22: Dual Stage Current Limited Battery Charger*

**Charging in Series:** Lead-acid batteries are strings of 2 volt cells connected in series, commonly 2, 3 ,4 or 6 cells per battery. Strings of Power-Sonic batteries up to 48 volts and higher may be charged in series safely and efficiently. However, as the number of batteries in series increases, so does the possibility of slight differences in capacity. These differences can result from age, storage history, temperature variations or abuse.

When a single constant voltage charger is connected across an entire high voltage string, the same current flows through all cells in the string. Depending on the characteristics of the individual batteries, some may overcharge while others remain in a slightly undercharged condition. When charging high voltage strings this way for extended periods it is generally recommended to use a low input voltage inverter to enhance service life and simplify charging requirements.

If one cell is lower in capacity than the others when discharging a long string in series, it may actually reverse polarity even though the total voltage of the string is at or above the cut-off voltage.

To minimize the effects of individual battery differences, use batteries of the same age and history and, if possible, charge in strings of no greater than 24 or 48 volts.

**Charging in Parallel:** Power-Sonic batteries may be used in parallel with one or more batteries of equal voltage.

When connected in parallel, the current from a charger will tend to divide almost equally between the batteries. No special matching of batteries is required. If the batteries of unequal capacity are connected in parallel, the current will tend to divide between the batteries in the ratio of capacities (actually, internal resistances).

When charging batteries in parallel, where different ratios of charge are to be expected, it is best to make provisions to assure that the currents will not vary too much between batteries. Holding a small resistance in series with each battery is all that is needed

## Temperature Compensation

Power-Sonic batteries perform well both at low and high temperatures. At low temperatures, however, charge efficiency is reduced; at temperatures above 45°C, charge efficiency increases so rapidly that there is a danger of thermal runaway if temperature compensation is not precise.

The effect of temperature on charge voltage is less critical in float applications, than in cyclic use where relatively high charge currents are applied for the purpose of short recharge times.

Temperature effects should definitely be considered when designing or selecting a charging system. As a rule of thumb, temperature compensation is desirable in the charging circuit when operating outside the range of 41°F to 95°F (5°C to 35°C) prevailing ambient. The temperature coefficient is -2mV/cell/°C below 20°C in standby service and -6mV/cell/°C below 20°C in cyclic use. For higher temperatures the charge voltage should be correspondingly decreased.

The table in *Figure 23* lists recommended charge voltages for different temperatures.

| AMBIENT TEMPERATURE | CHARGE VOLTAGE PER CELL | |
|---|---|---|
| | Cyclic use | Float Use |
| 4°F (-20°C) | 2.67-2.77V | 2.34-2.39V |
| 14°F (-10°C) | 2.61-2.71V | 2.32-2.37V |
| 32°F (0°C) | 2.55-2.65V | 2.30-2.35V |
| 50°F (+10°C) | 2.49-2.59V | 2.28-2.33V |
| 68°F (+20°C) | 2.43-2.53V | 2.26-2.31V |
| 77°F (+25°C) | 2.40-2.50V | 2.25-2.30V |
| 86°F (+30°C) | 2.37-2.47V | 2.24-2.29V |
| 104°F (+40°C) | 2.31-2.41V | 2.22-2.27V |
| 122°F (+50°C) | 2.25-2.35V | 2.20-2.25V |

*Figure 23: Temperature Compensated Charge Voltage*

**Power-Sonic rechargeable sealed lead-acid batteries are designed to provide years of dependable service. Adherence to the following guidelines in system design will ensure that battery life is maximized and operation is trouble-free.**

- Continuous over-or undercharging is the single worst enemy of a lead-acid battery. Caution should be exercised to ensure that the charger is disconnected after cycle charging, or that the float voltage is set correctly.

- Batteries should not be stored in a discharged state or at elevated temperatures. If a battery has been discharged for some time or the load was left on indefinitely, it may not readily take a charge. To overcome this, leave the charger connected and the battery should eventually begin to accept charge.

- Avoid exposing batteries to heat! Care should be taken to place batteries away from heat-emitting components. If close proximity is unavoidable, provide ventilation. Service life is shortened considerably at ambients above 30°C.

- Although Power-Sonic batteries have a low self-discharge rate which permits storage of a fully charged battery for up to a year, it is recommended that a battery be charged 6-9 months after receipt to account for storage from the date of manufacture to the date of purchase. Otherwise, permanent loss of capacity might occur as a result of sulfation. To prolong shelf life without charging, store batteries at 50°F (10°C) or less.

- Fasten batteries tightly and make provisions for shock absorption if exposure to shock or vibration is likely.

- Although it is possible to charge Power-Sonic batteries rapidly, i.e. in 6-7 hrs., it is not normally recommended. Unlimited current charging can cause increased off-gassing and premature drying. It can also produce internal heating and hot spots resulting in shortened service life. Too high a charge current will cause a battery to get progressively hotter. This can lead to “thermal runaway” and can destroy a battery in as little as a few hours.

- Caution: Never charge or discharge a battery in an airtight enclosure. Batteries generate a mixture of gases internally. Given the right set of circumstances such as extreme overcharging or shorting of the battery, these gases might vent into the enclosure and create the potential for an explosion when ignited by a spark. Generally, ventilation inherent in most enclosures is sufficient to avoid problems.

- Do not place batteries in close proximity to objects which can produce sparks or flames, and do not charge batteries in an inverted position.

- When charging batteries in series (positive terminal of one battery is connected to the negative terminal of another), all batteries in the string will receive the same amount of charge current, though individual battery voltages may vary.

- When charging batteries in parallel (positive terminals are connected to the positive terminal and negative terminals to the negative), all batteries in the string will receive the same charge voltage but the charge current each battery receives will vary until equalization is reached.

- High voltage strings of batteries in series should be limited to twenty 6 volt or ten 12 volt batteries when a single constant voltage charger is connected across the entire string . Differences in capacity can cause some batteries to overcharge while others remain undercharged thus causing premature aging of batteries. It is, therefore, not advisable to mix batteries of different capacities, make, or age in a series string.

To minimize the effects of cell or battery differences, charge the string in 24 volt battery groups through a constant current source with zener diode regulation across individual batteries or battery groups.

- To prevent problems arising from heat exchange between batteries connected in series or parallel, it is advisable to provide air space of at least 0.4” (10mm) between batteries.

- Battery containers, made of ABS plastic or styrene, can sustain damage if exposed to organic solvents or adhesives.

- Recharge time depends on the depth of the preceding discharge and the output current of the charger. To determine the approximate recharge time of a fully discharged battery, divide the battery’s capacity (amp. hrs.) by the rated output of the charger (amps.) and multiply the resulting number of hours by a factor of 1.75 to compensate for the declining output current during charge. If the amount of amp. hrs. discharged from the battery is known, use it instead of the battery’s capacity to make the calculation.

- For best results and generally acceptable performance and longevity, keep operating temperature range between -20°C and +40°C.

- Do not attempt to disassemble batteries. Contact with sulfuric acid may cause harm. Should it occur, wash skin or clothes with liberal amounts of water. Do not throw batteries into fire; batteries so disposed may rupture or explode. Disassembled batteries are hazardous waste and must be treated accordingly. It is unlawful to dispose of batteries except through a recycling center.

# GLOSSARY

**Ambient Temperature**
The prevailing surface temperature to which a battery is exposed.

**Ampere**
Unit of measurement for electric current.

**Ampere-Hour**
The product of current (amperes) multiplied by time (hours). Used to indicate the capacity of a battery. Also Amp.Hr. or A.H.

**Battery**
Two or more cells connected together, most typically in series.

**Capacity**
The electrical energy available from a cell or battery expressed in ampere-hours.
*Available capacity* refers to ampere-hours that can be discharged from a battery based on its state of charge, rate of discharge, ambient temperature, and specified cut-off voltage.
*Rated capacity* (“C”) is the discharge capacity the manufacturer says may be obtained at a given discharge rate and temperature.

**Cell**
The basic building block of a battery. The nominal voltage of a lead-acid battery is 2 volts.
*Cell reversal* **–** the act of driving a cell into reverse polarity by excessive discharge.
*Primary cell* **–** cell or battery that can be discharged only once.
*Secondary cell* – the process is reversible so that charging and discharging may be repeated over and over.

**Charge**
The conversion of electrical energy to chemical energy; the process which restores electrical energy to a cell or battery.
*Charge retention* refers to a battery’s ability to hold a charge. It diminishes during storage.
*Charge acceptance* quantifies the amount of electric charge which accumulates in a battery.
*Float charge* maintains the capacity of a cell or battery by applying a constant voltage.
*Trickle charge* maintains the capacity of a cell or battery by applying a small constant current.
*Charge equalization* brings all of the cells in a battery or string to the same state of charge.

**Discharge**
The process of drawing current from a battery.
*Deep Discharge* **–** the discharge of a cell or battery to between 80% and 100% of rated capacity.
*Depth of Discharge* **–** the mount of capacity – typically expressed as a percentage – removed during discharge.
*Self Discharge* **–** the loss of capacity while stored or not in use.
*Self Discharge Rate* **–** the percent of capacity lost on open circuit over a specified period of time.

**Electrode**
Positive or negative plate containing materials capable of reacting with electrolyte to produce or accept current.

**Energy Density**
Ratio of battery energy to volume or weight expressed in watt-hours per cubic inch or pound.

**Gas Recombination**
The process by which oxygen gas generated from the positive plate during the final stage of charge is absorbed into the negative plate, preventing loss of water.

**Impedance**
The resistive value of a battery to an AC current expressed in ohms (Ω). Generally measured at 1000 Hz at full charge.

**Internal Resistance**
The resistance inside a battery which creates a voltage drop in proportion to the current draw.

**Nominal Voltage / Nominal Capacity**
The nominal value of rated voltage / the nominal value of rated capacity. The nominal voltage of a lead-acid battery is 2 volts per cell.

**Open Circuit Voltage**
The voltage of a battery or cell when measured in a no load condition.

**Parallel Connection**
Connecting a group of batteries or cells by linking all terminals of the same polarity. This increases the capacity of the battery group.

**Series Connection**
The connection of a group of cells or batteries by linking terminals of opposite polarity. This increases the voltage of the battery group.

**Separator**
Material isolating positive from negative plates. In sealed lead-acid batteries it normally is absorbent glass fiber to hold the electrolyte in suspension.

**SLA Battery**
Sealed lead-acid battery, generally having the following characteristics: Maintenance-free, leak-proof, position-insensitive. Batteries of this type have a safety vent to release gas in case of excessive internal pressure build-up. Hence also the term: Valve regulated battery.
*“Gel Cells”* are SLA batteries whose dilute sulfuric acid electrolyte is immobilized by way of additives which turn the electrolyte into a gel.

**Standby Service**
An application in which the battery is maintained in a fully charged condition by trickle of float charging.

**State of Charge**
The available capacity of a battery at a given time expressed as a percentage of rated capacity.

**Thermal Runaway**
A condition in which a cell or battery on constant potential charge can destroy itself through internal heat generation.

## Primary Power

- Portable Tools & Instruments
- Hand-held Lights
- Cordless & Portable Cellular Phones
- Power Packs
- Remote or Portable Data Gathering Devices
- Medical Apparatus
- Battery Powered Wheelchairs, Ride-on Toys
- Engine Starting Devices
- Robotics
- Consumer Electronics
- Hobby Craft

## Standby Power

- UPS Systems
- Emergency Lighting
- Fire & Burglar Alarm Systems
- Access Control Devices
- Telecommunications Equipment
- Electronic Equipment Requiring Memory Protection
- Solar Powered Systems
- Automotive Electronics

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PRINTED IN USA 25M 6/98