Maxell History of CR Cylindrical Battery Design

Maxell's introduction of the CR Cylindrical battery was first released commercially in 2005 as an innovative battery for industrial use. Although the exterior design appeared the same as conventional cylindrical batteries, the internal spiral wound electrode with both high energy density and high load durability together was unique. Conventional electrode designs such as Spiral type (wound electrode) and Bobbin type were commonly used, however, with the evolution of more high-power electronic components, traditional batteries could not support the energy or pulse requirements of emerging market applications. With Maxell's introduction of their CR Cylindrical technology, they achieved the demands of these electronics, supporting future generations of smart meter technology and other IoT applications with high capacity, extended life and heavy discharge current requirements.

As shown on the chart below, Spiral type has its advantage in high current load performance due to its large electrode, but there is a trade-off in energy density. The opposite trade-off occurs with Bobbin type with higher energy density, but not feasible for higher current discharge performance.

Cell Design Features (Electrode Configurations)

Table 1. Cell design feature of the developed Cylindrical CR cell

Cell design Type		Conventional		New
		Spiral	Bobbin	Maxell's CR cylindrical
Electrode configuration		 Thin & Wound	 Thick & Molded	 Best balanced
Communicating device requirement	Energy density	★★	★★★	★★★
	High load durability	★★★	★	★★★
	Storage (Self-discharge)	★	★★★	★★★

* The energy density is general value when it is considered A size cell (H; 17 mm x D; 50 mm).

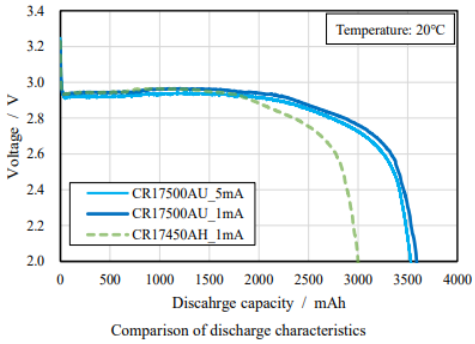
Maxell, however, has optimized their unique electrode design to meet device requirements with pulse current durability greater than 100mA while maintaining energy density to perform more than 10 years in the field. Although initially faced with technical challenges, Maxell design engineers were successful in extending the battery performance more than 10 years over extreme environmental conditions introducing the evolution of unique Maxell CR Battery Technology.

Maxell New Battery Development (CR17500AU)

Battery capacity which often equates to "run time" is recognized as one of the most important marketing features for new battery development. Maxell has succeeded in achieving the highest capacity cell in the industry for Cylindrical CR type battery [*1]. Maxell's new CR17500AU with high energy density using proprietary advanced electrode technology, was developed based on the existing model CR17450AH technology that has balanced properties of high energy density and long-term reliability. CR17500AU has 500mAh (approx. 17%) higher capacity [*1] while nominal discharge current is five times higher in comparison to CR17450AH.

Maxell CR17500AU Discharge Characteristics

***1 highest capacity: According to research in 17500 size cylindrical type lithium manganese dioxide battery by**



Comparison of discharge characteristics

*1 500mAh (approximately 17%) higher capacity: Compared with the capacity of "CR17450AH"

Maxell as of February 17th, 2021

Maxell Cell Design Features – Robustness and Reliability

Features for 10-year Life & High Load Current Battery

Energy density, high load durability and long-term performance and reliability are important properties for most industrial applications. Batteries are constructed from several components and chemical materials, all factors that are inter-related within the battery.

- Sealing property

Maxell proprietary Laser sealing between the negative can & upper lid insulates the cell from external environment eliminating electrolyte vaporization or external moisture penetration into the cell.

- Electrolyte solution

Electrolyte solution is the medium where ion diffusion is made between positive and negative. The electrolyte tends to react with active electrode and could result in high impedance after

long storage, so it requires balance throughout discharge under all conditions.

- **Positive electrode**

Manganese dioxide is well known material but requires control. Its reactive property is affected by manufacturing process that influences the crystallinity and purity. During battery discharge reaction, manganese dissolves and transfers via electrolyte solution with possible result of increased impedance.

- **Lithium Metal (Negative electrode material)**

Lithium metal is the highest energy material practically used for negative material. Maxell has adopted the unique surface treatment on the lithium electrode which prevents the passivation layer after the depletion of lithium. These unique Maxell technology design features result in reliability and stable cell impedance over long term use, as shown on graph below.

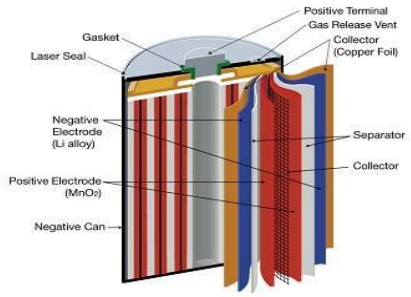
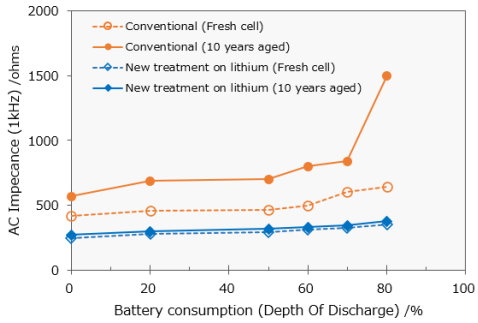


Figure. 1 Impedance growth of Cylindrical CR cell after discharge and long storage



Battery type; CR17450(Diameter; 17mm, Height; 45mm).
10 years aged cell is duplicated by stored at 80 deg. C for 57 days. The impedance was measured at each point of discharge.

Maxell Battery Pack Solutions

CR Cylindrical cells are capable of multi-cell pack design, offering both higher capacity and power capability.
Making parallel connection of the same format single cells, will

provide double the capacity achieving longer operational life. Increased voltage is achieved with series connection battery packs providing more power for devices.

History of Lithium Manganese Dioxide Technology (CR)

Lithium Manganese Dioxide technology (CR Technology) was first used in the handy calculator in 1976.
Since the 1990s, information and communication technology has rapidly developed using batteries in devices used throughout our daily life. Communication technology continues to be highly informative with interconnectivity and the cloud network further evolving through IoT with social infrastructure and more industrial applications.

CR Technology has been developed for use in many industrial applications requiring high energy density and twice the voltage of conventional aqueous button cells. Lithium metal used as the negative electrode minimizes oxidation-reduction potential for the CR battery. The Non-aqueous organic electrolyte with low solidification temperatures delivers stable performance, offering wider operational temperature range compared to conventional aqueous coin/button batteries.

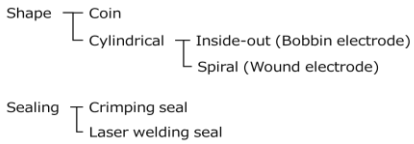
The battery chemical reaction is as follows.
Negative: $Li \rightarrow Li^+ + e^-$
Positive: $Mn(IV)O_2 + Li^+ + e^- \rightarrow Mn(III)O_2(Li^+)$

By using non-aqueous organic electrolyte solution instead of water-based electrolyte in conventional alkaline battery, self-discharge can be maintained low enough (> 1% /year at ambient temperature) to give CR batteries extremely long-life performance over wide temperature range.

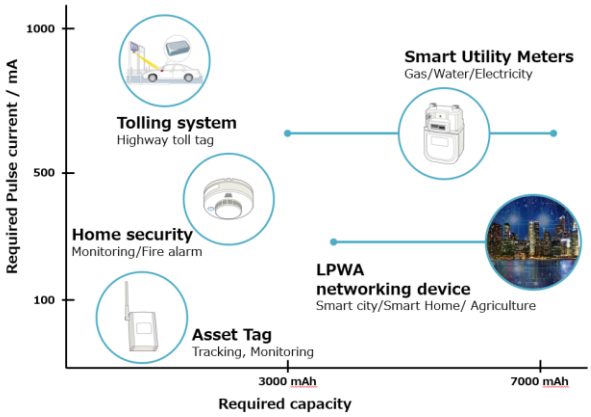
Maxell Battery Form Factors

- Maxell offers CR Battery technology in both Cylindrical and Coin cell type configurations. CR coin cells are one of the most extensively used battery worldwide due to manufacturing cost advantage and good affinity in small electronic devices, medical applications, and key fob designs. Coin cells generally range from 12mm to 24mm in diameter with height generally limited to 5mm considering mass productivity.
- CR Cylindrical battery design offers high durability and high reliability with extended life performance over extreme temperature environments, achieved through Maxell unique laser weld and sealing technology.
- Reliability, extended temperature performance, high energy density, and design flexibility provides enhanced solutions for communication devices in Smart Metering, Tracking Devices, Alarm Systems and many other industrial applications.

- Shown Below: Maxell cell configuration (shape), electrode and sealing method



Applications for Maxell CR Cylindrical Batteries



Maxell's advancement in cylindrical battery technology offers unique advantage to evolving markets such as IoT, Smart Metering, Security, and Tracking & Monitoring applications. With our new CR17500AU Lithium Manganese Dioxide battery which provides 3500mAh capacity, high discharge capability, extended temperature and long-life performance, this design has achieved Maxell excellence. Please contact us at OEMBatterySupport@maxell.com for more information or visit us at https://www.maxell.com.