3.0 Overview

Nickel Metal Hydride (NiMH) batteries are one of many secondary (rechargeable) battery chemistries in use today. Other secondary battery chemistries include Nickel Cadmium (NiCd), Lithium ion (Li-ion), and Sealed Lead Acid (Pb Acid). This section of the handbook explains the key advantages and disadvantages of each of the battery chemistries listed.

3.1.1 Nickel Metal Hydride (NiMH)

The rechargeable sealed NiMH cell absorbs hydrogen in the metal alloy makeup of its negative electrode during charge. As the cell is discharged, the metal alloy releases hydrogen to form water. The use of the metal alloy is the underlining reason for the high energy density of the NiMH cell compared to other chemistries (see Figure 3.1 *Energy Density Comparison*). For more detail description of the chemical reactions within a NiMH cell, see Section 2.1, *Principles of Operation and* Construction.

As shown in the following table, NiMH batteries have a long cycle life (minimum of 500 cycles) and good storage characteristics with a shelf life of 6 months in any state of charge (SOC). Furthermore, the battery can be recharged at any time without experiencing voltage depression (or memory effect). Most importantly, the NiMH battery is an environmentally friendly product.

Advantages	Disadvantages
High volumetric and gravimetric energy density Long cycle life Good storage characteristics No memory effect/voltage depression Environmentally friendly Slow and rapid charge compatible	Overcharge/overdischarge protection needed

3.1.2 Nickel Cadmium (NiCd)

The Nickel Cadmium (NiCd) cell chemistry is different to NiMH cells in that the NiCd cell absorbs cadmium where the NiMH cell stores hydrogen. Cadmium is much larger and heavier than hydrogen, which leads to lower volumetric and gravimetric energy densities of the NiCd cell (see Figure 3.1, *Energy Density Comparison*). Equivalent to NiMH batteries are the NiCd's cycle life and discharge voltage profile. Also, NiCds can be placed into storage at any state of charge (SOC). Nevertheless, the NiCd battery needs to be completely discharged before it is charged to avoid the occurrence of voltage depression (or memory effect). Furthermore, the primary disadvantage to the use of the NiCd chemistry is the environmental concerns and health risks associated with the use of cadmium.

Advantages	Disadvantages
Long cycle life Good storage characteristics Rapid charge compatible	Low volumetric and gravimetric energy density Memory effect/voltage depression Environmental and health concerns (e.g. kidney damage, itai-itai (ouch-ouch) disease in Japan, and Mutagenic)

3.1.3 Lithium ion (Li-ion)

Rechargeable Lithium Ion (Li-ion) cells have a negative electrode (anode) made from lithium. Lithium is a highly reactive material and is much lighter than the hydrogen-absorbing metal alloy of the NiMH negative electrode. This leads to higher gravimetric energy densities for the Li-ion cell (see Figure 3.1 *Energy Density Comparison*).

As shown in the following table, one of the advantages of Li-ion cells is that they have a self-discharge rate much lower than NiMH cells. As a result, Li-ion cells can stay in storage for 24 months without requiring maintenance. On the other hand, lithium is a very reactive material and it requires special circuitry to control charging as will as preventing overdischarge of the cells. If too high of a voltage is applied during charge, a catastrophic failure (e.g. explosion) will occur which may result in damage to the surrounding environment. In addition, a puncture penetrating the electrodes of the cell will also cause catastrophic failure. Furthermore, if the lithium of the negative electrode is exposed to water the negative electrode will spontaneously combust.

Along with the environmental concerns of a spontaneously combustible lithium electrode (especially in landfills), there are two other disadvantages to Li-ion chemistries. First, these batteries do not have the cycle life of the other chemistries. The expected cycle life of a Li-ion cell in an application is about 250-300 cycles. Second, Li-ion cells will not handle high discharge rates. Furthermore, as the temperature drops, the ability of the Li-ion cells to handle discharging at moderate rates is decreased.

Advantages	Disadvantages
Very high volumetric and gravimetric energy density Good storage characteristics	High cost Costly charge and discharge control required Short cycle life Low rate capability Low temperature performance Potential health risks/catastrophic failures

3.1.4 Sealed Lead Acid (Pb Acid)

The main attraction for Sealed Lead Acid (Pb Acid) cells is the low cost of lead. This makes the Pb Acid cell very inexpensive per watt-hour. Lead is relatively heavy resulting in low volumetric and gravimetric energy densities (see Figure 3.1, *Energy Density Comparison*). Also, the cycle life of a Pb Acid battery is directly proportional to the amount of energy removed from the battery during discharge. To obtain an equivalent cycle life of a NiMH system, only 30% of the Pb Acids capacity can be used. Another disadvantage to the Pb Acid chemistry is they need to be charged before being placed into storage or they will lose cycle life. Furthermore, there are some environmental concerns regarding the use of lead.

Advantages	Disadvantages
Low cost High rate capabilities	Low volumetric and gravimetric energy density Fair cycle life Must be charged to be stored Environmental and health concerns (e.g. metal retardation, interference with kidney and neurological function, hearing loss, blood disorders, hypertension)

Figure 3.1 Energy Density Comparison