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Market for nickel–cadmium batteries

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Abstract

Besides the lead/acid battery market, which has seen a tremendous development linked with the car industry, the alkaline rechargeable battery market has also been expanded for more than twenty years, especially in the field of portable applications with nickel–cadmium batteries. Today, nickel–cadmium batteries have to face newcomers on the market, such as nickel–metal hydride, which is another alkaline couple, and rechargeable lithium batteries; these new battery systems have better performances in some areas. This work illustrates the status of the market for nickel–cadmium batteries and their applications. Also, for two major applications — the cordless tool and the electric vehicles — the competitive situation of nickel–cadmium batteries; facing new systems such as nickel–metal hydride and lithium ion cells are discussed.

Keywords: Nickel–cadmium batteries; Marketing

1. Market for nickel–cadmium batteries

In 1995, the worldwide market for nickel–cadmium (Ni–Cd) batteries is estimated to amount to $3000 million of which more than 80% concerns batteries used in portable applications and less than 20% in industrial and propulsion usage.

In spite of the competition coming from nickel–metal hydride (Ni–MH) and lithium-ion (Li-ion) batteries, the market for Ni–Cd batteries continues to grow, both in the portable and the industrial/propulsion market.

1.1. Market success for nickel–cadmium batteries

Without entering into technical details the following key features of this electrochemical couple are outlined.

The following global charge/discharge equation:

$$2Ni(OH)_2 + Cd(OH)_2 \rightleftharpoons 2NiOOH + Cd + H_2O \quad (1)$$

has two major advantages: (i) the electrolyte does not take part in any of the electrochemical reactions, and (ii) the active materials are insoluble in the electrolyte.

Given these two essential features, one may mention the ten major key benefits of the Ni–Cd couple:

(i) a high level of specific energy, today 56 Wh/kg, with an ultimate development that will reach more than 65 Wh/kg;

(ii) a high specific power around 200 W/kg;

(iii) the highest level of reliability of all existing rechargeable batteries, with a proven λ of 10^{-8};

(iv) the longest life time: >2000 cycles with 80% of depth-of-discharge;

(v) high resistance to mechanical and electrical abuses;

(vi) capable of fast charging with beneficial effects on efficiency and ageing;

(vii) a broad operating temperature range of −30 to +60 °C;

(viii) extremely simple maintenance up to maintenance free;

(ix) the lowest cost of usage in spite of a higher purchase cost for some applications, and

(x) almost totally recycleable.

1.2. Applications of nickel–cadmium batteries

Today, Ni–Cd batteries can be found in a broad range of applications which continues to grow rapidly:

Consumer market represents more than 1 billion pieces yearly:

(i) home appliances: shavers, torches, vacuum cleaners, tooth brushes, food mixers, tin openers;

(ii) video: camcorder, video tape recorders;

(iii) professional tools: drills, screwdrivers, saws, hedge-trimmers;

(iv) communications: cellular phone, cordless phone, civil and military radio equipment;

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Table 1
Portable size 4/5 A cell, forecast performances

Parameter	Ni–Cd	Ni–MH	Li-ion
Voltage	1.2	1.2	3.5
Energy density (Wh/kg)	60	80	110
Volumetric energy (Wh/l)	175	230	260
Cycle life	500–1000	500–1000	500–1000

Table 2
General comparison of the application of power sources in the field of cordless tools

Parameter	Alkaline family			Li-ion
	Standard Ni–Cd	Enhanced Ni–Cd	Ni–MH	
Nominal capacity (mAh)	+	+ +	+ + +	−
Volumetric energy (Wh/l)	−	+	+ +	+ + +
Weight energy density (Wh/kg)	−	+	+ +	+ + +
Nominal voltage	1.2 V	1.2 V	1.2 V	3.6 V
Charge retention	+	+ +	−	+ + +
Cycle life	+ + +	+ +	+ +	+
High-rate charge	+ + +	+ +	+ +	+
Memory effect	−	−	+	+ + +
Overcharge ability	+ + +	+ +	+	− −
Overdischarge ability	+ + +	+ +	+ +	− −
Internal resistance during cycling	+ + +	+ +	+	−
Low-temperature operating ability	+ + +	+ +	+	−
Cost/Wh (in same volume) and cost of the charger/electronics	+ +	+ +	+	−

(v) office automation: portable computers, pocket copying machines, fax machines, cash and credit card registers, and

(vi) consumer electronics: toys, model racing cars, electronic games.

Emergency lighting: Central devices and single units.

Military and space usage: Mines and munitions, infrared devices, missiles, launchers and satellites.

Aviation: starting of aircraft turbine engines for commercial and business jets, commuter, helicopters, on-board safety.

Railway: Diesel-engine starting, lighting and signalling systems, high-speed train braking systems, mass transits and city people movers.

Back-up power supply: Stand-by power for utilities, production and distribution of stand-by power and energy for the oil and gas industry, stand-by energy for telecommunication, engine starting for gas turbines and diesel engines, safety stand-by for industrial uninterruptible power suppliers.

Propulsion: Automated guided vehicles, electric vehicles (full electrical propulsion and hybrid types).

2. Future of the nickel–cadmium battery

As can be concluded from the list of the different applications of Ni–Cd batteries, this system is now well implemented in our way of life and has given the possibility to create and spread equipment with autonomous energy. Will the Ni–Cd battery be replaced in the future by improved batteries? Whichever system is selected, the requirements of battery users are likely to be: maintenance free; lighter for portable and on-board use; less volumetric; electronic management capability; safe usage; recycleability, and cheaper.

Recent developments in rechargeable systems as Ni–MH, Li-ion and improved Ni–Cd systems have provided higher energy densities in terms of both weight and volume.

Further improvements are forecasted to the year 2000 as shown in Table 1.

It is clear that both Ni–MH and Li-ion batteries can provide a higher energy than the presently available Ni–Cd systems. However, a battery system is not to be evaluated solely on the basis of energy density. A whole range of other performance parameters have to be considered before selecting a battery for a particular application.

Two examples of applications will be evaluated where Ni–Cd batteries are in competition with Ni–MH and Li-ion ones, i.e., cordless tools and electric vehicles.

2.1. Cordless tools

In 1993–1994, the world market for cordless tools is estimated at 15 to 16 million units, a market with a growing rate of 3 to 4% per year, to reach about 25 million units in the

Table 3
Comparison of battery weight and volume of 15 kWh batteries for the application in electric vehicles

System	Weight (kg)	Volume (l)
High energy Ni–Cd	273	88
Advanced Ni–Cd	230	75
Ni–MH	200	70
Li-ion	140	55

year 2000, which corresponds to 220–230 million cells (1.2 V) integrated into original and replacement battery packs.

The main characteristics of the battery are:

- continuous discharge rate at 10–30 A
- recharge in a few minutes
- minimum 500 cycles and 1000 cycles as the objective
- low internal impedance maintained during cycle life
- operating temperature range 10–40 °C
- high resistance to shocks and vibrations
- complete battery to be safe and fully rechargeable

For the Ni–MH system, the existing available batteries should be improved in their performance characteristics in order to compete with Ni–Cd on power tool applications:

- fast chargeability presently limited to C rate
- high rate of dischargeability presently limited to $3C$
- internal impedance, 2 times greater than the existing Ni–Cd batteries and increasing during cycle life
- cost per Wh 35% higher than Ni–Cd batteries
- recycling ability

For the Li-ion system, the parameters to be improved are:

- fast chargeability limited to C rate
- high rate of discharge limited to $2C$
- internal impedance 3 to 4 times greater than existing the Ni–Cd systems
- voltage profile
- cost per Wh 2 to 3 times higher than Ni–Cd batteries

Ni–Cd batteries are, at the present time, the only power source able to fulfil the requirements of cordless tool applications that combine high rate of discharge and ultra-fast charge. Ni–MH can be considered as a candidate for some light tools and it is difficult to foresee this type of application for Li-ion cells on a medium-term basis.

Table 2 gives a summary of the application of different power sources in the filed of cordless tools.

2.2. Electric vehicles

The electric vehicle (EV) market presents a significant and challenging opportunity. In 1993, this EV battery market was valued at less than $ 10 million and it is projected to reach a value of $ 300 million in the year 2000.

If it is estimated that the lead/acid battery has a small chance to be involved in the large development of EV because of energy density limitations and lack of reliability, then other electrochemical systems operating at normal temperature are in competition to manage the propulsion of EVs until the years 2005–2010, namely Ni–Cd, Ni–MH and Li-ion batteries, see Table 3.

For a manufacturer of EVs, the key performances are the following:

- safety
- reliability
- maintenance
- stability of performance during lifetime
- weight and volume
- cost
- life time
- recycleability

Table 4
General comparison of the different power source options

Parameter	High energy Ni–Cd	Advanced Ni–Cd	Ni–MH	Li-ion
Wh/kg	+	+ +	+ +	+ + +
Wh/l	–	+	+ +	+ + +
W/kg	+	+ +	+	+
Charge retention	+	+ +	–	+ + +
Cycle life	+ + +	+ + +	+ +	+
High charge rate	+ +	+ +	+	+
Memory effect	+	+	+ +	+ + +
Overcharge ability	+ + +	+ +	+	– –
Overdischarge ability	+ + +	+ +	+	– –
Internal resistance during cycling	+ + +	+ +	+	–
High-temperature ability	+ +	+ + +	+	+ +
Low-temperature ability	+ + +	+ +	+	–
Power reliability	+ + +	+ +	+	–
Voltage profile	+ + +	+ + +	+ +	+
Proven safe usage	+ + +	+ +	+ +	+
Recycleability	+ + +	+ + +	–	+ +
Cost/Wh	+	+ +	+	+ + +

However, all these characteristics are necessary for the choice of a battery and up to now Ni–Cd is the only couple already developed and industrialized able to fulfil the demand coming from the EV manufacturers. For this reason, the first EV launched on the market by large car manufacturers will include high energy Ni–Cd batteries. It is however clear that all developments made on Ni–MH and Li-ion batteries will provide a chance beyond year 2000 for these couples when they will have proven reliability and stability of their performances during lifetime, see Table 4.

3. Conclusions

The very good performance level in most areas is responsible for the success of Ni–Cd batteries in the world of rechargeable batteries. This system has created the possibility to develop cordless equipment which is now spread everywhere in our daily life. The market is demanding more powerful batteries and new systems such as Ni–MH and Li-ion will have some advantages to fit these requirements. The examples of applications shown in this paper, in particular the cordless tool and EV, are showing that the market should be split in the future between the different systems. The Ni–Cd system should keep a major share of the rechargeable battery market, thanks to definitive advantages such as its reliability, long lifetime, power density, lower cost of usage, capability of reliable fast charging and behaviour in the face of abused usage.

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