

Comparison of NiCd, NiMH, and Li-Ion Batteries

Land mobile portables have traditionally used Nickel Cadmium (NiCd) and Nickel Metal Hydride (NiMH) batteries. Lithium-Ion (Li-Ion) batteries were recently introduced as an additional chemistry alternative. This white paper will help users make an informed decision when selecting among NiCd, NiMH, and Li-Ion batteries. All chemistries have advantages and disadvantages that must be weighed before choosing a battery pack chemistry.

Battery Characteristics

NiMH batteries provide the following advantages over NiCd:

- Higher capacity
- Limited memory effect
- Environmentally friendly

NiCd batteries provide the following advantages over NiMH:

- Longer cycle life
- Wider range of operating temperatures
- Lower price

Li-Ion batteries provide the following advantages over the Nickel chemistries:

- Light weight
- Environmentally friendly
- No memory effect
- Highest energy density of the three chemistries

Choosing a Battery Type

Table 1 shows key parameter comparisons of NiCd, NiMH, and Li-Ion batteries.

Table 1 – Comparison of NiCd, NiMH, and Li-Ion Batteries

Parameter	NiCd	NiMH	Li-Ion
Relative Capacity	1	1.4	3
Charge/Discharge Cycle Life	500+ cycles	300+ cycles	300+ cycles
Memory Effect	Noticeable effect. Can be eliminated by periodic conditioning	Little effect	No memory effect
Conditioning	Recommended periodically to eliminate memory	Recommended when new and after long storage periods	Not necessary
Operating Temperature	-22 to +140°F (-30 to +60°C)	-4 to +122°F (-20 to +50°C)	+14 to +122°F (-10 to +50°C)
Charging Temperature	+32 to 113°F (0 to +45°C)	+32 to +113°F (0 to +45°C)	+32 to +104°F (0 to +40°C)
Storage Temperature (>90 days)	+32 to +86°F (0 to +30°C)	+32 to +86°F (0 to +30°C)	+32 to +86°F (0 to +30°C)
High-Temperature Susceptibility	Some permanent loss of capacity above 140°F (60°C)	Greater permanent loss of capacity above 140°F (60°C)	Greater permanent loss of capacity above 140°F (>60°C)
Self-Discharge	20% loss of charge/month at 77°F (25°C)	30% loss of charge/month at 77°F (25°C)	Self-discharge is much lower than Nickel chemistries. 3% loss of charge/month at 77°F (25°C).
Recycling	Required by law in the U.S.	Not Required, but recommended	Not Required

Operating Parameters

1. **Relative Capacity** – Electrical capacity of the batteries when compared to a NiCd pack. M/A-COM determines the capacity of its battery packs by testing. Some third parties rate their packs by using individual cell specifications. Cell manufacturers rate cells based on a slow charge and discharge. In land mobile radio applications, batteries are charged and discharged much more aggressively and will not reach their rated capacity. Also, when cells are connected in series, as they are in all battery packs, it is impossible to extract the rated cell capacity from the pack.
2. **Charge/Discharge Cycle Life** – This represents the number of times a battery can be charged and discharged, which equates to the lifetime of the pack. Usage patterns can lengthen or shorten this number.
3. **Memory Effect** – The memory effect occurs when a battery pack is repeatedly recharged before it has been completely discharged. The result is that even after a full recharge, the battery will not allow its full capacity to be extracted. Memory can be minimized by conditioning. NiMH batteries are less susceptible to memory effect. Li-Ion is not susceptible to memory effect.

4. **Conditioning** – Conditioning entails fully discharging and then recharging a battery 3 or more times. This can be performed with a Cadex C7400 or iTech BC3506QP-5 battery conditioner available from M/A-COM. See the Cadex or iTech manuals for instructions on how to use the products.
5. **Operating Temperature** – This is the range of temperatures at which the battery can be reliably used due to characteristics of the chemical reactions involved. At lower temperatures, the battery is not able to convert its chemical energy into electrical energy. At higher temperatures, safety devices called positive temperature coefficient (PTC) resistors inside the battery prevent it from being used until the temperature falls. Batteries that are used in very cold or very hot conditions for extended periods of time can be permanently damaged.
6. **Charging Temperature** – This is the temperature range in which batteries can be charged due to limitations of the chemistry. All M/A-COM chargers limit charging outside of this range per cell manufacturer's ratings. This often affects vehicular chargers because vehicle temperatures can vary to extremes.
7. **Storage Temperature** – If batteries are stored above or below their storage temperature range, permanent performance degradation can result. In short, batteries must not be stored in excessively hot or cold locations.
8. **Storage Charge State and Duration** – All cells degrade over time. Nickel packs should be stored in a fully discharged state. Li-Ion packs should be stored at 40% charge. Li-Ion packs should not be stored for extended periods of time (3 to 6 months from manufacture).
9. **High-Temperature Susceptibility** – Prolonged high-temperature discharge damages the organic materials for both NiCd and NiMH. High-temperature discharge can occur while a user is operating the radio in a high-temperature environment, or if the battery is stored in a high-temperature environment. Short exposure to high temperatures will not permanently damage the cells. Short-term performance will be degraded, but can be recovered through a couple of charge/discharge cycles at room temperature (typically 77°F or 25°C).
10. **Self-Discharge** – Self-discharge is the gradual loss of charge over time for an unused cell. It is directly proportional to ambient temperature. The higher the temperature, the faster the battery discharges. The lower the temperature, the slower the battery discharges.
11. **Recycling** – By U.S. law, NiCd batteries must be recycled. Currently, NiMH cells are recommended but are not required to be recycled. Li-Ion batteries are not required to be recycled.

Conclusion

This white paper presents the advantages and disadvantages of NiCd, NiMH, and Li-Ion batteries for portable radios to help users make an informed choice when selecting batteries. NiCd batteries provide more recharging cycles, operate over a wider temperature range, and are lower priced than NiMH batteries. NiMH batteries have a higher relative capacity, limited induced memory effect, and are environmentally friendly. Li-Ion has a higher volumetric efficiency than the nickel-based batteries. Li-Ion batteries have no memory effect and are environmentally friendly.

NiCd and NiMH batteries are shipped uncharged. Both types of batteries must be charged before the first use. In addition, NiMH batteries should be conditioned prior to their first use or after storage for longer than three months or they will deliver only a small fraction of their rated capacity. Li-Ion batteries should be fully charged before the first use.

Excessive heat degrades all NiCd, NiMH, and Li-Ion batteries, but NiMH and Li-Ion are noticeably more sensitive. Batteries must be protected from heat extremes during storage, charging, and operation to prolong their service life. Users should consider operating environment temperatures when determining which type of battery to use. NiCd batteries have a greater range of operation than NiMH batteries. NiMH or Li-Ion should not be selected for very cold environments.

Users select NiMH or Li-Ion generally to take advantage of the greater capacity or “playtime” that these higher capacity cells offer; however, longer playtime is at the expense of the total service life of the battery as compared to NiCd. The charge/discharge cycle life of NiMH batteries that do not receive routine maintenance, or are stored, operated, or charged at high ambient temperatures is reduced. NiMH and Li-Ion **cannot** be used in environments where the battery temperature could fall below 14°F (-10°C). If the battery temperature falls below this level, the radio will not operate.

Critical communications fleets should have a battery maintenance program that includes the use of battery conditioners or analyzers so that end users are assured of having fully compliant batteries on their radios. Good service records provide the foundation for reliable operation and allow planning for replacements in a timely manner.