1 Introduction

Within the last decade rapid advancements in the development and miniaturization of electronic devices have created a demand for lightweight, compact, high performance power sources which can be used under a wide range of conditions. Lithium batteries, which deliver high energy output due to the use of elemental lithium, have become the focus of considerable attention as an optimum power source to satisfy this demand.

The term "lithium batteries" describes the family of battery systems which use lithium as the anode, but differ in cathode material, electrolyte, cell design, and other mechanical features. Each lithium system has its own intrinsic characteristics, setting it apart from other lithium systems in terms of electrical characteristics, rate capability, energy density, operating temperature, reliability, shelf life, and safety

Lithium primary batteries are classified into three groups, depending upon the type of cathode and electrolyte that is used. Examples of common lithium battery systems are shown in Table 1.

Duracell selected the lithium/manganese dioxide (Li/MnO_2) system as it offers the best balance of performance and safety for consumer replaceable battery applications. DURACELL® Li/MnO_2 batteries possess high energy density, excellent shelf life, long-term reliability, and high rate capability (high power construction) over a broad temperature range. Light in weight and compact, DURACELL® Li/MnO_2 batteries are ideally suited when portability is a prime requisite in equipment design.

DURACELL® Li/MnO_2 batteries are being used in a wide range of applications, from powering all functions of fully-automatic 35mm flash cameras to providing long-term standby power for computer clock/calendars. DURACELL® Li/MnO_2 batteries are revolutionizing equipment design by allowing reductions in size and weight, while increasing production performance and capabilities to levels previously unattainable.

LITHIUM PRIMARY BATTERY SYSTEMS		
SOLID ELECTROLYTE SYSTEMS	**LIQUID ELECTROLYTE SYSTEMS**	
Solid Cathode	**Solid Cathode**	**Liquid Cathode**
Iodine (I_2)	Manganese Dioxide (MnO_2) Poly-Carbonmonoflouride (CF) Silver Chromate (Ag_2CrO_4) Iron Disulfide (FeS_2) Copper Oxide (CuO)	Sulfur Dioxide (SO_2) Thionyl Chloride ($SOCl_2$) Sulfur Chloride SO_2Cl_2)

TABLE 1 *Various primary lithium battery systems*

2 General Characteristics

The general characteristics of DURACELL® Li/ MnO_2 batteries are listed below. Performance characteristics are described in detail in Section 5.

- High energy density.
- High rate discharge capability under intermittent or continuous drain (high power construction).
- Safety.
- Light in weight.
- High cell voltage.
- Immediate start-up capability and flat discharge voltage.
- Wide operating and storage temperature capability.
- Very long shelf life.
- High level of reliability.
- Resistance to shock and vibration.
- Operation in any orientation.
- Operation at high altitudes.
- UL recognized.

3 Composition & Chemistry

3.1 Anode

The anode material in DURACELL® Li/ MnO_2 cells is pure lithium metal. Lithium, the lightest of all metals, has the highest electrode potential and offers the greatest ampere-hour capacity per-unit-weight. Table 2 illustrates the advantage that lithium offers in terms of weight and electrochemical equivalence.

ANODE MATERIAL	ATOMIC WEIGHT	AMPERE HOUR CAPACITY PER GRAM (Ah /g)
Pb	207.19	0.26
Zn	65.37	0.82
Fe	55.85	0.96
Li	6.94	3.86

TABLE 2 *Lithium versus other anode materials*

3.2 Cathode

The cathode material used in DURACELL® Li/ MnO_2 cells is a mixture of heat-treated electrolytic manganese dioxide and conductive agents blended together for high conductivity. The conductivity of the MnO_2 cathode results in higher initial cell voltage and operating voltage during discharge than that achieved when using highly-resistive active cathode materials, such as poly-carbonmonofluoride. The thermodynamic stability of this specially processed MnO_2 cathode ensures high reliability and performance, even after very long periods of storage.

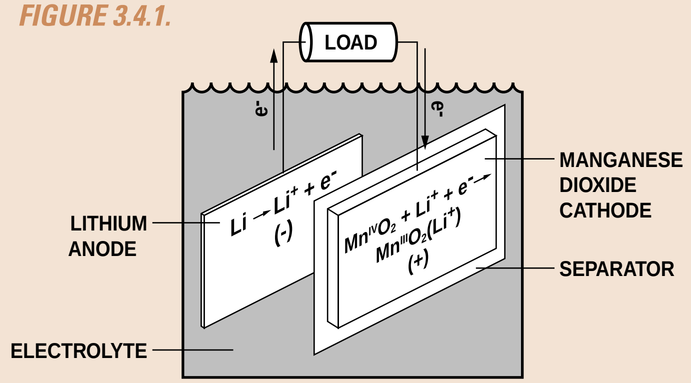
3.3 Electrolyte

The electrolyte in DURACELL® Li/MnO_2 cells is an organic solvent mixture into which an alkali metal salt is dissolved. This solution is a stable, nonpressurized medium which balances the attributes of reliability, long life, performance, and safety. High ionic conductivity and low viscosity permit efficient cathode utilization over a wide range of temperatures, even at high rates of discharge.

3.4 Cell Reaction

The cell reaction involves the oxidation of lithium metal at the anode to produce positively charged lithium ions (Li^+) and electrons (e^-), as shown in Figure 3.4.1. Li^+ ions go into solution and diffuse through the electrolyte and separator to the cathode. Electrons travel through the external circuit and arrive at the cathode where MnO_2, Li^+ ions and electrons combine. The MnO_2 is reduced from the tetravalent to the trivalent state. The solid discharge reaction product remains in the cathode. No gases are evolved during discharge to cause a pressurized condition.

FIGURE 3.4.1.



Li/MnO_2 total cell reaction:

$Li + Mn^{IV}O_2 \rightarrow Mn^{III}O_2(Li^+)$.

4 Construction

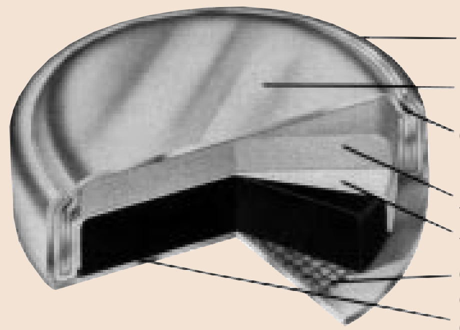
Three structural designs of Li/MnO_2 cells satisfy the complete range of today's electronic needs for small lightweight, portable power sources.

4.1 MicroLithium™ Coin (Button) Cells

Duracell offers a selection of flat, coin-shaped Li/MnO_2 cells for applications requiring small, thin, long-life batteries, such as memory retention, watches, calculators, remote control units, medical equipment, electronic games, and many other low current drain electronic devices.

Figure 4.1.1. shows a cutaway illustration of a typical coin cell. The manganese dioxide cathode pellet faces the lithium anode disc. The electrodes are separated by a nonwoven polypropylene separator impregnated with electrolyte. The cell is crimp-sealed, with the can serving as the positive terminal and the cap serving as the negative terminal.

FIGURE 4.1.1.



Microlithium™ coin (button) cell.

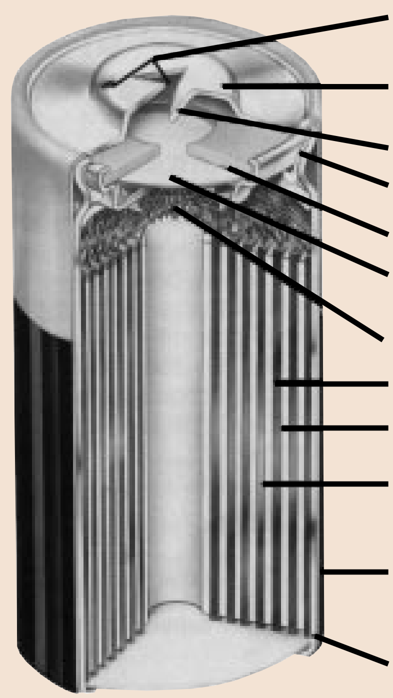
4.2 High Rate Spiral-Wound Cylindrical Cells

Spiral wound cylindrical cells are designed for high-current pulse capability (up to 5 ampere), as well as for continuous high rate operation (up to 1.2 ampere). The lithium anode and the cathode are wound together with a microporous polypropylene separator interspaced between thin electrodes to form a "jelly roll." In this way, high surface area is achieved and rate capability is optimized.

DURACELL® high rate spiral-wound cells are used in a wide range of devices requiring high-current pulses and/or very low temperature operation. In the new generation of fully automatic 35mm cameras, for example, DURACELL® high rate batteries operate all camera functions and provide rapid flash recycling time even at subzero temperatures. DURACELL® high rate spiral-wound cells are also used in computer memory back-up where consumer replaceability is desired.

High rate spiral-wound cells contain a safety vent mechanism to relieve internal pressure in the event of severe mechanical abuse. High rate cells also contain a resettable PTC (Positive Temperature Coefficient) device which limits current flow and prevents the cell from overheating if accidentally short-circuited. **Figure 4.2.1.** shows a cutaway illustration of the spiral-wound DURACELL® DL2/3A cell.

FIGURE 4.2.1.



DURACELL® high rate spiral-wound cell.

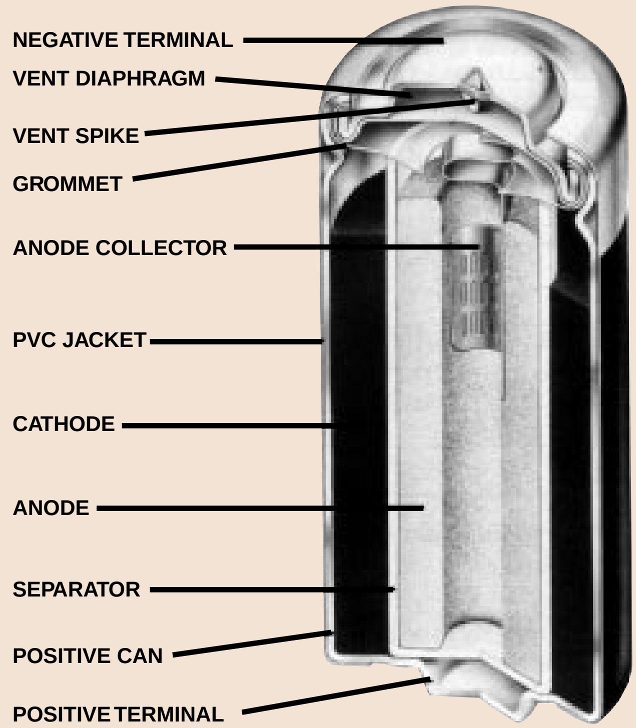
Construction (cont.)

4.3 MicroLithium™ Bobbin-Type Cylindrical Cells

The increasing demand for extra long shelf life and very high energy density has inspired the development of Li/MnO_2 bobbin cells. The bobbin-type design maximizes the energy density due to the use of thick electrodes. However, unlike the spiral-wound cell design, electrode surface area is very limited. This restricts the usage of these cell types to very low drain applications. DURACELL® MicroLithium™ bobbin cells are particularly suited for memory back-up applications that do not require the availability of replacement cells in the consumer or industrial market.

MicroLithium™ bobbin cells contain a central lithium anode core surrounded by a manganese dioxide cathode, separated by a polypropylene separator impregnated with electrolyte solution. The cell top contains a safety vent mechanism to relieve internal pressure in the event of electrical or mechanical abuse. A cross section of a typical bobbin cell is shown in **Figure 4.3.1.**

FIGURE 4.3.1.



DURACELL® MicroLithium™ bobbin cell.

5 Performance Characteristics

5.1 Voltage

The nominal voltage of Li/M nO_2 cells is 3.0 volts, twice that of conventional cells due to the high electrode potential of elemental lithium. Consequently a single Li/MnO_2 cell can replace two conventional cells connected in series, as shown in Table 3. Actual open circuit voltage is typically 3.1 to 3.3 volts.

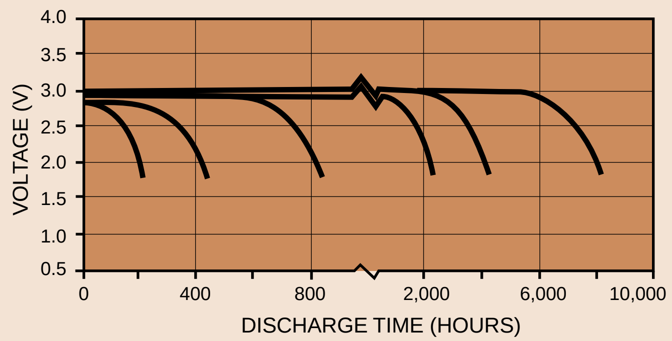
The operating voltage of a battery during discharge is dependent on the discharge load and temperature. Typical discharge curves for Li/MnO_2 coin and spiral-wound cylindrical cells at 20°C (68°F) are shown in Figure 5.1.1. and Figure 5.1.2. The end or cutoff voltage by which most of the cell's capacity has been expended is usually 2.0 volts.

Figure 5.1.1. illustrates the voltage profile of all DURACELL® MicroLithium™ coin cells when discharged at a resistive value relative to the specific cell size leading to the hours of service indicated. As is evident in Figures 5.1.1. and 5.1.2, the voltage profile of DURACELL® Li/MnO_2 cells is flat throughout most of the discharge with a gradual slope near the end of life. The moderately sloping profile towards the end of life can be an advantage in certain applications, such as utility meters and security devices. The gradual drop-off in voltage can serve as a state-of-charge indicator to show when the battery is approaching the end of its useful life. Incorporating a low voltage indicator into equipment circuitry provides a way of alerting users to replace the battery before it drops below the minimum voltage required to operate the device.

BATTERY SYSTEM	NOMINAL VOLTAGE	TYPICAL OPERATING VOLTAGE
Nickel Cadmium	1.20	1.15 – 1.25
Mercuric Oxide	1.35	1.15 – 1.30
Alakline-Manganese Dioxide	1.50	1.10 – 1.30
Silver Oxide	1.50	1.20 – 1.50
Lithium-Manganese Dioxide	3.00	2.50 – 3.00

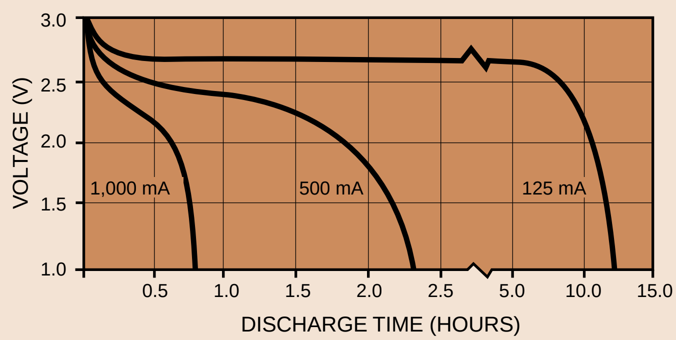
TABLE 3 *Voltage of Li/MnO_2 versus conventional cells.*

FIGURE 5.1.1.



Typical constant resistance discharge profile for all Li/MnO_2 coin cells at 20°C.

FIGURE 5.1.2.



Typical constant current discharge profiles of Li/MnO2 spiral-wound DL2/3A cells at 20°C.

Performance Characteristics (cont.)

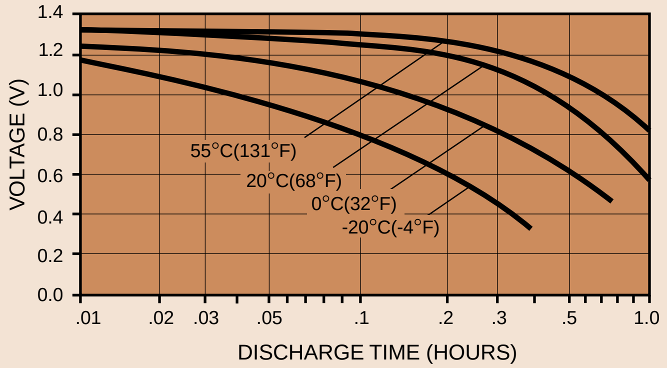
5.2 Capacity

The output capability of a cell over a period of time is referred to as *cell capacity.* Cell capacity is the amount of current withdrawn from the cell multiplied by the number of hours that the cell delivers current to a specific end-point voltage.

Rated capacity is the capacity a cell typically delivers under specific conditions of load and temperature. A cell will usually deliver less than rated capacity when discharged at loads heavier than the rated load, and/or temperatures lower than the rated temperature. Conversely, capacity greater than the rated value is usually obtained at lighter loads and higher temperatures. The relationship between discharge load, temperature, and capacity is illustrated in Figure 5.2.1. The spiral-wound DURACELL® DL123A cell is used to demonstrate how capacity decreases with increasing current drain and decreasing temperature.

DURACELL® Li/MnO_2 cells are offered in a variety of cell sizes and capacities. Coin cells range from 75 to 550 mAh; spiral-wound cells are available in 160 and 1,300 mAh capacities; and bobbin cells range from 650 to 1,900 mAh. Capacity ratings for DURACELL® Li/MnO_2 products are listed in the DURACELL® Product Specification Summary brochure and individual product data sheets, available from Duracell upon request.

FIGURE 5.2.1.



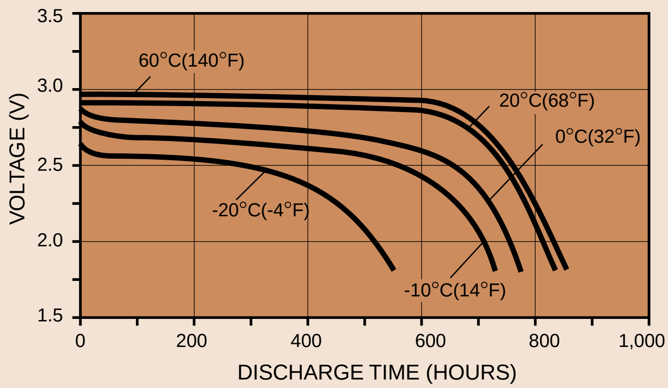
Capacity of a DURACELL® spiral-wound DL123A cell as a function of continuous discharge rate and temperature to a 2.0 volt cutoff.

5.3 Effect of Temperature

Li/MnO_2 cells are capable of performing over a wide temperature range. The temperature range recommended for each cell type is a function of cell construction and seal design. Although -20°C to 60°C is the range in temperature recommended for optimum efficiency, Li/MnO_2 cells are being used in applications ranging from -40°C to 71°C

Operation at low temperatures is limited to very low rates of discharge when using coin cells and laser-sealed bobbin cells. Figure 5.3.1. shows the effect of temperature on the discharge characteristics of a DURACELL® MicroLithium™ coin cell under low microampere drain.

FIGURE 5.3.1.



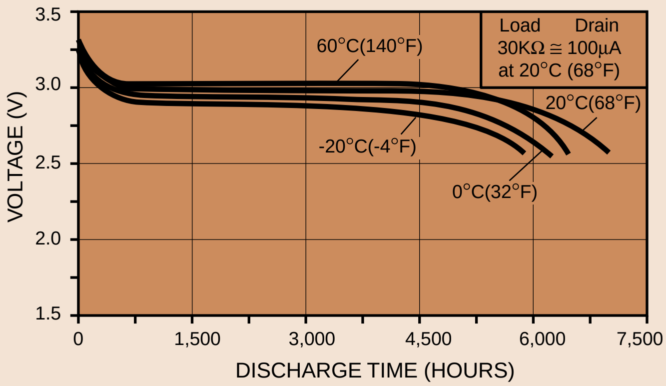
Effect of temperature on Li/MnO_2 coin cell performance; 800 hour rate.

Performance Characteristics (cont.)

Figure 5.3.2. illustrates the effect of temperature on the discharge characteristics of a bobbin cell under microampere drain. As shown, the Li/MnO_2 cell provides reliable, continuous operation even under extreme temperature conditions.

Spiral-wound Li/MnO_2 cells are designed to operate effectively during high rates of discharge at very low temperatures. In **Figure 5.3.3.** and **Figure 5.3.4.**, the performance of the spiral-wound DURACELL® DL123A size cell is shown at various temperatures to -20°C (-4°F). Good voltage regulation is evident over the wide temperature range. DURACELL® Li/MnO_2 cells are able to perform at temperature extremes where most consumer replaceable battery types no longer operate.

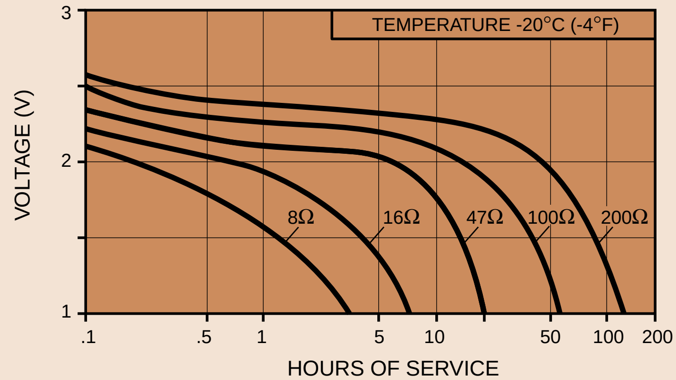
FIGURE 5.3.2.



Effect of temperature on performance of a DURACELL® Microlithium™ Li/MnO_2 bobbin cell (DL1/2AAL).

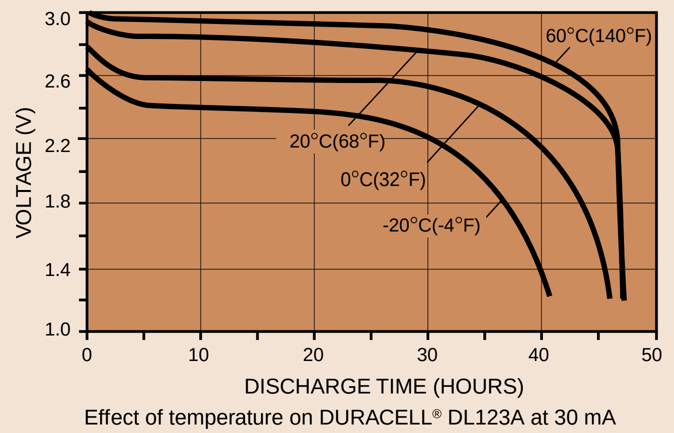
Actual testing of commercially available spiral-wound Li/(CF)n 2/3A-size cells and DURACELL® Li/MnO_2 spiral-wound 2/3A-size cells at low temperatures indicates that the DURACELL® Li/MnO_2 product delivers much more service at moderate to high rates of discharge than the spiral-wound poly-carbonmonofluoride 2/3A-size cell currently available (**Figure 5.3.5.**).

FIGURE 5.3.3.



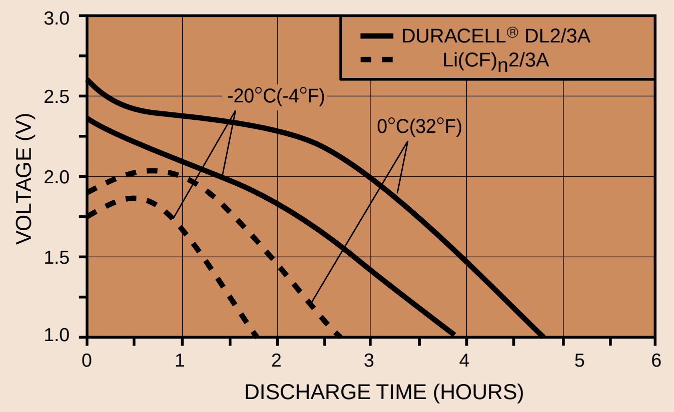
Discharge characteristics of DURACELL® DL123A at -20°C (4°F) under various loads.

FIGURE 5.3.4.



Effect of temperature on DURACELL® DL123A at 30 mA continuous current.

FIGURE 5.3.5.



DURACELL® DL2/3A Li/MnO_2 cell versus Li/(CF)n 2/3A cell at 8 ohms continuous discharge.

Performance Characteristics (cont.)

5.4 Energy Density

Energy density is the ratio of the energy available from a cell to its volume or weight. A comparison of the performance of various battery systems is normally made on practical, delivered energy density per-unit-weight or volume using production-based cells and performance as opposed to theoretical energy density.

To determine the practical energy density of a cell under specific conditions of load and temperature, multiply the capacity in ampere-hours that the cell delivers under those conditions by the average discharge voltage, and divide by cell volume or weight.

Gravimetric Energy Density:

$$\frac{\text{(Drain in Amperes x Service Hours) x Average Discharge Voltage}}{\text{Weight of Cell in Pounds or Kilograms}} = \frac{\text{Watt-Hours}}{\text{Pound or Kilogram}}$$

Volumetric Energy Density:

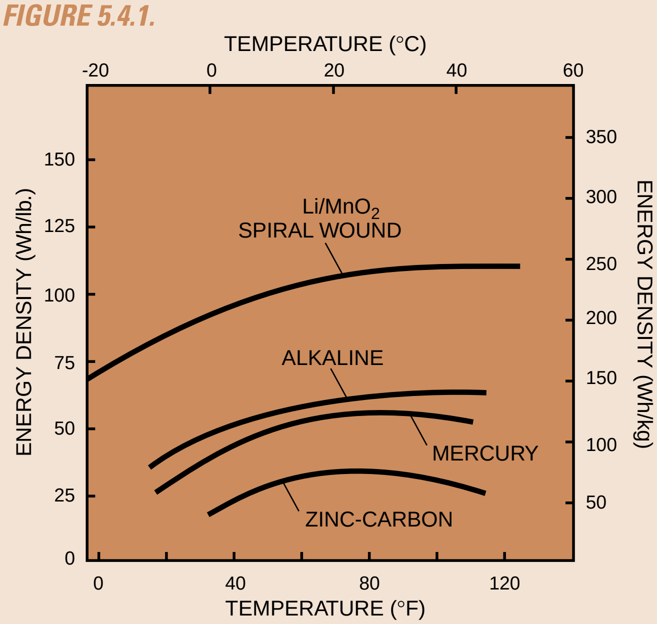
$$\frac{\text{(Drain in Amperes x Service Hours) x Average Discharge Voltage}}{\text{Volume of cell in Cubic Inches or Liters}} = \frac{\text{Watt-Hours}}{\text{Cubic Inch or Liter}}$$

Designers of battery-powered devices should place minimal emphasis on the theoretical energy density of electrochemical systems. Theoretical energy density comparisons have limited practical significance: they are calculated from the weight or volume of active anode and cathode materials with no consideration given to the weight or volume of inactive materials required for cell construction. Additionally, losses due to cell polarization on discharge are not factored into theoretical values. Consequently, comparative testing may show that the battery system with the higher theoretical value does not deliver higher actual energy output. For example, the theoretical gravimetric energy density of the lithium/poly-carbonmonofluoride system, Li/(CF)n, is over 2,000 Wh/kg when the fluorocarbon used for the cathode is produced under optimum conditions. By comparison, the theoretical gravimetric energy density of the Li/MnO_2 system is 914 Wh/kg.

Comparing energy densities, one must consider the influence of cell size, internal design (bobbin or spiral-wound configuration), discharge rate, and temperature conditions, as these parameters strongly impact performance characteristics.

- **Spiral-Wound Lithium Cells versus Conventional Cells** - A comparison of the performance of DURACELL® Li/MnO_2 spiral-wound cylindrical cells and similar-size conventional cells, under favorable conditions on a weight (gravimetric) basis, is shown in Figure 5.4.1. The energy delivered by the Li/MnO_2 cell is two to four times greater than the practical energy delivered by many similar-size conventional cells. As is evident in the illustration, the advantage becomes more significant at low temperatures.

FIGURE 5.4.1.



Gravimetric energy density comparison of primary cylindrical cells.

Performance Characteristics (cont.)

In **Figure 5.4.2.** a comparison of the performance of spiral-wound DURACELL® Li/MnO_2 cells with similar-size conventional cells on a volumetric basis is shown. Under favorable conditions of load and temperature, Li/MnO_2 cells deliver considerably more energy on a volumetric basis than the conventional zinc systems shown.

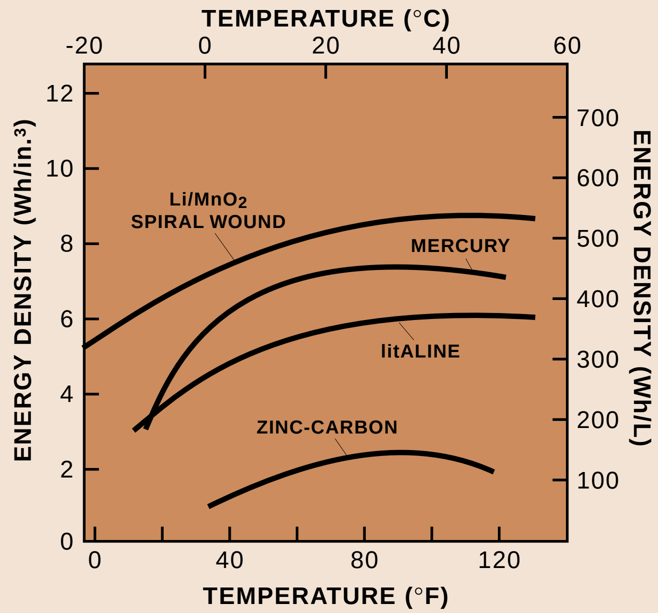
- **Coin Cells** - Energy-per-unit-volume is usually of more interest than energy-per-unit-weight in applications requiring coin (button) cells. Figure 5.4.3. compares the average volumetric energy density of Li/MnO_2 coin cells with conventional button cells under favorable load conditions. DURACELL® MicroLithium™ coin cells deliver more energy on a volumetric basis than alkaline-manganese dioxide and mercuric oxide button cells, and compare favorably with silver oxide button cells when cost is a factor. (Silver oxide button cell costs vary with the market price of silver.)

As a general rule, energy density decreases with decreasing cell size since the percentage of inactive materials, such as grommets and cell containers, take up proportionately more of the total cell weight and volume. Table 4 compares the energy density of various Li/MnO_2 coin cells under conditions of rated load and temperature.

DURACELL® MicroLithium™ COIN CELLS	ENERGY DENSITY			
	VOLUMETRIC		GRAVIMETRIC	
	Wh/L	Wh/in.³	Wh/kg	Wh/lb.
DL2016	433	7.1	129	59
DL2032	555	9.1	198	90
DL2325	555	9.1	190	86
DL2430	598	9.8	210	95
DL2450	699	11.5	270	122

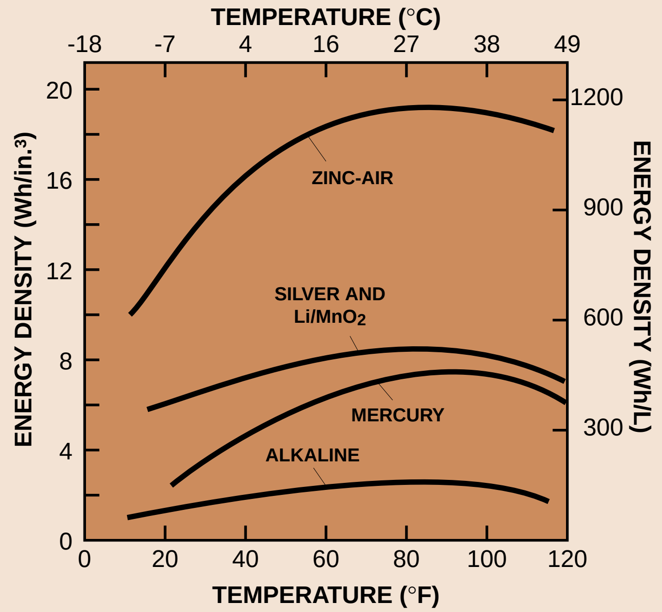
TABLE 4
Energy density of various DURACELL® MicroLithium™ coin cells.

FIGURE 5.4.2.



Volumetric energy density comparison of primary cylindrical cells.

FIGURE 5.4.3.



Volumetric energy density comparison of primary button cells.

Performance Characteristics (cont.)

- **Bobbin Cells** - Due to the use of thick electrodes, bobbin-type Li/MnO_2 cylindrical cells have slightly greater energy density (up to 1.2 times as much) than spiral wound Li Li/MnO_2 cells of similar size. Table 5 compares the energy density of various bobbin cells under conditions of rated load and temperature. As shown, energy density increases with increasing cell size.

DURACELL® MicroLithium™ BOBBIN CELLS	ENERGY DENSITY			
	VOLUMETRIC		GRAVIMETRIC	
	Wh/L	Wh/in.³	Wh/kg	Wh/lb.
DL1/2AAL	7.5	456	95	209
DL2/3AL	9.4	574	132	291
DLAAL	10.9	668	149	329

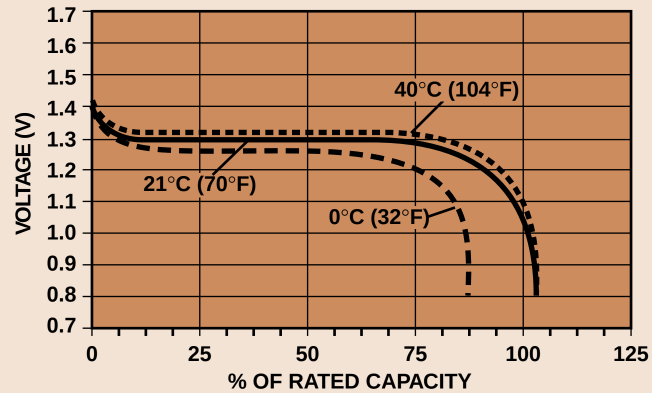
TABLE 5
Energy density of various DURACELL® MicroLithium™ bobbin cells.

5.5 Internal Impedance

The conductivity of organic electrolytes used in lithium cells is about 100 to 300 times less than aqueous electrolytes used in zinc anode cells. Consequently, lithium batteries are generally higher in internal impedance than batteries using aqueous electrolytes. The impedance of Li/MnO_2 cells varies with cell structure and size. Typically, impedance decreases with increasing cell size and electrode surface area.

DURACELL® Li/MnO_2 spiral-wound cells utilize high surface area electrodes in a "jelly roll" configuration to achieve low impedance and high current carrying capability. Figure 5.5.1 shows the relationship between impedance and depth of discharge for a spiral-wound DURACELL® DL123A cell. Internal impedance is plotted using a one kilohertz AC signal versus the discharge voltage under a continuous drain. As illustrated, the internal impedance remains essentially constant throughout the discharge of the Li/MnO_2 cell. Table 6 compares the impedance of various Li/MnO_2 cells at 1 kHz. The range in values shown is typical of fresh cells.

FIGURE 5.5.1.



Internal impedance of a DURACELL® DL123A at 1kHz versus discharge voltage at 1 ampere continuous current.

Li/MnO_2 CELL TYPE	MODEL NO.	IMPEDANCE AT 1 kHz (OHMS)
Coin Cells	DL2016	12-18
	DL2025	12-18
	DL2032	12-18
	DL2325	8-15
	DL2430	8-15
	DL2450	8-15
Bobbin Cells	DL1/2AAL	9-13
	DL2/3AL	5-8
	DLAAL	4-6
Spiral-Wound	DL1 /3N	3-5
Cells	DL2/3A	.2-.6

TABLE 6
Internal impedance of DURACELL® Li/MnO_2 cells.

Performance Characteristics (cont.)

5.6 Shelf Life and Performance After Storage

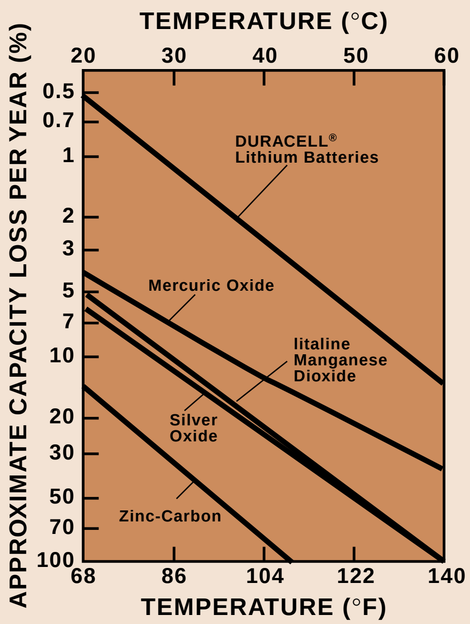
In order to withstand extreme fluctuations in temperature and humidity conditions and perform after long periods of storage, a battery must have a precise balance of cell chemistry and internal and external hardware. DURACELL® Li/MnO_2 batteries are designed to store exceptionally well under a range of environmental conditions. Figure 5.6.1. shows the capacity retention of various primary battery systems when discharged under rated conditions. DURACELL® Li/MnO_2 batteries have superior capacity retention characteristics, with capacity determined to be over 97 percent after five years at room temperature.

In addition to having excellent capacity retention characteristics, DURACELL® Li/MnO_2 spiral-wound batteries possess excellent rate retention capabilities. When discharged under a continuous or intermittent drain after very long storage periods, DURACELL® Li/MnO_2 batteries maintain their ability to perform on demand.

Figure 5.6.2. demonstrates the ability of the spiral-wound DURACELL® DL123A cell to operate at high rates of continuous discharge, even after years of ambient storage or after long periods at high temperatures (as shown in Figure 5.6.2., 3.3 years of ambient storage is equated to 60 days of storage at 60 °C or (140°F)

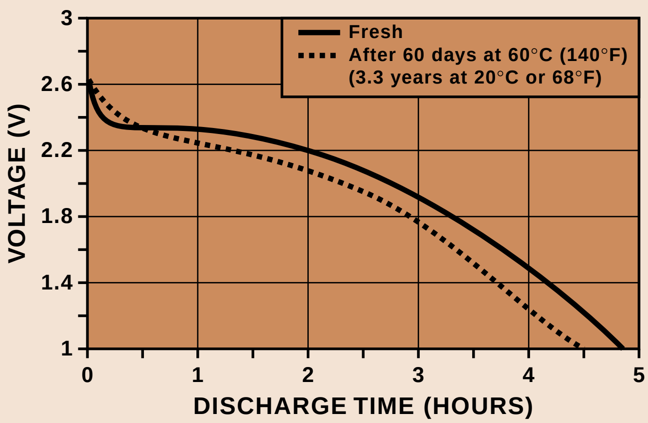
Figure 5.6.3. and Figure 5.6.4. show the ability of the DURACELL® DL123A to perform at high current pulse drains after lengthy storage periods. Unlike liquid cathode lithium systems, such as lithium-thionyl chloride, voltage delays do not pose a problem when using DURACELL® Li/MnO_2 batteries. The absence of a voltage delay ensures immediate start-up of battery-powered devices even at very low temperatures.

FIGURE 5.6.1.



Capacity retention charachteristics at various storage temperatures.

FIGURE 5.6.2.

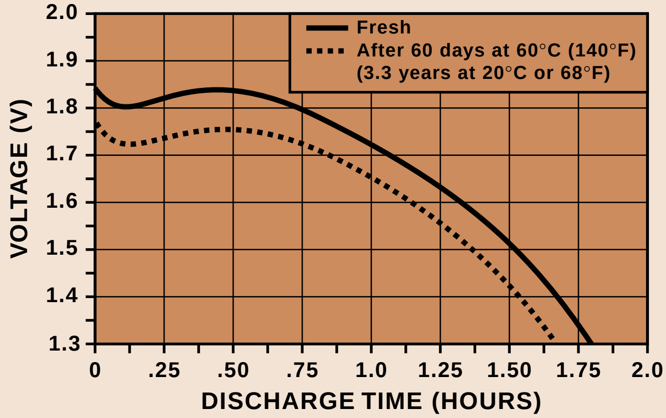


Continuous discharge of fresh versus stored DURACELL® DL123A cells at 8 ohms at 0°C (32°F).

Performance Characteristics (cont.)

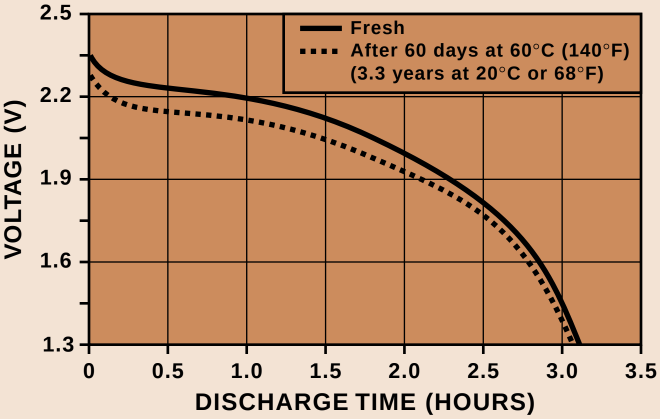
Many battery operated electronic devices such as cameras, are allowed to sit idle for a long period of time between uses. Having a battery which can tolerate this intermittent use pattern is therefore very important. While many battery systems are not tolerant to this type of intermittent usage cycle, DURACELL® Li/MnO_2 batteries deliver equivalent energy even after long periods of storage. As illustrated in Figure 5.6.5., the DURACELL® DL123A, stored for the equivalent of 3.3 years in a 60 percent discharged state, performed as well as a 60 percent discharged DL123A that had not been stored at all.

FIGURE 5.6.4.



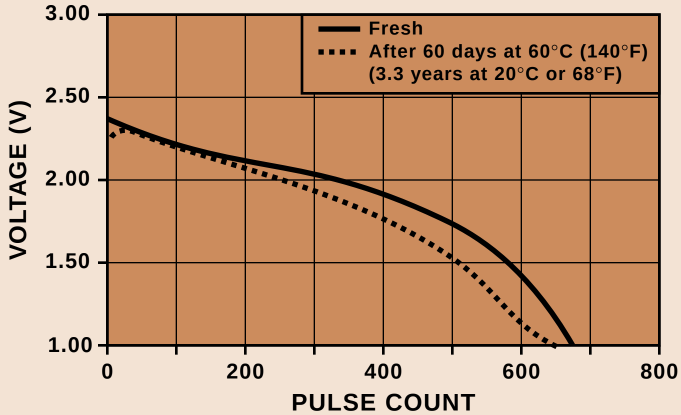
Pulse discharge of fresh versus stored DURACELL® DL123A cells at -20°C (-4°F), 3 seconds on, 7 seconds off at 1.2A.

FIGURE 5.6.3.



Pulse discharge of fresh versus stored DURACELL® DL123A cells at 20°C (68°F), 3 seconds on, 7 seconds off at 1.2A.

FIGURE 5.6.5.



Performance of 60 percent discharged DURACELL® DL123A after storage, 3 seconds on, 7 seconds off at 1.2A at 20°C (68°F).

6 Application & Battery Selection Guide

6.1 Fundamentals of Battery Selection

The battery selection process should begin in the early stages of equipment design, not when the battery cavity is fixed. In this way the most effective marriage between battery capabilities and equipment features can be made. This is especially true when considering the design-in of new battery products such as the spiral-wound DURACELL® DL123A. Early consideration gives the designer the opportunity to increase the number and types of features offered while reducing size and weight of the new product.

The fundamental requirements which should be considered early in the battery selection process are:

- **Voltage:** Maximum permissible voltage; minimum operating voltage; start-up time (maximum permissible voltage delay).
- **Load or Current Drain:** Constant resistance, constant current or constant power; variable load; pulse load; peak current.
- **Duty Cycle:** Continuous or intermittent usage pattern.
- **Service Life:** Length of time operation is required.
- **Physical Requirements:** Battery size, shape and weight; terminals.
- **Temperature Requirements:** Operating temperature range; storage temperature range.
- **Environmental Conditions:** Shock; vibration; atmospheric conditions, such as humidity and pressure.
- **Shelf Life:** Capacity retention requirements; storage time; temperature.
- **Reliability:** Permissible performance variability; failure rates. Is there potential for outgassing or leakage?
- **Safety:** Consumer industrial or military usage. Is the use of hazardous materials permissible? Will the battery withstand abusive conditions that are likely to occur?
- **Contacts:** Equipment contact materials should be compatible with battery terminal materials to prevent galvanic corrosion due to use of dissimilar metals. See Section 12.1 of the Appendix for contact materials recommended when using DURACELL® Li/MnO_2 batteries.
- **Cost:** Operating or life cycle cost, as well as initial cost.
- **Replacement:** Is battery replacement required? If so, who will replace the battery and where will a replacement be obtained?

When the important fundamental requirements are identified, the decision as to what battery system best fits the needs of the application can be made. With so many types of batteries and battery systems available today, choosing the most suitable battery for a specific application can be a difficult task.

Many applications have requirements that zinc systems cannot satisfy. For light weight and compactness in a power source, very long shelf life, extreme temperature capability high current pulse capability and more, DURACELL® Li/MnO_2 batteries are very often the optimum choice.

Application & Battery Selection Guide

6.2 Application Guide

In Table 7 application guidelines are provided to aid in identifying the types of applications particularly suited for each of the three designs of DURACELL® high-performance Li/MnO_2 batteries.

A number of important application parameters are given, profiling a hypothetical application, along with the Li/MnO_2 cell type which best satisfies those parameters. Typical applications for each cell type are also shown.

APPLICATION PARAMETERS	RECOMMENDED CELL TYPE	TYPICAL APPLICATIONS
• Small, low profile, lightweight battery with capacity of 75 to 550 mAh. • Low drain (4 mA maximum on continuous drain and 20 mA maximum pulse). • Demanding storage or operating temperatures: -20°C to 60°C (-4°F to 140°F). • Long shelf life of approximately 5 to 10 years with minimal loss in capacity. • Worldwide availability at retail.	DURACELL® MicroLithium™ Coin Cell	• Memory back-up • Watches • Calculators • Medical equipment • Digital scales • Electronic games • Security devices • Small, low power electronic devices • Automatic sensors and transmitters
• Cylindrical cell with capacity of 650 to 1,900 mAh. • Low drain (5 mA maximum on continuous drain and 20 mA maximum pulse). • Demanding storage or operating temperatures: -20°C to 60°C (-4°F to 140°F). • Long shelf life of approximately 5 to 10 years with minimal loss in capacity. • OEM replacement only.	DURACELL® MicroLithium™ Bobbin Cell	• Memory back-up • Real time clock/calendar • Low power electronic devices
• Lightweight battery with capacity of 160 to 1,300 mAh. • Continuous drain of up to 1.2 A or intermittent drain with current pulses of up to 5 A. • Immediate start-up capability at -20°C to 60°C (-4°F to 140°F). • Minimal loss in performance and in rate capability after long periods of storage and/or intermittent usage. • Long shelf life of approximately 5 to 10 years with minimal loss in capacity. • Assurance of safety without compromising power. • Worldwide availability at retail.	DURACELL® MicroLithium™ Spiral-Wound Cell	• Small power tools • Alarms and detection devices • Communications equip. • High-performance flashlights • Medical instruments • Remote sensing devices • Handheld test apparatus • Loss prevention equip. • Marine strobes • Utility meters • Flash cameras • Computers • Access controls • Laser devices • Data entry terminals • Consumer electronics • Bar code readers • Memory back-up • Real-time clock

TABLE 7.
Guidelines for selecting Li/MnO_2 cells for typical applications.