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GENESIS APPLICATION MANUAL

FIFTH EDITION

Hawker

MISSION STATEMENT

Always high performance.
Always high-reliability battery products.
Always.

Fifth Edition

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Certificate Number FM 32099
ISO 9001 Certified

Certificate Number EMS 39520
ISO 14001 Certified

GENESIS Application Manual

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Part 1 — Introduction

Background

When GENESIS was first introduced, the battery had certain features not necessarily required by some users. The flash arrestor vent system, angled terminals, lifting handles and UL 94V-0 rated non-halogenated flame-retardant case and cover material are cases in point.

Recognizing the need to offer more cost-effective alternatives to the user, without sacrificing any of the superior performance characteristics that have earned kudos for this unique battery, Hawker now offers two different models.

The thrust of the GENESIS battery program is to offer the same battery performance in different packaging options, having features tailored to individual requirements. See the ***GENESIS Selection Guide*** for packaging options.

Transportation classification

Effective September 30, 1995, GENESIS batteries were classified as “nonspillable batteries”, and are excepted from the Department of Transportation’s comprehensive packaging requirements if the following conditions are satisfied: (1) The battery is protected against short circuits and is securely packaged and (2) The battery and outer packaging must be plainly and durably marked “NONSPILLABLE” or “NONSPILLABLE BATTERY”. GENESIS shipments from the Hawker Warrensburg location, will be properly labeled in accordance with applicable regulations. **Packaging changes performed at other locations may require additional labeling, since in addition to the battery itself containing the required marking, the outer packaging of the battery must also contain the required marking: “NONSPILLABLE” or “NONSPILLABLE BATTERY”.**

GENESIS batteries have been tested and determined to be in compliance with the vibration and pressure differential tests contained in 49 CFR § 173.159(d).

Because GENESIS are classified as “Nonspillable” and meet the conditions above, [from § 173.159(d)] they do not have an assigned UN number nor do they require additional DOT hazard labeling.

The regulation change effective September, 1995, was to clarify and distinguish to shippers and transporters, all batteries that have been tested and determined to be in compliance with the DOT Hazardous Material Regulations, the International Civil Aeronautics Organization (ICAO), and the International Air Transport Association (IATA) Packaging Instruction 806 and Special Provision A67, and therefore excepted from all other requirements of these regulations and classified as a “nonspillable battery”.

UL component recognition

All GENESIS products are recognized as components per UL 1989.

Non-halogenated plastics

As the world becomes more environmentally aware, Hawker is striving to provide the most environmentally friendly products possible. With this in mind, we are proud to state that the plastics used in our GENESIS product line are non-halogenated and therefore do not contain any of the following materials:

-polybrominated biphenyls (PBB’s), polybrominated biphenyl ethers (PBBE’s), polybrominated biphenyloxides (PBBO’s), polybrominated diphenyl ethers (PBDPE’s), polybrominated diphenyl oxides (PBDPO’s), Tetrabromobisphenol-A (TBBA) or deca-bromo biphenyl ethers (DBBPE’s).

The battery meets the non-halogenated flame retardancy requirements of UL 94V-0 by utilizing plastics with non-halogenated frame retardants.

GE Plastics manufactures the Noryl material which is the plastic used in our GENESIS product line. Please note they do not use deca-bromo biphenyl ethers in any of their resin products. Also note that the Noryl resin which is used for the GENESIS product is not among the plastics which contain PBBE. Please note that the plastic does not contain TBBA.

The Noryl material which we use in the manufacture of the GENESIS products is in full compliance with the German Dioxin Ordinance of 1994.

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Key GENESIS benefits

The following is just a partial listing of GENESIS benefits. All of the features listed below have been incorporated into GENESIS to make a battery well suited for almost any application—be it high rate, low rate, float or cyclic.

- *Very high volumetric and gravimetric power densities at high rates of discharge*—offering more power in less space and weight.
- *Excellent high-rate discharge capability*—due to its thin plates.
- *Very low internal resistance*—allowing superior terminal voltage characteristics under high-rate discharges.
- *Negligible gassing*—gassing under normal charging conditions is minimal, making it safe for installation in human environments, such as offices and hospitals.
- *100% maintenance-free terminals*—making GENESIS a true fit-and-forget battery.
- *Flexible mounting orientation*—allowing users to place the battery in any position.
- *Advanced manufacturing techniques*—ensuring high reliability and consistency.
- *Use of very high purity lead-tin grid*—translating into lower corrosion rates and hence longer life.
- *Non-halogenated flame-retardant case and cover material option*—featuring an LOI > 28%, meeting UL 94V-0 requirements.
- *Excellent high-rate recharge capability*—allowing > 90% recharge in less than one hour.
- *Excellent storage capabilities*—providing long shelf life
- *Wide operating temperature capability*—GENESIS will perform in environments ranging from -40°C to +60°C (optional metal jacket required).
- *Greater performance at low temperatures*—At -20°C, GENESIS batteries will deliver 65% of its 15-minute room temperature capacity

Part 2 — Technical information

Introduction

This section constitutes the most important part of the manual. Because of the wide variety of data and information included in this chapter, we have divided it into smaller, self-contained sub-sections, to allow the reader to locate specific information in the quickest possible time.

General physical specifications

Model nomenclature explanation

Below are two examples of a model number:

Example: G12V26Ah10EP

G — identifies the battery as a GENESIS product

12V — shows the battery to have a nominal voltage of 12 volts

26Ah & 10 — stems from the fact that the battery is rated at 26 ampere-hours at the 10-hour rate

EP — denotes enhanced packaging

It is to be noted here that although the model number does not specifically refer to the end-of-discharge voltage, this end voltage is 1.70 volts per cell or 10.20 volts per battery. The same model-numbering rationale applies to all other GENESIS batteries of the EP series.

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Example: G12V42Ah10VP

G — identifies the battery as a GENESIS product

12V — shows the battery to have a nominal voltage of 12 volts

42Ah & 10 — stems from the fact that the battery is rated at 42 ampere-hours at the 10-hour rate

VP — denotes value packaging

It is to be noted here that although the model number does not specifically refer to the end-of-discharge voltage, this end voltage is 1.70 volts per cell or 10.20 volts per battery. The same model-numbering rationale applies to all other GENESIS batteries of the VP family.

Expected battery life

The life expectancy of the GENESIS battery is dependent on the specific application and is expressed either in terms of *cycles* or *years.* While life in years is self-explanatory, a cycle refers to a sequence in which a charged battery is discharged and then charged back up. One complete sequence constitutes one cycle. In general, if the battery is to be discharged frequently, cycle life rather than calendar life is more relevant. On the other hand, if the battery is to be used primarily as power backup, calendar life of the battery should be considered.

In those situations where one is not quite sure whether the application is cyclic or standby (float), the following definition may be used to determine the application category: *IF THE* ***AVERAGE*** *TIME ON CHARGE BETWEEN TWO SUCCESSIVE DISCHARGES IS THIRTY (30) DAYS, THE APPLICATION MAY BE CONSIDERED TO BE OF A STANDBY (FLOAT) NATURE. ALSO, THE* ***MINIMUM*** *TIME BETWEEN TWO SUCH SUCCESSIVE DISCHARGES MUST BE NO LESS THAN FOURTEEN (14) DAYS.* If these two criteria are not satisfied, the application should be considered cyclic.

While several factors affect the life of a battery (both cyclic and float), cycle life is very dependent on the depth of discharge (DOD). At a DOD of 80%, the GENESIS battery will deliver about 500 cycles; at 100% DOD, that number decreases to about 400 cycles.

In contrast, float life is dramatically impacted by the ambient temperature. For every 7° to 10°C rise in ambient temperature, the expected float life of a sealed-lead battery is cut in half. In other words, a ten (10) year battery at 25°C, such as the GENESIS line, will have its life expectancy reduced to five (5) years at an ambient temperature of 32° to 35°C.

Battery rating

Contrary to the normal industry practice of rating batteries at the 20-hour or 10-hour rate of discharge, Hawker rates the GENESIS batteries at rates appropriate to the application.

Constant-power and constant-current discharge performance

This section is one of the most important, because batteries are generally called upon to support either *constant-power* (CP) or *constant-current* (CC) loads. It is therefore imperative that any battery-application manual contain discharge information for both types of loads.

CP and CC discharge curves are provided in Appendix A in both tabular and graphical formats, with each curve representing the discharge profile for a specific model to a specific end voltage. *For applications requiring high power or high-current deliveries for periods less than the minimum run time shown on any graph, a Hawker application support representative should be consulted.*

If intermediate run times are required, such as *watts per battery* for 7 minutes to 1.67 volts per cell, the graphs may be used to estimate the *watts per battery* available.

Generally speaking, a majority of the battery systems for indoor applications are in temperature-regulated environments. However, there are occasions when this is not the case. Particularly, this can occur when the batteries are installed in close proximity to heat generating sources (e.g., transformers) or in remote areas where the batteries are exposed to varying weather conditions, with no ambient-temperature regulation.

In such cases, the user needs to know what kind of performance to expect from the batteries, since it is well established that a battery's overall performance is acutely sensitive to ambient temperature.

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For sealed-lead batteries, the accepted rule of thumb is:

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For every 7° to 10°C rise in battery ambient temperature, the expected life of the battery is reduced by 50%.

The previous statement is based on the Arrhenius equation, which defines the relationship between the ambient temperature and the rate of internal positive-grid corrosion of the battery, which is the natural process of battery aging.

A key point to note is that the temperature in question is the battery ambient temperature. Thus, if the system is in a 77°F (25°C) environment and the battery is installed right next to a power transformer where the temperature averages 90°F, then all battery calculations must be based on 90°F (32°C).

The Arrhenius equation is the theoretical foundation for the relationship used in practice to derive the overall acceleration factor for a given set of parameters. This factor combines the effects of ambient temperature and charge voltage.

$$\text{A.F.} = \left[2^{10(V_T - 2.27)} \times 2^{(T-25)/10}\right]$$

where:

A.F.: Acceleration factor
V_T: Charge voltage per cell at test temperature
2.27: Recommended charge voltage per cell
T: Test temperature in °C

To appreciate the application of this equation to test results, consider the case where a GENESIS battery, subjected to a charge voltage of 2.30 volts per cell at an ambient temperature of 80°C, failed to deliver at least 80% capacity after 178 days on test. The value for T is 80, because the test temperature is 80°C.

If we substitute these values into the above equation, the acceleration factor (A.F.) works out to be 55.715. As the battery lasted for a total of 55 days, by applying the computed acceleration factor the projected float life of the battery will be given by

$$\left[\frac{55x55.715}{365}\right] \text{ or about 8.4 years.}$$

In addition to the above dependence of battery life on ambient temperature, battery capacity also varies with the temperature. The following table illustrates this variation in battery capacity as a function of the ambient temperature:

Temperature, °C	-20	0	25	40	55
Percent Capacity @ 15 minute rate	65	84	100	110	120

A graph of capacity as a function of temperature is shown in Appendix B, Figure B-1 for various rates of discharge.

Note that although the GENESIS battery may be used, with appropriate derating, within a temperature range of -40°C (-40°F) to 60°C (140°F), it is strongly recommended that every effort be made to install batteries in temperature-regulated environments. Optional metal jacket required exceeding 45°C.

Before we proceed further, we should emphasize once more that all battery temperatures refer to the actual temperatures experienced by the active materials *inside* the battery. The time required by the active materials to reach thermal equilibrium within the battery environment may be considerable.

Charging characteristics & requirements

As outlined in the ***GENESIS Selection Guide***, a constant-voltage regime is the preferred method of charging GENESIS, although a constant-current charger may also be used.

There are no current limitations that need be imposed on the charge current during constant-voltage charging of a GENESIS battery. Because of the GENESIS battery's low internal resistance design, it is able to accept any level of inrush current provided by a constant-voltage source or charger.

Note: The following paragraphs on battery charging have been considerably simplified for better understanding. For example, no account has been taken of the polarization voltage. Secondly, the battery resistance has been assumed to be static. This, however, is not true since, as the battery charges up, the internal resistance will change continuously.

This dynamism in the impedance occurs because of the changing state of charge and the fact that the temperature of the active materials within the battery is dynamic.

Owing to these simplifications, the current magnitudes obtained in the sample calculations are exaggerated. However, if one remembers that certain assumptions have been made and that the *mathematical steps are for illustration only,* then the actual current values calculated become immaterial.

It is known from standard electric-circuit theory that the current in any circuit is directly proportional to the voltage differential in the circuit (Ohm's Law). Therefore, as charging continues at a constant voltage, the charging current decreases due to the decreasing difference between the charger-output voltage and the battery-terminal voltage. Expressed differently, the charging current is at its highest value at the beginning of the charge cycle and at its lowest value at the end of the charge cycle.

Thus, in a constant-voltage-charge circuit, the battery itself is allowed to be the current regulating device in the circuit. It will draw only that amount of current as necessary to reach full charge. Once it attains 100% state of charge, it continues to draw small currents in order to compensate for standing/parasitic losses.

Example: Assume that the 12V battery under consideration has an internal resistance of 4 milliohms, measured at 1KHz, when fully charged. Also assume that it has an internal resistance of 8 milliohms, or 0.008 ohm, when discharged to an end voltage of 10.5 volts. However, the instant the load is removed from the battery, its voltage jumps back up to 12 volts, and this is the initial back electromotive force (EMF) the charger output terminals will see. The influence of this voltage on the charge-current inrush is illustrated in the initial and final charging magnitudes.

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It is now decided to recharge the battery at a constant voltage of 2.25 volts per cell or 13.50 volts per battery. Further assume that when the battery reaches a state of full charge, the internal resistance reduces to 4 milliohms and the terminal voltage rises to 13.48 volts. *For illustrative purposes, this final end-of-charge terminal voltage has been kept deliberately slightly lower than the charging voltage.*

In reality, the charging process is dynamic. As soon as a charging source is placed across the terminals of a discharged battery, its voltage begins rising in an attempt to match the charger-output voltage. Given enough time, one would expect that the battery voltage at some point would exactly equal the charger voltage, thereby reducing the voltage difference in the charging circuit to zero and thus forcing the charge current to zero. However, this does not happen because of the internal electrochemistry, which ensures that the battery will keep drawing small charging currents—even when fully charged.

However, almost immediately, the battery self-discharges, depressing its terminal voltage below the charger voltage, thereby initiating a current flow once again. The entire process, as outlined in the previous paragraph, will then repeat itself.

Utilizing Ohm's Law, stating that *the current in a circuit is equal to the voltage gradient (difference) in the circuit divided by the total resistance in the circuit,* and substituting the various parameters' assumed values, we have the following charging currents. Note that all connection resistances, such as those for cables, are neglected for simplicity. This omission does not affect the final outcome since its influence would be the same in both cases, neglecting changes due to electrical heating.

$$\textbf{\textit{Initial charging current}} = \frac{13.50-12.00}{0.008} = 188 \text{ amperes}$$

$$\textbf{\textit{Final charging current}} = \frac{13.50-13.48}{0.004} = 5 \text{ amperes}$$

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This example shows how the battery acts as a current regulator in a CV charge circuit, decreasing the current flow in the circuit to suit its own state of charge. Thus, even if the current limit on the charger was 200 amperes, the battery would see an inrush current of 188 amperes, before it tapered off and finally dropped to its lowest value at the end of the charge cycle.

Although the 200A figure is impractical because of prohibitive charger costs, it serves to drive home the point that as far as the battery is concerned, a specific current limit is not necessary for GENESIS, provided the charger is of the constant-voltage type. In an actual situation, the choice of current limit would be dictated by a combination of technical and economic considerations. Note also that, in general, most other battery manufacturers recommend current limits based on battery capacity, usually $C_{10}/4$, where C_{10} is the 1-hour rating.

Increasing the current limit's magnitude will reduce the total recharge time, but at greater cost. The reduction in recharge time occurs mainly up to the 90% state of charge level; the impact on total recharge time is much less. The charger-output voltage exercises a much greater influence on the total recharge time.

The question then becomes whether the reduction in the time needed for a recharge can justify the additional costs. In some critical applications, this may certainly be the case, while in other situations the added cost may not be justifiable.

The succeeding two sections detail the parameters for constant-voltage and current-regulated modes of charge.

Constant-voltage (CV) regime

(a) Float: 13.50 to 13.80 volts per battery at 77°F (25°C); no current limit specified

(b) Cyclic: 14.70 to 15.00 volts per battery at 77°F (25°C); no current limit specified

Note: In both (a) and (b), there are no restrictions on the current limit. The value of this limit is entirely up to the battery user. We recommend the highest practical and economic current limit possible.

In order to achieve optimum performance at low temperatures and optimum life at high temperatures, the charge or float voltage should be temperature compensated. The ideal temperature compensation curve for float conditions is shown in Figure B-5 of Appendix B. A reasonable approximation can be achieved by increasing the charge voltage by 30mV per 12V battery per degree Celsius below 25°C and by decreasing the charge voltage by 18mV per degree Celsius above 25°C. The voltage at 25°C would be either the float or cyclic voltages shown in (a) and (b).

Constant-current (CC) regime

(a) Constant-current charge up to full state of charge in 5-48 hours

(b) Constant-current overcharge (after full recharge) should be at C/500, i.e., at the 500-hour rate

Note: When using a CC-recharge regime, care must be exercised to ensure that the charge current switches from a high (starting) rate to a low (finishing) rate when the battery reaches 100% state of charge. The precise point at which this switch occurs may be determined by using a timer or by sensing the battery voltage.

The timer setting can be determined by calculating the time needed to return 105% to 110% of the ampere-hours drawn out. Alternatively, the transition from a high-charge current to a low-charge current can be accomplished by monitoring the battery-terminal voltage as the charging proceeds. This is based on the fact that the battery voltage reaches a peak value and then begins to decline to the steady-state, fully charged value. The point at which this gradual drop begins depends on the charge current's magnitude. This point should be used as the point at which the switch is made from a high rate to a low rate.

The CV method is the preferred charge regime.

GENESIS may, therefore, be recharged using either a constant-current (CC) or constant-voltage (CV) charger, although the CV regime is the method of choice. This flexibility in the charging scheme is a big advantage, because it makes it very easy for the user to replace existing batteries with GENESIS, without having to alter the charging circuitry.

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Because of the proven Hawker technology and GENESIS battery design, the internal resistance is significantly lower than that of conventional sealed-lead batteries. For example, the G12V26Ah10EP has an internal resistance of about 5 milliohms when fully charged. This compares very favorably with a typical value of 10 to 15 milliohms for competitive products of equal capacity.

In terms of charging characteristics, this low internal resistance allows the battery to accept large inrush currents without any deleterious effects. This may be explained by the fact that the heat generated by the charging current is kept at a low level because of the very low internal resistance value, since heating is directly proportional to the battery's internal resistance. In actual tests performed on the G12V26Ah10EP battery, the initial current drawn by the battery was 175 amperes.

Thus, the GENESIS battery may be recharged much more rapidly than conventional sealed-lead batteries, because of its ability to accept very high currents with no damage. In fact, GENESIS may be recharged, using a CV regime, to better than 90% in 30 minutes, depending of course on the magnitude of the charger's current limit. The current limit required to achieve 90% recharge in one (1) hour would generally be two (2) times the one (1) hour rating of the battery. If the battery under consideration is the Hawker G12V26Ah10EP, the minimum inrush current would be 42 amperes, since the 1-hour rate of this battery is 21 amperes.

This fast-charge capability is a remarkable feature in a sealed-lead battery. This feature makes the GENESIS battery competitive with a nickel-cadmium battery, which traditionally had an advantage over sealed-lead because of its very short recharging times.

The fact that GENESIS allows itself to be recharged very rapidly makes this battery particularly suited to those applications where the battery needs to be returned quickly to backup status, fully recharged, after a battery-power usage.

Detailed information on charging may be found in the OEM batteries literature section on our website at **www.hepi.com.**

Storage characteristics

Improper storage conditions constitute some of the most common forms of battery misuse. These include such abusive practices as high ambient temperatures in the battery storage area and inadequate frequency of freshening charges.

In order to appreciate and better understand the various mechanisms influencing sealed-lead batteries kept in storage, the following paragraphs discuss in general terms several aspects of the batteries' storage requirements. Graphical information on storage may be found in Appendix B.

Self-discharge

Any battery, primary or secondary, loses charge over time when it is kept on open circuit. This phenomenon is termed *self-discharge.*

If the capacity loss due to self discharge is not compensated by recharging in a timely fashion, the battery capacity may become irrecoverable due to irreversible sulfation, where the active materials (PbO_2, lead dioxide, at the positive plates and sponge lead at the negative plates) are gradually converted into an electroinactive from of lead sulfate, $PbSO_4$.

Therefore, if the capacity loss associated with self-discharge is not replenished, the battery ultimately fails because storage is equivalent to a very low rate of discharge.

The key factor influencing the self-discharge rate is the storage temperature. This is because the ambient temperature plays a major role in determining the speed at which the internal chemical reaction proceeds. The higher the temperature, the faster the speed of chemical reactions.

Just as every 7° to 10°C rise in operating temperature cuts the battery's life expectancy in half, so does every 7° to 10°C increase in ambient temperature reduce the allowable storage life of a battery by 50%. Conversely, a reduction in storage temperature will have the reverse effect by increasing the allowable storage time. A plot of capacity over time at various temperatures is shown in Appendix B, Figure B-3.

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Voltage loss during storage

Since most batteries are subject to some kind of storage, it is important for the user to have some method of obtaining a fairly accurate estimate of the remaining battery capacity after it has been in storage. It is important to be aware of the type and duration of all storage conditions.

Although every effort should be made to ensure that batteries are stored in temperature-controlled environments, a refreshening charge should be administered once every twenty-four (24) months, or when the open-circuit voltage (OCV) reading drops to 2.00 volts per cell, whichever comes first.[1] *The battery may be permanently damaged if the OCV is allowed to drop below 1.93 volts per cell.*

Charge retention during storage

Capacity loss under storage is an important consideration, particularly in those applications where any performance loss due to storage is unacceptable. However, knowing how much charge is remaining in the battery at any point in its storage life is equally important. This is because the battery must be maintained at a minimum charge level in order to prevent permanent damage.

This minimum charge level corresponds to a specific OCV and has the value of about 1.93 volts per cell. At a voltage of 1.93vpc, no permanent damage has occurred to the cell; however, it has no remaining useful capacity at this point.

The graph in Appendix B entitled GENESIS State of Charge, Figure B-2, summarizes this section. If the OCV reading is about 1.93 vpc or 11.58 V per 12V module, then the battery is at a 0% state of charge. If the OCV reading is about 2.14 vpc or 12.84 V per 12V module, the battery is at a 100% state of charge.

Note that the graph will yield useful information only if the voltage reading is taken at least 24 hours after a charge or discharge.

Hawker batteries possess excellent storage characteristics; their low self-discharge rates provide superior capacity retention, translating into an ability to be stored for extended periods without permanent damage.

[1] As the graph of state of charge (SOC) versus OCV in Appendix B shows, at this voltage (12.00V), the GENESIS battery is still at about 35% SOC.

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Summary

■ When a battery is kept in storage, the ambient temperature should be controlled to prolong storage time and maintain maximum capacity over time.

■ In addition, the OCV of each battery must be monitored on an individual basis. If the OCV measures 1.93 vpc or 11.58 V, the battery has zero effective capacity and should be charged immediately. Even if the OCV reads higher than 2.00 vpc at the end of 24 months' storage, the battery should be recharged. Thus, batteries should receive a refreshening charge once every twenty four months or when the OCV reads 2.00 vpc, whichever comes first to maintain maximum reliability.

■ If the OCV under storage is allowed to drop below 1.93 vpc, some permanent damage may occur to the battery. Every effort should be made to prevent storage conditions where OCV levels drop below 1.93 vpc.

■ To get the best storage results, batteries should be charged prior to storage, stored at room temperature or below and charged prior to becoming deeply discharged.

■ Under no circumstances should the OCV of a battery under storage be allowed to drop below 1.93 vpc, or 11.58 V.

Life characteristics

As accepted by the industry, a battery designed for standby applications is considered to have reached its end-of-life when it fails to deliver at least 80% of its rated capacity. Thus, if a battery is rated for 15 minutes of backup, its end of life is reached when it fails to support its load for a minimum of 12 minutes, which is 80% of its rated run time.

As far as the term "life" is concerned, it may be defined in various ways, one of them obviously being calendar life such as 120 months or 10 years. However, for the purposes of expressing the life expectancy of a battery, two types of life expectancies are defined — float life and cycle life.

The ***GENESIS Selection Guide*** states the anticipated life from two different viewpoints. The following two sections discuss float life and cycle life separately, as well as the factors affecting these figures.

Although the two life expectancies are different, based on the service profile, they are not fully and completely independent of each other, as later sections will illustrate.

Finally, since life expectancy of a battery is of critical importance, a separate section is devoted to a discussion of the factors directly affecting the life of a battery.

Float life expectancy

For float life applications, where the battery is essentially kept connected across a battery charger which continuously replenishes the battery's standing losses, the life expectancy is established in terms of months or years.

The GENESIS battery has a float life of ten (10) years at 25°C or fifteen (15) years at 20°C. This calendar-life figure is based on the battery's ability to deliver at least 80% of rated capacity, when discharged at the 5-hour rate.

Hawker defines end-of-life of a battery as the point in time at which the battery fails to deliver a *minimum of 80% of its rated capacity.* This is in contrast with some battery manufacturers that define end-of-life of their products as a failure to deliver a minimum of 50-60% of its rated capacity. When evaluating battery specifications from different manufacturers, it is critical that end-of-life definitions are the same because the difference between 60% and 80% of rate capacity is significant.

Cycle life expectancy

An alternative method of expressing the expected useful life of a battery is to state the number of cycles one may obtain. The cycle must, of course, be fully defined.

Consider the G12V26Ah10EP battery, which has a 100% rating of 120 watts per cell for 15 minutes at 25°C to an end voltage of 1.67 volts per cell or 10.02 volts per battery. If the battery is discharged at this rate, one may expect 250 complete cycles from the battery. However, if the battery duty cycle consists of discharges at the 5-hour rate, the number of cycles will increase to about 400, again to 100% *depth of discharge* (DOD). At lower DOD, the cycle life increases.

Factors affecting battery life

Just as there are two different methods of defining the battery's life expectancy, the factors affecting the life of a battery are somewhat different for float service and cycle service applications.

Factors affecting float life

In float applications, the battery is essentially being continuously overcharged in order to ensure that the battery, at all times, remains fully charged. Since the normal failure mode of a battery is grid corrosion, and the magnitude of the charge current critically influences the corrosion rate, minimizing the overcharge current while maintaining enough current to offset standing losses, will tend to maximize the battery float life.

Charge Current/Voltage

An efficient method of restricting the charge current to the minimum level is to utilize the constant voltage (CV) method of charge and allow the battery to determine for itself the amount of current it draws at any point in the charge cycle. In other words, no current limit is necessary under CV charging.

However, the constant voltage setting should be adjusted such that the overcharge current flowing into the battery is just above the self-discharge rate. At room temperature (25°C or 77°F), the nominal CV setting should be between 2.25 and 2.30 vpc, for a float application.

Battery Temperature

The grid-corrosion rate in a battery is intimately linked to the battery's ambient temperature. The higher the temperature, the greater the corrosion rate—and the sooner the failure of the battery. This accelerated corrosion at higher temperatures occurs regardless of the charge current flowing into the battery.

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However, since higher temperatures give rise to increased currents at a given voltage setting, the net result of an elevated battery ambient temperature is to intensify the negative effects on the battery. This negative impact may be lessened to some extent by compensating the float charge voltage for higher temperatures. The coefficient of temperature compensation for the GENESIS battery is graphically illustrated in Appendix B, Figure B-5.

Battery Discharge Parameters

Clearly, the DOD of each battery cycle will exert considerable influence on the battery's life expectancy. As explained earlier, the expected calendar life of a battery is determined largely by its service profile. This fact is duly reflected in the ***GENESIS Selection Guide***, where a distinction is made in the life projections for float and cycling applications.

Factors affecting cycle life

A cyclic application is basically *an application where the discharge and charge times are of about the same order.* This type of service scenario is vastly different from a float-service application. It should be noted that, in cycle-life situations, calendar life does not have the same significance as in float-life applications.

Depth of Discharge (DOD)

The DOD is an important variable affecting the battery's cycle-life expectancy. The effect of DOD on cycle life is a nonlinear relationship, so the shallower the DOD, the higher the number of available cycles.

The number of cycles obtained from a battery can be significantly increased simply by oversizing the battery, if you can tolerate increased size and weight, thereby lowering the depth of discharge in each cycle.

Over a large range of DOD (about 25% to 100%), the number of cycles a battery can deliver is approximately proportional to the DOD. For example, at the $C_{10}/5$ rate of discharge at 25°C, the GENESIS battery delivers 500 cycles at 80% DOD. Increasing the DOD of individual cycles to 100% lowers the cycle life to 400. Thus, a 20 point rise in the DOD (from 80% to 100%) results in a

20% decrease (from 500 to 400) in the number of cycles the battery will deliver before reaching-end-of-life, again defined as a failure to deliver a minimum of 80% of rated capacity.

However, as the discharge becomes shallower and shallower, the above linearity fails. One must therefore apply caution when estimating the cycle life of a battery for a specific application. In addition, all cycle-life numbers assume adequate and proper charging on each cycle, since our experience has shown the extreme importance of correctly matching the charge profile with the application.

Cycle Time

Next in importance to DOD in determining the battery's cycle life is cycle time. The time allowed for a recharge between discharges is critical to the battery's life expectancy. Generally speaking, the longer the time allowed for a recharge, the longer the battery's life expectancy.

The preceding paragraph may be better understood if one remembers that a battery is fully recharged when between 105 to 110% of the ampere-hours discharged are put back in the recharge. If the time allowed for a recharge is less, then the current magnitude for a given ampere-hour must be increased. An increase in the charge current can be accomplished only if the charge voltage is also increased. This, in turn, leads to a higher level of overcharge, which speeds up the battery's aging process.

Thus, the longer the recharge time, the lower the overcharge rate, and the better it is for the battery. Conversely, the shorter the recharge time, the higher the overcharge and the harsher the condition for the battery.

Charging Parameters

In contrast to float applications where more than adequate time is allowed for a 100% recharge, in cyclic applications a major concern is whether the batteries are being fully recharged in the time allowed between discharges. If the recharge time is insufficient, the battery will remain in a state of perpetual undercharge, which in turn will lead to premature battery failure.

Generally speaking, the recommended charge voltage for cyclic applications is higher than that for float-service applications. This is done because in cyclic applications, the time available for a full (100%) recharge is much less than that in float applications. To compensate for this shorter recharge time, the charging voltage, and thereby the charging current, in cyclic applications is raised so that more ampere-hours can be supplied to the battery in the given time.

A detailed treatment of charging parameters and characteristics is presented in the manual titled ***Charging pure lead-tin batteries: A guide for CYCLON and GENESIS products*** and may be found on our Internet website at **www.hepi.com.**

Part 3 — General test data

Introduction

This section's purpose is to furnish actual data of various tests conducted by Hawker. These tests may be of particular interest to system designers and application engineers. Some of the tests are already mandated or shortly will be, in existing and/or proposed standards. Other test results serve to confirm the data published in the ***GENESIS Selection Guide.***

The following tests are covered in this chapter:

- Thermal Runaway Test
- Altitude Test
- Overdischarge Recovery Tests
  - *DIN standard test*
  - *High temperature test*
- Accelerated Float Test
- Gassing Test
- Performance Test at Different Temperatures
- Vibration Test

■ Thermal runaway test

This test was conducted to determine the threshold limits beyond which GENESIS will go into thermal runaway. (Thermal runaway is where the battery, connected to a CV source, is not able to maintain a stabilized current or reaches a very high internal battery temperature.)

As the battery draws more current, the internal heating also increases, because heating is a direct function of the square of the current, I^2. The increased heating accelerates the internal reaction rate, forcing the battery to draw more current, which in turn gives rise to additional heat generation.

Thus, the increasing heat generation and subsequent higher current draws feed on each other, finally resulting in the battery destroying itself.

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The following chart tabulates the data obtained from actual GENESIS Thermal Runaway tests:

Charging Volts	*Time in hours*	*Charge current, mA*	*Temperature °C*
2.25 vpc	96	10	20
2.45 vpc	16	23	20
2.60 vpc	24	98	24
	48	100	24
	72	120	26
	96	151	27
	120	211	30
	144	319	37
	168	524	46
	192	664	56

The battery under test was encapsulated in 0.75" thick styrofoam over all six surfaces, in order to ensure that as little heat as possible escaped from the battery. This was done because thermal runaway can be initiated only if the heat generated by the battery is more than the heat dissipated from the battery. Since styrofoam is an extremely poor thermal conductor, covering the battery with a substantial layer of styrofoam would present conditions which are ideal for the onset of thermal runaway.

The test began by charging the battery at 2.25 vpc for four (4) days, or 96 hours, at which time the float current was measured at 10 mA, at 68°F (20°C). The charge voltage was then raised to 2.45 vpc, and the battery was charged at this new voltage for an additional sixteen (16) hours. The current rose to 23mA, but the temperature remained the same.

In an effort to forcibly initiate thermal runaway, the charge voltage was raised to 2.60 vpc (which is well beyond our maximum voltage recommendations) for another twenty-four (24) hours. The charge current increased to 98mA, with the corresponding temperature moving up to 24°C.

The charge voltage was maintained at 2.60 vpc, and only after the battery was allowed to maintain this very high charge voltage for a total of about six (6) days did it exhibit some definite symptoms of a thermal-runaway scenario, rapidly escalating charge currents and battery temperatures.

Although the test results demonstrate very clearly that it is difficult to provide a set of operating conditions which will force GENESIS into thermal runaway, the battery must be maintained in any application within our suggested parameters in order to obtain reasonable performance and life. *Note that the battery had to be subjected to extremely abusive conditions (0.75" thick thermal insulation covering and extremely high charge voltage) before it showed distinct signs of entering a thermal runaway condition (rapidly increasing charge current and temperature).*

■ Altitude test

This test was designed to conclusively prove that the GENESIS battery is capable of operating safely without any performance loss at altitudes up to and including 10,000 feet.

Since the Bunsen design of the GENESIS safety valve does not rely on atmospheric pressure to operate, the battery will operate over a wide range, from vacuum to as much as 100 feet under water.

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■ Overdischarge recovery test: *DIN standard test*

This test was designed to determine GENESIS' ability to recover from overdischarge using standard charging techniques. In addition, this test also gives an indication of the resistance of the GENESIS battery to permanent damage caused by *internal sulfation* (a phenomenon which occurs when a battery is left in a discharged condition for an extended length of time).

The test began by discharging a fully charged 26Ah battery at the 20-hour rate to 1.70 vpc. Following the discharge, a 5-ohm resistor was connected across the battery terminals and left connected for twenty-eight (28) days. At the end of this 28-day period, the battery was recharged at a constant voltage of 2.25 vpc for forty-eight (48) hours.

The battery was tested for capacity after the 48-hour recharge, and 97% of the initial capacity was obtained. A subsequent recharge/discharge cycle yielded a capacity of 94% of the initial capacity. The entire overdischarge test exercise is summarized below:

- **Conditions:** C/20 rate discharge to 1.70 vpc
- **Followed by:** 5-ohm resistor connected across terminals for 28 days
- **Recharge:** 2.25 vpc CV charge for 48 hours
- **Results:** Initial capacity—26.8 Ah
- **Recovered capacity (1st cycle):** 25.9 Ah (97%)
- **Recovered capacity (2nd cycle):** 25.3 Ah (94%)

The results clearly show GENESIS' ability to resist severe permanent damage due to extreme overdischarge. The battery was able to accept recharge via normal methods without any problems.

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■ Overdischarge recovery test: *Recovery from discharged storage at 50°C*

This test is a rather extreme case of application abuse because it stresses the battery in two equally destructive ways. First, it involves storing the battery in a fully discharged condition, and second, the discharged battery is stored at a very high temperature.

The test protocol involves discharging two GENESIS 42Ah battery samples at the 1 hour rate to an end voltage of 1.50 volts per cell or 9V per battery. The discharged batteries are then stored at 50°C for a period of four (4) weeks.

At the end of the storage period, both batteries are charged for 16 hours using the cyclic charge voltage of 14.7V per battery. As shown in Figure 1, for the first two cycles the inrush current was limited to only $0.125C_{10}$ while the remaining cycles saw an inrush of $1C_{10}$. Clearly, the lower inrush was insufficient because both samples were cycling down. Raising the inrush current allowed the batteries to fully recover from an extremely harsh storage environment.

This test, together with the German DIN standard test described in the previous section demonstrates the exceptional overdischarge recovery characteristics of the GENESIS line of VRLA batteries.

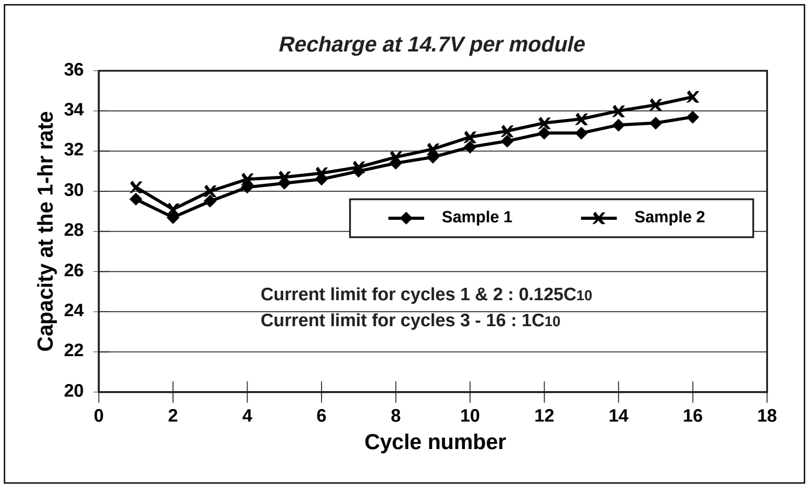

Figure 1: Discharged storage @ 50°C for 4 weeks

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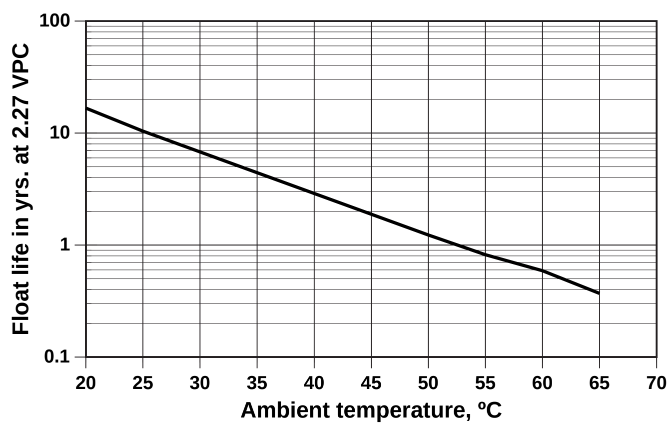
■ Accelerated float test

This test utilizes well-established techniques to determine GENESIS' expected float life. The test uses high ambient temperatures to accelerate the battery's aging process. Float life projections are estimated with the help of the Arrhenius equation.

The graph below plots the float life expectancy of GENESIS product as a function of the ambient temperature when float charged at 2.27 volts per cell or 13.62V per battery.



■ Gassing test

The GENESIS battery was designed to be used safely in human environments, such as offices and hospitals. To determine how much hydrogen gas, if any, evolved under normal operating conditions, a test, (summarized on the next page) was developed.

This test's rationale is that any weight loss suffered by the battery can only be attributed to the water lost by the battery. Knowing the amount of water lost by the battery and the chemical composition of water, a relatively straightforward calculation yields the actual amount of emitted hydrogen gas.

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- **Conditions:** Temperature 60°C
- **Voltage:** 2.30 vpc
- **Duration:** 180 days
- **Weight Loss:** 65.6 grams
  = 3.65 moles (gm equiv) H_2O
  = 3.65 moles H_2 and 1.82 moles O_2
- **Gas Evolved:** Total 122.6 liters
  Duration at 25°C—2,880 days
  (4,147,200 min)
- **Gassing rate:** Total 0.03 cc/min
  Hydrogen, H_2: 0. 02 cc/min

The oxygen evolved is recombined, while the rate of hydrogen emission is negligible, as the above results clearly show. Nevertheless, the battery should not be recharged in a gas-tight container. Ventilation *must always* be provided in the charging area.

Performance test at different temperatures

This test was performed to determine the variation of battery capacity, as a function of the ambient temperature. Note that the run time obtained at 25°C (77°F) is taken as the 100% rate. Also, all discharges were at 120 watts per cell constant power.

Temperature °C	-20	0	25	40	55
Run time in minutes	9.75	12.6	15.0	16.5	18.0
% Capacity	65	84	100	110	120

It is worth noting here that this table clearly shows the superior low-temperature performance capability of the GENESIS battery. At a temperature of 0°C, this battery is still capable of delivering its rated capacity for 12.6 minutes, 84% of its nominal rating of 15 minutes at 25°C. At -20°C, GENESIS technology delivered 65% of room temperature rated capacity.

■ Vibration test

In this test, the GENESIS battery was subjected to gradually increasing levels of vibration in all three axes. At the end of each test phase, the batteries were tested for potential damage.

The batteries were then mounted on a vibrating plate and exposed to sinusoidal vibrations at a frequency of 33 Hz. The vibration level started at 3g for a period of two hours, then raised to 4g for two more hours. At the end of this second two-hour period, the vibration level was raised to 6g and the batteries vibrated for two additional hours.

The above vibration regime was repeated for each of the three axes, i.e., the "x" axis, the "y" axis and the "z" axis. Thus, the batteries were vibrated at varying levels for a total duration of eighteen (18) hours, since the vibration in each axis was for 6 hours.

In order to determine whether the batteries were damaged in any test-procedure phase, the batteries were checked in two stages:

(i) high-rate discharges were performed before and after each vibration sequence, and

(ii) the batteries were physically cut open to check for internal damages.

Results from (i) did not reveal any damage to the batteries, while (ii) showed that except for a slight shifting of the plate packs, there were no signs of physical damage to the battery.

This sequence of vibration tests proves that the GENESIS battery has more-than-adequate resistance to very high levels of sustained vibration in any of the three axes. The test results prove that there should be no concerns about installing the GENESIS battery in areas exposed to high vibration levels.

Appendix A

Run time to 1.50 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	1437	149.6	5.00	47.90	754.00	25.10	299.40	10.00
5 min	791	76.7	6.40	65.95	415.20	34.60	164.90	13.70
10 min	488	45.3	7.55	81.40	256.30	42.70	101.75	17.00
15 min	364	33.0	8.25	90.90	190.80	47.70	75.75	18.90
20 min	293	26.2	8.70	97.80	153.90	51.30	61.10	20.40
30 min	215	18.9	9.45	107.40	112.70	56.35	44.75	22.40
45 min	156	13.5	10.10	117.00	81.85	61.40	32.50	24.40
1 hr	124	10.6	10.60	123.60	64.85	64.85	25.75	25.75
2 hr	69	5.8	11.60	138.00	36.20	72.40	14.40	28.75
3 hr	49	4.1	12.30	145.80	25.50	76.50	10.10	30.40
4 hr	38	3.2	12.80	151.20	19.80	79.30	7.90	31.50
5 hr	31	2.6	13.00	153.00	16.10	80.30	6.40	31.90
8 hr	20	1.7	13.60	158.40	10.40	83.10	4.10	33.00
10 hr	16	1.4	14.00	162.00	8.50	85.00	3.40	33.75
20 hr	8	0.7	14.00	168.00	4.40	88.15	1.75	35.00

Table A-1: 13Ah GENESIS Performance Data at 25°C

Run time to 1.60 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	1354	136.2	4.50	45.10	710.50	23.70	282.10	9.40
5 min	783	74.3	6.20	65.25	410.80	34.20	163.10	13.60
10 min	491	44.9	7.50	81.80	257.50	42.90	102.25	17.00
15 min	367	32.9	8.20	91.65	192.35	48.10	76.40	19.10
20 min	295	26.2	8.70	98.40	154.90	51.60	61.50	20.50
30 min	216	18.8	9.40	108.00	113.30	56.70	45.00	22.50
45 min	156	13.4	10.05	117.00	81.85	61.40	32.50	24.40
1 hr	123	10.5	10.50	123.00	64.50	64.50	25.60	25.60
2 hr	68	5.7	11.40	135.60	35.60	71.15	14.10	28.25
3 hr	47	4.0	12.00	142.20	24.90	74.60	9.90	29.60
4 hr	36	3.1	12.40	146.40	19.20	76.80	7.60	30.50
5 hr	30	2.5	12.50	150.00	15.70	78.70	6.25	31.25
8 hr	20	1.6	12.80	158.40	10.40	83.10	4.10	33.00
10 hr	16	1.3	13.00	162.00	8.50	85.00	3.40	33.75
20 hr	8	0.7	14.00	168.00	4.40	88.15	1.75	35.00

Table A-2: 13Ah GENESIS Performance Data at 25°C

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Run time to 1.67 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	1268	123.9	4.10	42.30	665.20	22.20	264.10	8.80
5 min	758	70.8	5.90	63.20	397.90	33.20	158.00	13.20
10 min	482	43.6	7.30	80.30	252.80	42.10	100.40	16.70
15 min	361	32.2	8.05	90.30	189.50	47.40	75.25	18.80
20 min	292	25.7	8.60	97.20	153.00	51.00	60.75	20.25
30 min	214	18.6	9.30	106.80	112.10	56.00	44.50	22.25
45 min	154	13.2	9.90	115.65	80.90	60.70	32.10	24.10
1 hr	121	10.4	10.40	121.20	63.60	63.60	25.25	25.25
2 hr	67	5.7	11.40	134.40	35.30	70.50	14.00	28.00
3 hr	47	3.9	11.70	140.40	24.60	73.70	9.75	29.25
4 hr	36	3.0	12.00	144.00	18.90	75.55	7.50	30.00
5 hr	29	2.5	12.50	147.00	15.40	77.10	6.10	30.60
8 hr	19	1.6	12.80	153.60	10.10	80.60	4.00	32.00
10 hr	16	1.3	13.00	156.00	8.20	81.85	3.25	32.50
20 hr	8	0.7	14.00	168.00	4.40	88.15	1.75	35.00

Table A-3: 13Ah GENESIS Performance Data at 25°C

Run time to 1.75 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	1153	108.6	3.60	38.40	605.10	20.20	240.25	8.00
5 min	715	65.5	5.50	59.60	375.30	31.30	149.00	12.40
10 min	463	41.4	6.90	77.10	242.70	40.45	96.40	16.10
15 min	349	30.9	7.70	87.30	183.20	45.80	72.75	18.20
20 min	283	24.8	8.30	94.40	148.60	49.50	59.00	19.70
30 min	208	18.0	9.00	104.10	109.20	54.60	43.40	21.70
45 min	151	12.9	9.70	112.95	79.00	59.30	31.40	23.50
1 hr	119	10.1	10.10	119.40	62.65	62.65	24.90	24.90
2 hr	66	5.5	11.00	132.00	34.60	69.30	13.75	27.50
3 hr	46	3.8	11.40	138.60	24.20	72.70	9.60	28.90
4 hr	36	3.0	12.00	144.00	18.90	75.55	7.50	30.00
5 hr	29	2.4	12.00	147.00	15.40	77.10	6.10	30.60
8 hr	19	1.6	12.80	153.60	10.10	80.60	4.00	32.00
10 hr	16	1.3	13.00	156.00	8.20	81.85	3.25	32.50
20 hr	8	0.7	14.00	168.00	4.40	88.15	1.75	35.00

Table A-4: 13Ah GENESIS Performance Data at 25°C

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Run time to 1.85 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	1001	89.2	3.00	33.40	525.10	17.50	208.50	6.95
5 min	647	57.8	4.80	53.90	339.40	28.30	134.75	11.20
10 min	429	37.9	6.30	71.50	225.10	37.50	89.40	14.90
15 min	328	28.8	7.20	82.05	172.20	43.05	68.40	17.10
20 min	268	23.3	7.80	89.40	140.70	46.90	55.90	18.60
30 min	199	17.1	8.55	99.30	104.20	52.10	41.40	20.70
45 min	145	12.4	9.30	108.90	76.20	57.10	30.25	22.70
1 hr	115	9.7	9.70	115.20	60.40	60.40	24.00	24.00
2 hr	64	5.3	10.60	128.40	33.70	67.40	13.40	26.75
3 hr	45	3.7	11.10	135.00	23.60	70.80	9.40	28.10
4 hr	35	2.9	11.60	139.20	18.30	73.00	7.25	29.00
5 hr	29	2.3	11.50	144.00	15.10	75.55	6.00	30.00
8 hr	19	1.5	12.00	148.80	9.80	78.10	3.90	31.00
10 hr	15	1.2	12.00	150.00	7.90	78.70	3.10	31.25
20 hr	8	0.7	14.00	156.00	4.10	81.85	1.60	32.50

Table A-5: 13Ah GENESIS Performance Data at 25°C

Run time to 1.50 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	1900	195.7	6.50	63.30	807.40	26.90	306.50	10.20
5 min	1028	98.4	8.20	85.65	436.70	36.40	165.80	13.80
10 min	624	57.2	9.50	104.00	265.10	44.20	100.65	16.80
15 min	460	41.3	10.30	115.05	195.50	48.90	74.20	18.60
20 min	368	32.7	10.90	122.80	156.50	52.20	59.40	19.80
30 min	268	23.4	11.70	133.80	113.70	56.85	43.20	21.60
45 min	192	16.6	12.45	144.00	81.60	61.20	31.00	23.20
1 hr	151	13.0	13.00	151.20	64.20	64.20	24.40	24.40
2 hr	83	7.1	14.20	166.80	35.40	70.90	13.45	26.90
3 hr	58	4.9	14.70	174.60	24.70	74.20	9.40	28.20
4 hr	45	3.8	15.20	180.00	19.10	76.50	7.30	29.00
5 hr	37	3.1	15.50	183.00	15.55	77.75	5.90	29.50
8 hr	24	2.0	16.00	192.00	10.20	81.60	3.90	31.00
10 hr	19	1.6	16.00	192.00	8.20	81.60	3.10	31.00
20 hr	10	0.8	16.00	204.00	4.30	86.70	1.65	32.90

Table A-6: 16Ah GENESIS Performance Data at 25°C

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Run time to 1.60 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	1797	178.0	5.90	59.90	763.50	25.45	289.80	9.70
5 min	1010	94.8	7.90	84.20	429.30	35.80	163.00	13.60
10 min	622	56.4	9.40	103.70	264.40	44.10	100.35	16.70
15 min	460	41.0	10.25	115.05	195.50	48.90	74.20	18.60
20 min	369	32.6	10.90	123.00	156.80	52.30	59.50	19.80
30 min	268	23.3	11.65	133.80	113.70	56.85	43.20	21.60
45 min	192	16.5	12.40	144.00	81.60	61.20	31.00	23.20
1 hr	151	12.9	12.90	150.60	64.00	64.00	24.30	24.30
2 hr	83	7.0	14.00	165.60	35.20	70.40	13.35	26.70
3 hr	58	4.9	14.70	172.80	24.50	73.40	9.30	27.90
4 hr	44	3.8	15.20	177.60	18.90	75.50	7.20	28.65
5 hr	37	3.1	15.50	183.00	15.55	77.75	5.90	29.50
8 hr	24	2.0	16.00	192.00	10.20	81.60	3.90	31.00
10 hr	19	1.6	16.00	192.00	8.20	81.60	3.10	31.00
20 hr	10	0.8	16.00	204.00	4.30	86.70	1.65	32.90

Table A-7: 16Ah GENESIS Performance Data at 25°C

Run time to 1.67 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	1674	161.2	5.40	55.80	711.25	23.70	270.00	9.00
5 min	976	90.0	7.50	81.30	414.50	34.50	157.35	13.10
10 min	610	54.8	9.10	101.60	259.00	43.20	98.30	16.40
15 min	454	40.1	10.00	113.40	192.70	48.20	73.20	18.30
20 min	364	32.0	10.70	121.40	154.70	51.60	58.70	19.60
30 min	265	23.0	11.50	132.30	112.40	56.20	42.70	21.30
45 min	190	16.3	12.20	142.65	80.80	60.60	30.70	23.00
1 hr	149	12.7	12.70	149.40	63.50	63.50	24.10	24.10
2 hr	82	6.9	13.80	164.40	34.90	69.85	13.30	26.50
3 hr	57	4.8	14.40	171.00	24.20	72.65	9.20	27.60
4 hr	44	3.7	14.80	177.60	18.90	75.50	7.10	28.65
5 hr	36	3.0	15.00	180.00	15.30	76.50	5.80	29.00
8 hr	23	2.0	16.00	187.20	9.90	79.50	3.80	30.20
10 hr	19	1.6	16.00	192.00	8.20	81.60	3.10	31.00
20 hr	10	0.8	16.00	204.00	4.30	86.70	1.65	32.90

Table A-8: 16Ah GENESIS Performance Data at 25°C

Run time to 1.75 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	1502	140.0	4.70	50.10	638.10	21.30	242.20	8.10
5 min	919	83.0	6.90	76.60	390.55	32.55	148.30	12.35
10 min	587	52.0	8.70	97.90	249.60	41.60	94.70	15.80
15 min	441	38.6	9.65	110.25	187.40	46.80	71.10	17.80
20 min	356	30.9	10.30	118.60	151.20	50.40	57.40	19.10
30 min	260	22.3	11.15	129.90	110.40	55.20	41.90	20.95
45 min	187	15.9	11.90	139.95	79.30	59.50	30.10	22.60
1 hr	147	12.5	12.50	147.00	62.50	62.50	23.70	23.70
2 hr	81	6.8	13.60	162.00	34.40	68.80	13.10	26.10
3 hr	56	4.7	14.10	169.20	24.00	71.90	9.10	27.30
4 hr	43	3.6	14.40	172.80	18.35	73.40	7.00	27.90
5 hr	35	3.0	15.00	177.00	15.00	75.20	5.70	28.55
8 hr	23	1.9	15.20	187.20	9.90	79.50	3.80	30.20
10 hr	19	1.6	16.00	186.00	7.90	79.00	3.00	30.00
20 hr	10	0.8	16.00	204.00	4.30	86.70	1.65	32.90

Table A-9: 16Ah GENESIS Performance Data at 25°C

Run time to 1.85 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	1267	113.2	3.80	42.20	538.15	17.90	204.30	6.80
5 min	832	72.9	6.10	69.35	353.60	29.50	134.20	11.20
10 min	551	47.6	7.90	91.90	234.30	39.05	88.90	14.80
15 min	419	36.0	9.00	104.85	178.20	44.55	67.65	16.90
20 min	341	29.1	9.70	113.60	144.80	48.30	55.00	18.30
30 min	251	21.3	10.65	125.40	106.60	53.30	40.45	20.20
45 min	181	15.3	11.50	135.90	77.00	57.70	29.20	21.90
1 hr	143	12.0	12.00	142.80	60.70	60.70	23.00	23.00
2 hr	79	6.6	13.20	157.20	33.40	66.80	12.70	25.35
3 hr	55	4.6	13.80	163.80	23.20	69.60	8.80	26.40
4 hr	43	3.5	14.00	170.40	18.10	72.40	6.90	27.50
5 hr	35	2.9	14.50	174.00	14.80	73.90	5.60	28.10
8 hr	23	1.9	15.20	182.40	9.70	77.50	3.70	29.40
10 hr	19	1.5	15.00	186.00	7.90	79.00	3.00	30.00
20 hr	10	0.8	16.00	192.00	4.10	81.60	1.55	31.00

Table A-10: 16Ah GENESIS Performance Data at 25°C

HAWKER

Run time to 1.50 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	2898	302.4	10.10	96.60	784.20	26.10	273.40	9.10
5 min	1674	162.2	13.50	139.50	453.00	37.75	157.90	13.20
10 min	1045	96.9	16.15	174.20	282.85	47.10	98.60	16.40
15 min	778	70.6	17.65	194.40	210.40	52.60	73.40	18.30
20 min	625	56.0	18.70	208.40	169.20	56.40	59.00	19.70
30 min	454	40.0	20.00	227.10	122.90	61.50	42.85	21.40
45 min	326	28.4	21.30	244.35	88.20	66.10	30.70	23.05
1 hr	256	22.1	22.10	256.20	69.30	69.30	24.20	24.20
2 hr	140	11.9	23.80	279.60	37.80	75.70	13.20	26.40
3 hr	97	8.3	24.90	291.60	26.30	78.90	9.20	27.50
4 hr	75	6.3	25.20	300.00	20.30	81.20	7.10	28.30
5 hr	61	5.1	25.50	303.00	16.40	82.00	5.70	28.60
8 hr	39	3.3	26.40	312.00	10.55	84.40	3.70	29.40
10 hr	32	2.7	27.00	318.00	8.60	86.10	3.00	30.00
20 hr	16	1.4	28.00	324.00	4.40	87.70	1.50	30.60

Table A-11: 26Ah GENESIS Performance Data at 25°C

Run time to 1.60 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	2644	265.7	8.90	88.10	715.60	23.85	249.45	8.30
5 min	1609	153.3	12.80	134.10	435.50	36.30	151.80	12.65
10 min	1026	94.5	15.75	171.00	277.65	46.30	96.80	16.10
15 min	769	69.6	17.40	192.15	208.00	52.00	72.50	18.10
20 min	620	55.5	18.50	206.60	167.70	55.90	58.50	19.50
30 min	451	39.9	19.95	225.60	122.10	61.05	42.60	21.30
45 min	324	28.3	21.20	243.00	87.70	65.80	30.60	22.90
1 hr	254	22.0	22.00	254.40	68.80	68.80	24.00	24.00
2 hr	139	11.8	23.60	277.20	37.50	75.00	13.10	26.15
3 hr	96	8.2	24.60	288.00	26.00	77.90	9.10	27.20
4 hr	74	6.2	24.80	295.20	20.00	79.90	7.00	27.85
5 hr	60	5.1	22.50	300.00	16.20	81.20	5.70	28.30
8 hr	38	3.3	26.40	307.20	10.40	83.10	3.60	29.00
10 hr	31	2.6	26.00	312.00	8.40	84.40	2.90	29.40
20 hr	16	1.4	28.00	324.00	4.40	87.70	1.50	30.60

Table A-12: 26Ah GENESIS Performance Data at 25°C

HAWKER

Run time to 1.67 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	2419	235.8	7.90	80.60	654.50	21.80	228.20	7.60
5 min	1532	143.4	11.95	127.65	414.50	34.50	144.50	12.00
10 min	995	90.7	15.10	165.90	269.40	44.90	93.90	15.65
15 min	751	67.4	16.85	187.65	203.10	50.80	70.80	17.70
20 min	607	54.1	18.00	202.40	164.30	54.80	57.30	19.10
30 min	444	39.0	19.50	222.00	120.15	60.10	41.90	20.90
45 min	319	27.8	20.85	239.40	86.40	64.80	30.10	22.60
1 hr	251	21.7	21.70	250.80	67.90	67.90	23.70	23.70
2 hr	137	11.7	23.40	273.60	37.00	74.00	12.90	25.80
3 hr	95	8.0	24.00	284.40	25.65	77.00	8.90	26.80
4 hr	73	6.1	24.00	290.40	19.65	78.60	6.85	27.40
5 hr	59	5.0	25.00	297.00	16.10	80.40	5.60	28.00
8 hr	38	3.2	25.60	307.20	10.40	83.10	3.60	29.00
10 hr	31	2.6	26.00	312.00	8.40	84.40	2.90	29.40
20 hr	16	1.4	28.00	324.00	4.40	87.70	1.50	30.60

Table A-13: 26Ah GENESIS Performance Data at 25°C

Run time to 1.75 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	2141	200.9	6.70	71.40	579.50	19.30	202.00	6.70
5 min	1424	129.9	10.80	118.65	385.30	32.10	134.30	11.20
10 min	947	84.7	14.10	157.90	256.40	42.70	89.40	14.90
15 min	721	63.8	15.95	180.30	195.20	48.80	68.00	17.00
20 min	587	51.5	17.20	195.60	158.80	52.90	55.40	18.45
30 min	431	37.5	18.75	215.70	116.70	58.40	40.70	20.35
45 min	311	26.9	20.20	233.55	84.30	63.20	29.40	22.00
1 hr	245	21.0	21.00	244.80	66.25	66.25	23.10	23.10
2 hr	134	11.3	22.60	267.60	36.20	72.40	12.60	25.25
3 hr	93	7.8	23.40	279.00	25.20	75.50	8.80	26.30
4 hr	71	6.0	24.00	285.60	19.30	77.30	6.70	26.90
5 hr	58	4.9	24.50	291.00	15.75	78.75	5.50	27.45
8 hr	37	3.1	24.80	297.60	10.10	80.50	3.50	28.10
10 hr	31	2.5	25.00	306.00	8.30	82.80	2.90	28.90
20 hr	16	1.3	26.00	324.00	4.40	87.70	1.50	30.60

Table A-14: 26Ah GENESIS Performance Data at 25°C

HAWKER

Run time to 1.85 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	1795	159.4	5.30	59.80	485.80	16.20	169.40	5.65
5 min	1273	111.4	9.30	106.10	344.55	28.70	120.10	10.00
10 min	876	75.8	12.60	146.00	273.10	39.50	82.60	13.80
15 min	677	58.2	14.55	169.20	183.15	45.80	63.85	16.00
20 min	555	47.5	15.80	185.00	150.20	50.10	52.40	17.45
30 min	412	35.0	17.50	205.80	111.40	55.70	38.80	19.40
45 min	299	25.3	19.00	224.10	80.90	60.60	28.20	21.10
1 hr	236	19.9	19.90	235.80	63.80	63.80	22.25	22.25
2 hr	130	10.8	21.60	259.20	35.10	70.10	12.20	24.45
3 hr	90	7.5	22.50	270.00	24.40	73.10	8.50	25.50
4 hr	69	5.7	22.80	276.00	18.70	74.70	6.50	26.00
5 hr	56	4.7	23.50	282.00	15.30	76.30	5.30	26.60
8 hr	37	3.0	24.00	292.80	9.90	79.20	3.45	27.60
10 hr	29	2.4	24.00	294.00	8.00	79.60	2.80	27.70
20 hr	16	1.3	26.00	312.00	4.20	84.40	1.50	29.40

Table A-15: 26Ah GENESIS Performance Data at 25°C

Run time to 1.50 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	4046	417.0	13.90	134.90	723.20	24.10	275.20	9.20
5 min	2498	240.5	20.00	208.15	446.50	37.20	169.90	14.20
10 min	1607	148.3	24.70	267.90	287.30	47.90	109.35	18.20
15 min	1210	109.2	27.30	302.40	216.20	54.05	82.30	20.60
20 min	979	87.2	29.10	326.20	174.90	58.30	66.60	22.20
30 min	716	62.7	31.35	357.90	127.95	64.00	48.70	24.35
45 min	516	44.6	33.45	387.00	92.20	69.20	35.10	26.30
1 hr	406	34.8	34.80	406.20	72.60	72.60	27.60	27.60
2 hr	223	18.8	37.60	446.40	39.90	79.80	15.20	30.40
3 hr	155	13.1	39.30	466.20	27.80	83.30	10.60	31.70
4 hr	119	10.0	40.00	477.60	21.30	85.40	8.10	32.50
5 hr	98	8.2	41.00	489.00	17.50	87.40	6.65	33.30
8 hr	64	5.3	42.40	508.80	11.40	90.95	4.30	34.60
10 hr	52	4.3	43.00	516.00	9.20	92.20	3.50	35.10
20 hr	28	2.3	46.00	564.00	5.00	100.80	1.90	38.40

Table A-16: 42Ah GENESIS Performance Data at 25°C

HAWKER TECHNOLOGY Pb PERFORMANCE BY DESIGN

HAWKER

Run time to 1.60 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	3622	361.2	12.00	120.70	647.35	21.60	246.40	8.20
5 min	2404	226.2	18.85	200.35	429.70	35.80	163.55	13.60
10 min	1586	144.3	24.05	264.40	283.60	47.30	107.90	18.00
15 min	1201	107.5	26.90	300.30	214.70	53.70	81.70	20.40
20 min	973	86.1	28.70	324.20	173.85	57.95	66.20	22.05
30 min	710	62.1	31.05	354.90	126.90	63.40	48.30	24.10
45 min	510	44.2	33.15	382.50	91.20	68.40	34.70	26.00
1 hr	400	34.4	34.40	399.60	71.40	71.40	27.20	27.20
2 hr	218	18.5	37.00	435.60	38.90	77.90	14.80	29.60
3 hr	152	12.8	38.40	455.40	27.10	81.40	10.30	31.00
4 hr	117	9.8	39.20	468.00	20.90	83.65	8.00	31.80
5 hr	95	8.0	40.00	477.00	17.05	85.30	6.50	32.45
8 hr	62	5.2	41.60	499.20	11.15	89.20	4.20	34.00
10 hr	52	4.3	43.00	516.00	9.20	92.20	3.50	35.10
20 hr	28	2.3	46.00	564.00	5.00	100.80	1.90	38.40

Table A-17: 42Ah GENESIS Performance Data at 25°C

Run time to 1.67 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	3317	322.3	10.70	110.60	593.00	19.80	225.70	7.50
5 min	2291	212.0	17.70	190.95	409.60	34.10	155.90	13.00
10 min	1540	138.4	23.10	256.60	275.20	45.90	104.70	17.50
15 min	1173	104.1	26.00	293.25	209.70	52.40	79.80	19.95
20 min	953	83.8	27.90	317.60	170.30	56.80	64.80	21.60
30 min	698	60.8	30.40	348.90	124.70	62.40	47.50	23.70
45 min	502	43.3	32.50	376.65	89.80	67.30	34.20	25.60
1 hr	394	33.8	33.80	393.60	70.35	70.35	26.80	26.80
2 hr	215	18.2	36.40	429.60	38.40	76.80	14.60	29.20
3 hr	149	12.6	37.80	448.20	26.70	80.10	10.20	30.50
4 hr	115	9.7	38.80	460.80	20.60	82.40	7.80	31.35
5 hr	94	7.9	39.50	471.00	16.80	84.20	6.40	32.00
8 hr	62	5.1	40.80	494.40	11.05	88.40	4.20	33.60
10 hr	51	4.2	42.00	510.00	9.10	91.20	3.50	34.70
20 hr	28	2.3	46.00	564.00	5.00	100.80	1.90	38.40

Table A-18: 42Ah GENESIS Performance Data at 25°C

HAWKER

Run time to 1.75 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	2978	279.9	9.30	99.30	532.40	17.75	202.60	6.75
5 min	2130	193.0	16.10	177.50	380.70	31.70	144.90	12.10
10 min	1461	129.4	21.60	243.50	261.15	43.50	99.40	16.60
15 min	1124	98.5	24.60	281.10	201.00	50.25	76.50	19.10
20 min	919	80.0	26.70	306.20	164.20	54.70	62.50	20.80
30 min	678	58.5	29.25	339.00	121.20	60.60	46.10	23.10
45 min	491	42.0	31.50	368.10	87.70	65.80	33.40	25.00
1 hr	386	32.9	32.90	385.80	69.00	69.00	26.20	26.20
2 hr	212	17.9	35.80	423.60	37.90	75.70	14.40	28.80
3 hr	147	12.4	37.20	441.00	26.30	78.80	10.00	30.00
4 hr	113	9.5	38.00	453.60	20.30	81.10	7.70	30.90
5 hr	93	7.7	38.50	465.00	16.60	83.10	6.30	31.60
8 hr	61	5.0	40.00	484.80	10.80	86.70	4.10	33.00
10 hr	50	4.1	41.00	498.00	8.90	89.00	3.40	33.90
20 hr	28	2.3	46.00	552.00	4.90	98.70	1.90	37.55

Table A-19: 42Ah GENESIS Performance Data at 25°C

Run time to 1.85 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	2581	231.2	7.70	86.00	461.30	15.40	175.55	5.85
5 min	1901	167.4	13.95	158.45	339.90	28.30	129.35	10.80
10 min	1338	116.1	19.35	223.00	239.20	39.90	91.00	15.20
15 min	1046	90.0	22.50	261.45	186.90	46.70	71.10	17.80
20 min	863	73.9	24.60	287.80	154.30	51.40	58.70	19.60
30 min	646	54.9	27.45	323.10	115.50	57.75	44.00	22.00
45 min	473	39.9	29.90	355.05	84.60	63.50	32.20	24.15
1 hr	376	31.5	31.50	375.60	67.10	67.10	25.55	25.55
2 hr	208	17.3	34.60	416.40	37.20	74.40	14.20	28.30
3 hr	145	12.1	36.30	435.60	25.95	77.90	9.90	29.60
4 hr	112	9.3	37.20	448.80	20.10	80.20	7.60	30.50
5 hr	91	7.6	38.00	456.00	16.30	81.50	6.20	31.00
8 hr	59	4.9	39.20	475.20	10.60	84.90	4.00	32.30
10 hr	48	4.0	40.00	480.00	8.60	85.80	3.30	32.65
20 hr	26	2.2	44.00	516.00	4.60	92.20	1.80	35.10

Table A-20: 42Ah GENESIS Performance Data at 25°C

HAWKER

Run time to 1.50 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	6792	647.0	19.4	203.8	693.9	20.8	279.5	8.4
5 min	4226	395.6	31.6	338.1	431.7	34.5	173.9	13.9
10 min	2717	249.6	42.4	461.9	277.6	47.2	111.8	19.0
15 min	2041	185.2	46.3	510.1	208.5	52.1	84.0	21.0
20 min	1648	148.1	48.9	543.7	168.3	55.5	67.8	22.4
30 min	1202	106.7	53.3	601.2	122.8	61.4	49.5	24.7
45 min	865	75.7	56.8	648.9	88.4	66.3	35.6	26.7
1 hr	680	59.0	59.0	680.4	69.5	69.5	28.0	28.0
2 hr	374	31.7	63.4	747.6	38.2	76.4	15.4	30.8
3 hr	261	21.9	65.7	783.0	26.7	80.0	10.7	32.2
4 hr	202	16.8	67.2	806.4	20.6	82.4	8.3	33.2
5 hr	165	13.7	68.5	825.0	16.9	84.3	6.8	34.0
8 hr	108	8.9	71.2	864.0	11.0	88.3	4.4	35.6
10 hr	88	7.3	73.0	882.0	9.0	90.1	3.6	36.3
20 hr	47	3.9	78.0	948.0	4.8	96.9	2.0	39.0

Table A-21: 70Ah GENESIS Performance Data at 25°C

Run time to 1.60 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	5899	570.6	17.1	177.0	602.6	18.1	242.7	7.3
5 min	3963	371.5	29.7	317.0	404.9	32.4	163.1	13.0
10 min	2638	241.3	41.0	448.5	269.5	45.8	108.6	18.5
15 min	2007	181.0	45.2	501.7	205.0	51.3	82.6	20.6
20 min	1631	145.5	48.0	538.2	166.6	55.0	67.1	22.1
30 min	1196	105.3	52.6	598.2	122.2	61.1	49.2	24.6
45 min	863	75.0	56.2	647.1	88.1	66.1	35.5	26.6
1 hr	679	58.4	58.4	678.6	69.3	69.3	27.9	27.9
2 hr	371	31.4	62.8	742.8	37.9	75.9	15.3	30.6
3 hr	259	21.7	65.1	775.8	26.4	79.3	10.6	31.9
4 hr	199	16.6	66.4	796.8	20.4	81.4	8.2	32.8
5 hr	163	13.5	67.5	816.0	16.7	83.4	6.7	33.6
8 hr	107	8.8	70.4	854.4	10.9	87.3	4.4	35.2
10 hr	87	7.2	72.0	870.0	8.9	88.9	3.6	35.8
20 hr	47	3.9	78.0	948.0	4.8	96.9	2.0	39.0

Table A-22: 70Ah GENESIS Performance Data at 25°C

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Run time to 1.67 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
					Energy and power densities			
2 min	5193	500.4	15.0	155.8	530.5	15.9	213.7	6.4
5 min	3680	342.4	27.4	294.4	376.0	30.1	151.5	12.1
10 min	2519	228.5	38.8	428.3	257.4	43.8	103.7	17.6
15 min	1940	173.4	43.3	485.1	198.2	49.6	79.9	20.0
20 min	1587	140.5	46.4	523.7	162.1	53.5	65.3	21.6
30 min	1173	102.5	51.2	586.5	119.8	59.9	48.3	24.1
45 min	850	73.4	55.0	637.6	86.9	65.1	35.0	26.2
1 hr	670	57.4	57.4	670.2	68.5	68.5	27.6	27.6
2 hr	368	31.0	62.0	735.6	37.6	75.2	15.1	30.3
3 hr	256	21.4	64.2	7668.6	26.2	78.5	10.5	31.6
4 hr	197	16.4	65.6	789.6	20.2	80.7	8.1	32.5
5 hr	161	13.4	67.0	807.0	16.5	82.4	6.6	33.2
8 hr	105	8.7	69.6	840.0	10.7	85.8	4.3	34.6
10 hr	86	7.1	71.0	858.0	8.8	87.7	3.5	35.3
20 hr	47	3.9	78.0	936.0	4.8	95.6	1.9	38.5

Table A-23: 70Ah GENESIS Performance Data at 25°C

Run time to 1.75 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
					Energy and power densities			
2 min	4393	414.9	12.4	131.8	448.8	13.5	180.8	5.4
5 min	3304	301.9	24.1	264.3	337.6	27.0	136.0	10.9
10 min	2341	209.0	35.5	398.0	239.2	40.7	96.3	16.4
15 min	1832	161.5	40.4	457.9	187.1	46.8	75.4	18.8
20 min	1513	132.3	43.7	499.4	154.6	51.0	62.3	20.5
30 min	1132	97.9	48.9	565.8	115.6	57.8	46.6	23.3
45 min	827	70.9	53.2	620.5	84.5	63.4	34.0	25.5
1 hr	656	55.8	55.8	655.8	67.0	67.0	27.0	27.0
2 hr	362	30.5	61.0	724.8	37.0	74.0	14.9	29.8
3 hr	253	21.1	63.3	757.8	25.8	77.4	10.4	31.2
4 hr	195	16.2	64.8	780.0	19.9	79.7	8.0	32.1
5 hr	159	13.2	66.0	795.0	16.2	81.2	6.5	32.7
8 hr	104	8.6	68.8	830.4	10.6	84.8	4.3	34.2
10 hr	85	7.0	70.0	846.0	8.6	86.4	3.5	34.8
20 hr	46	3.8	76.0	912.0	4.7	93.2	1.9	37.5

Table A-24: 70Ah GENESIS Performance Data at 25°C

Run time to 1.85 vpc	Watts	Amps	Capacity (Ah)	Energy (Wh)	Energy and power densities: Watts per liter	Wh per liter	Watts per kilogram	Wh per kilogram
2 min	3482	313.1	9.4	104.5	355.8	10.7	143.3	4.3
5 min	2810	247.4	19.8	224.8	287.1	23.0	115.6	9.3
10 min	2082	180.7	30.7	353.9	212.7	36.2	85.7	14.6
15 min	1667	143.5	35.9	416.7	170.3	42.6	68.6	17.1
20 min	1397	119.7	39.5	460.9	142.7	47.1	57.5	19.0
30 min	1063	90.5	45.2	531.6	108.6	54.3	43.8	21.9
45 min	790	66.8	50.1	592.2	80.7	60.5	32.5	24.4
1 hr	631	53.2	53.2	630.6	64.4	64.4	26.0	26.0
2 hr	355	29.6	59.2	709.2	36.2	72.5	14.6	29.2
3 hr	248	20.7	62.1	745.2	25.4	76.1	10.2	30.7
4 hr	191	15.9	63.6	765.6	19.6	78.2	7.9	31.5
5 hr	157	13.0	65.0	783.0	16.0	80.0	6.4	32.2
8 hr	101	8.4	67.2	811.2	10.4	82.9	4.2	33.4
10 hr	83	6.8	68.0	828.0	8.5	84.6	3.4	34.1
20 hr	44	3.6	72.0	876.0	4.5	89.5	1.8	36.0

Table A-25: 70Ah GENESIS Performance Data at 25°C

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Appendix B

Figure B-1: Capacity as a function of temperature

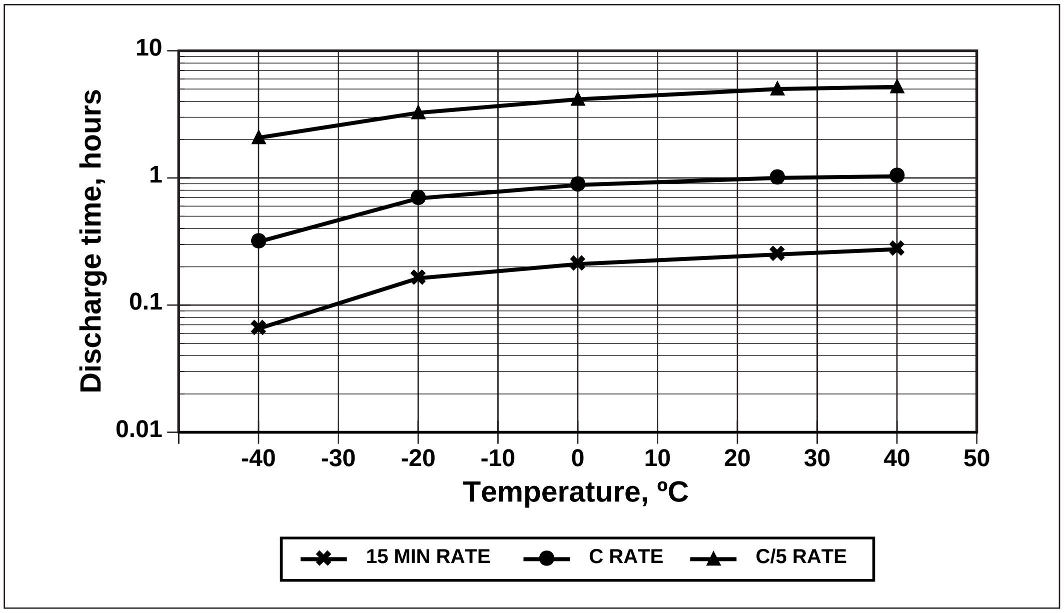

Figure B-2: GENESIS state of charge

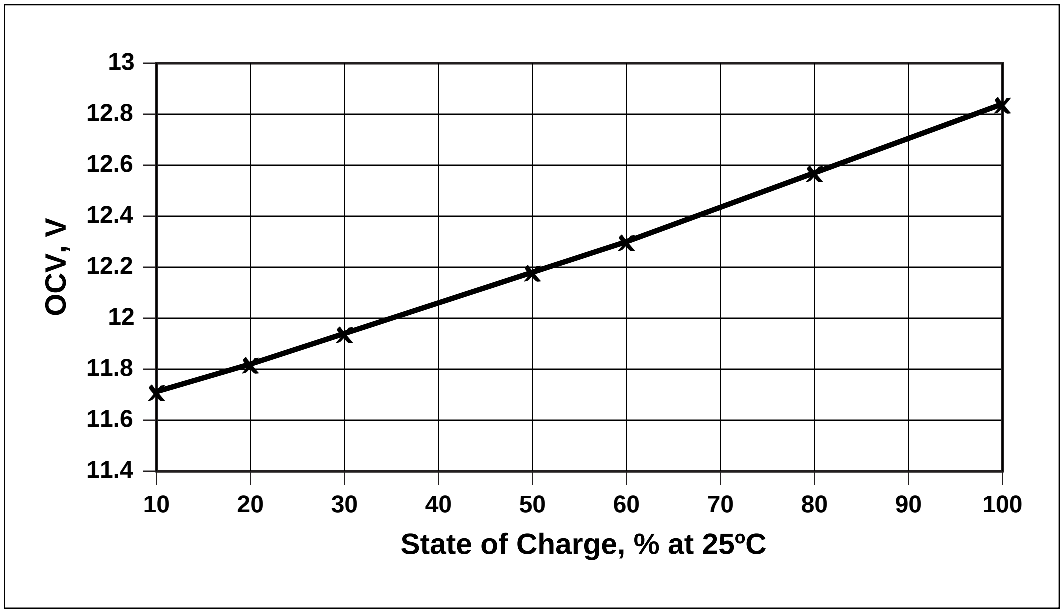

Figure B-3: GENESIS storage capacity at various temperatures

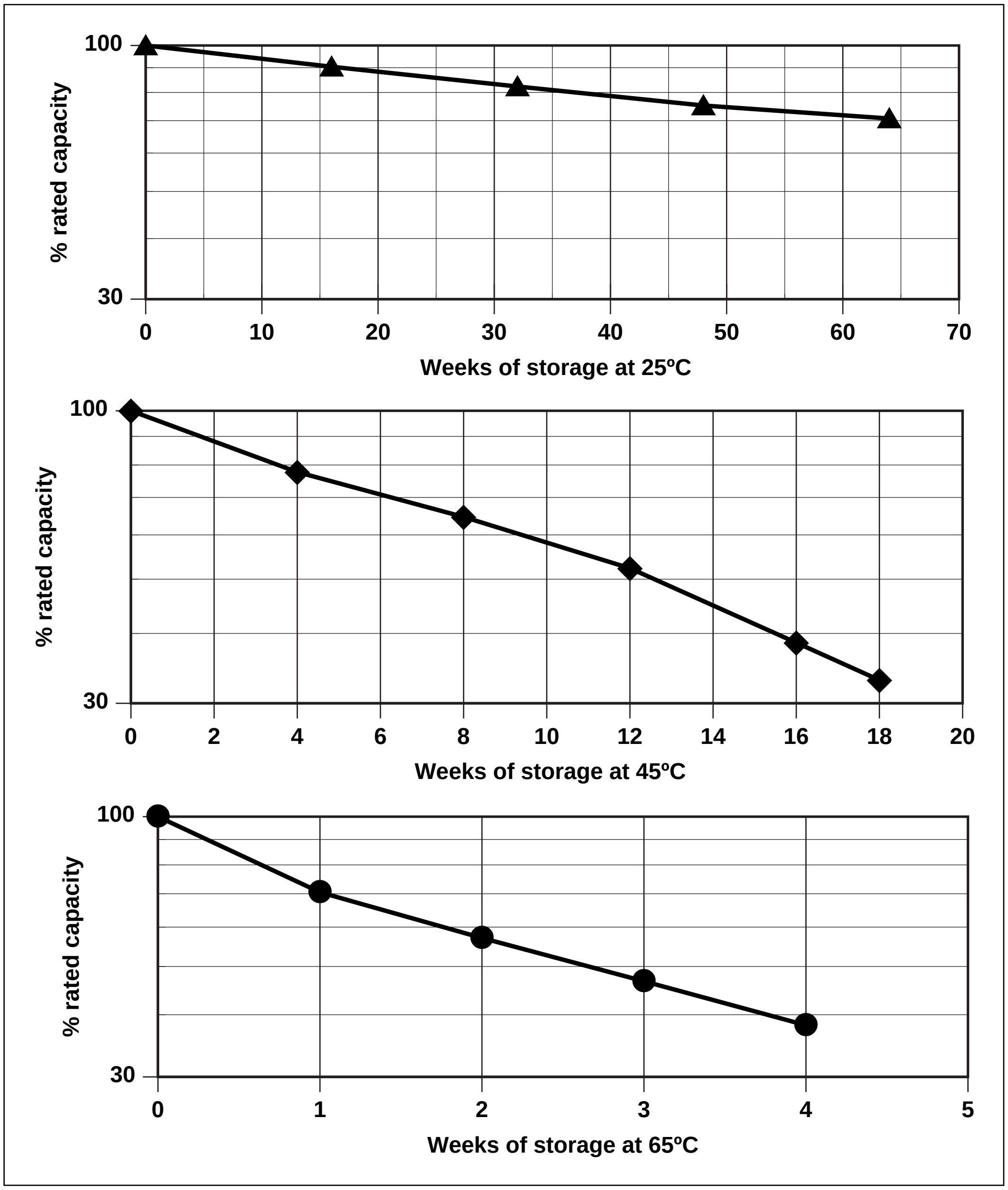

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Figure B-4: GENESIS float life at 2.27 VPC

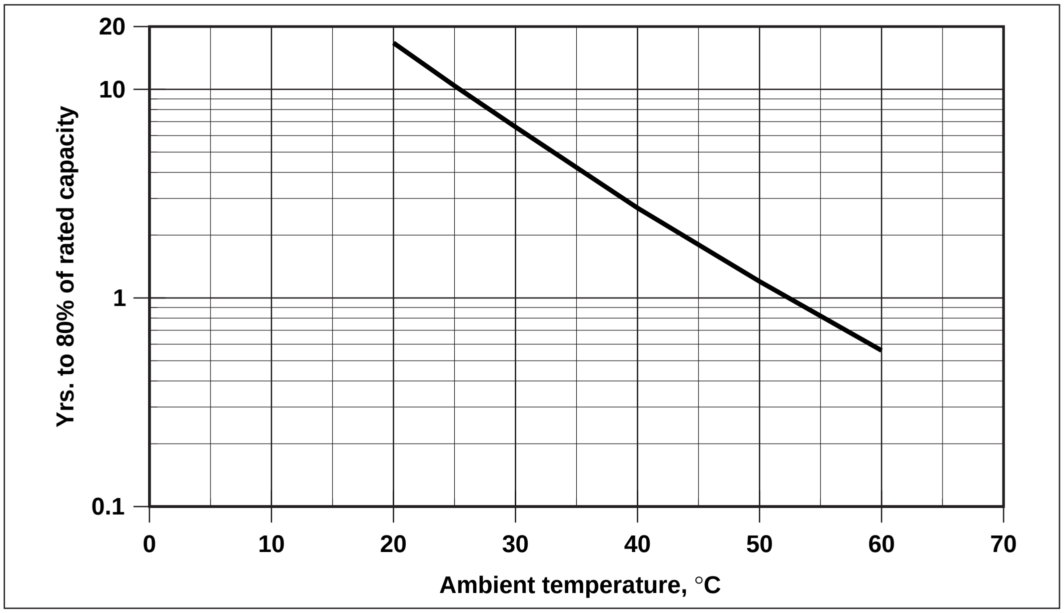


Figure B-5: Float Voltage Temperature Compensation

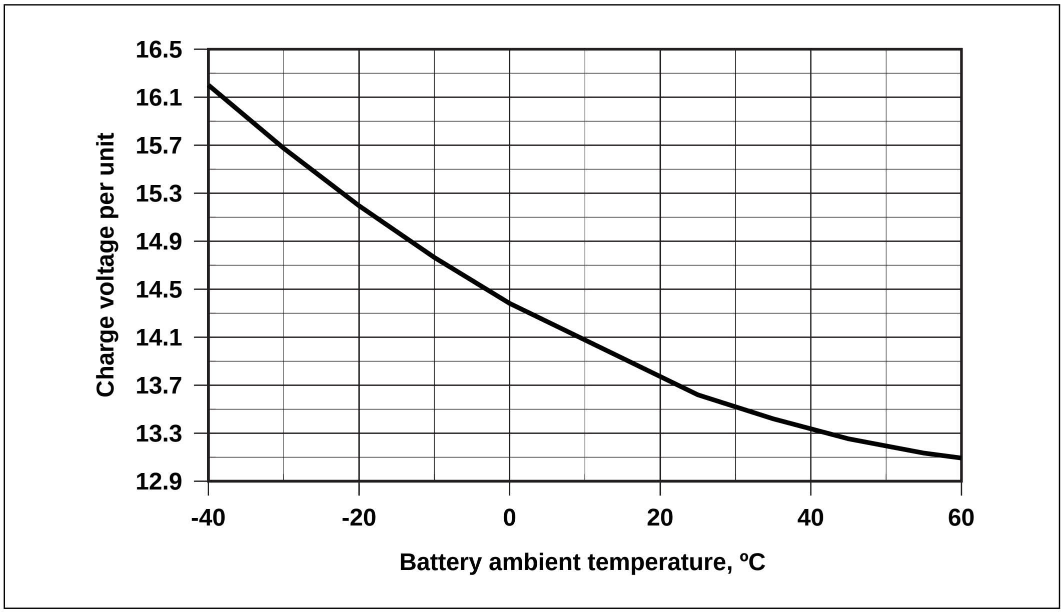
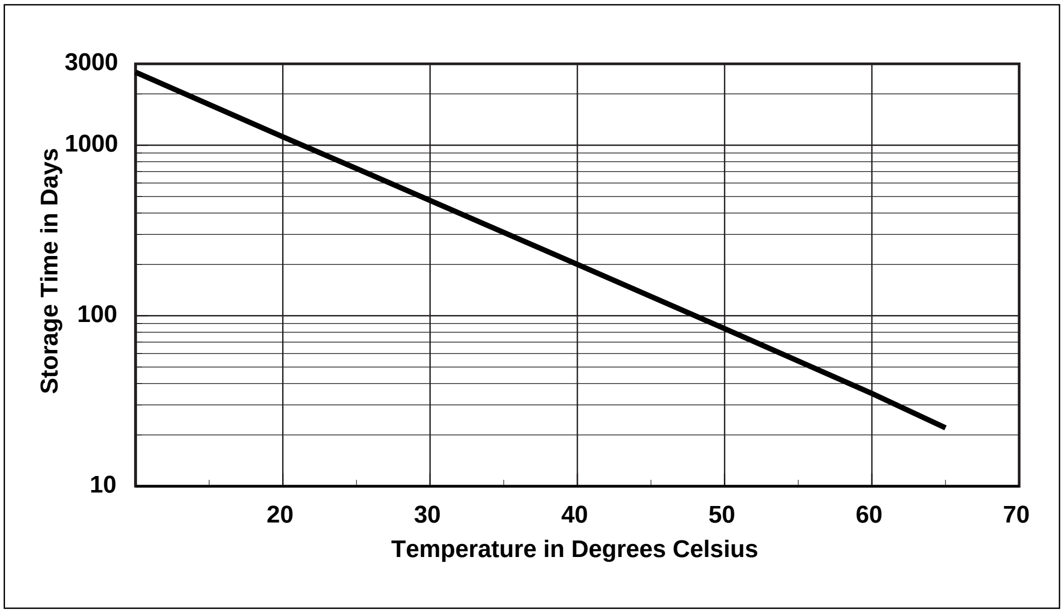


Figure B-6: Storage time as a function of temperature



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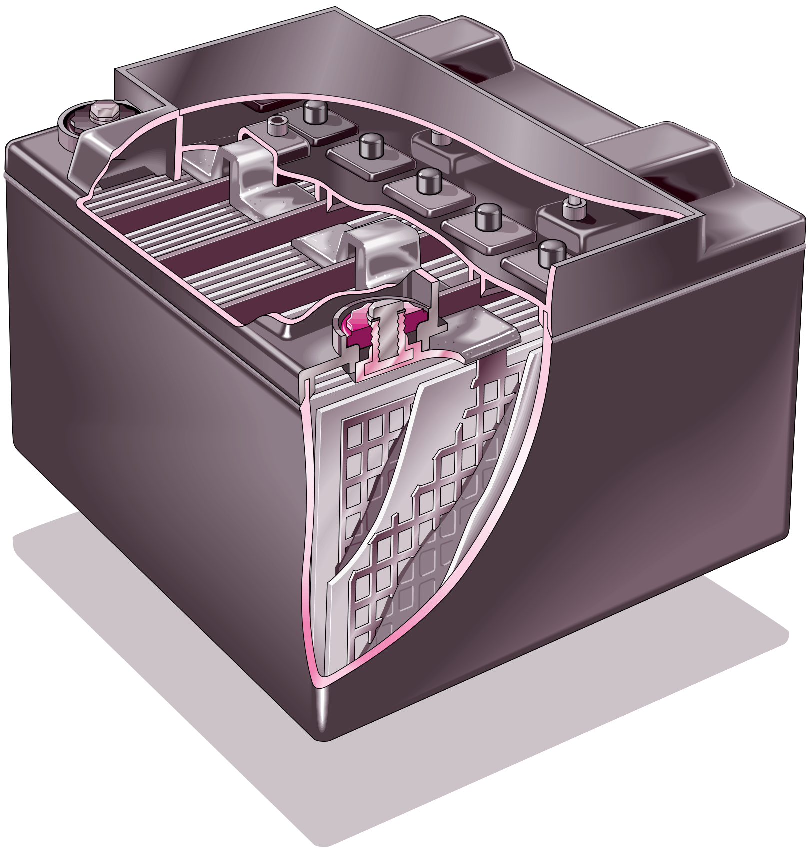

GENESIS 26Ah

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Revised 2/00

IBD-BR-020