

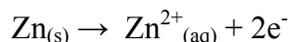


ZINC-CARBON BATTERIES (Leclanche' and Zinc Chloride Cell Systems)

Dry Cells

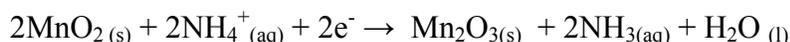
Invented by George Leclanche, a French Chemist in the 1860's, The common dry cell or LeClanche cell, has become a familiar household item. An active zinc anode in the form of a can house a mixture of MnO_2 and an acidic electrolytic paste, consisting of NH_4Cl , $ZnCl_2$, H_2O and starch powdered graphite improves conductivity. The inactive cathode is a graphite rod.

Anode (oxidation):



Cathode (reduction):

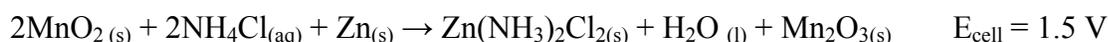
The cathodic half-reaction is complex and even today, is still being studied. $MnO_{2(s)}$ is reduced to $Mn_2O_{3(s)}$ through a series of steps that may involve the presence of Mn^{2+} and an acid-base reaction between NH_4^{+} and OH^{-} :



The ammonia, some of which may be gaseous, forms a complex ion with Zn^{2+} , which crystallize in contact Cl^{-} ion:



Overall Cell reaction:



Uses: common household items, such as portable radios, toys, flashlights,

Advantage; Inexpensive, safe, available in many sizes

Disadvantages: At high current drain, $NH_{3(g)}$ builds up causing drop in voltage, short shelf life because zinc anode reacts with the acidic NH_4^{+} ions.

Features:

- Inexpensive, widely available
- Inefficient at high current drain
- Poor discharge curve (sloping)
- Poor performance at low temperatures

The major advantages and disadvantages of Leclanche' and Zinc-Chloride batteries are listed in Table 1 below.



Table 1: Major Advantages and Disadvantages of Leclanche´ and Zinc-Chloride Batteries

Standard Leclanché battery		
Advantages	Disadvantages	General comments
Low cell cost Low cost per watt-hour Large variety of shapes, sizes, voltages, and capacities Various formulations Wide distribution and availability Long tradition of reliability	Low energy density Poor low temp service Poor leakage resistance under abusive conditions Low efficiency under high current drains Comparatively poor shelf life Voltage falls steadily with discharge	Good shelf life if refrigerated For best capacity the discharge should be intermittent Capacity decreases as the discharge drain increases Steadily falling voltage is useful if early warning of end of life is important
Standard Zinc-chloride battery		
Advantages	Disadvantages	General comments
Higher energy density Better low-temperature service Good leak resistance High efficiency under heavy discharge loads	High gassing rate Requires excellent sealing system due to increased oxygen sensitivity	Steadily falling voltage with discharge Good shock resistance Low to medium initial cost

TYPES OF CELLS AND BATTERIES

During the last 125 years the development of the zinc-carbon battery has been marked by gradual change in the approach to improve its performance. It now appears that zinc-carbon batteries are entering a transitional phase. While miniaturization in the electrical and electronic industries has reduced power demands, it has been offset by the addition of new features requiring high power, such as motors to drive compact disc players or cassette recorders, halogen bulbs in lighting devices, etc. This has increased the need for a battery that can meet heavy discharge requirements. For this reason, as well as competition from the alkaline battery system for heavy drain applications, many manufacturers are no longer investing capital to improve the Leclanche´ or zinc-carbon technology. The traditional Leclanche ´ cell construction, which utilizes a starch paste separator, is being gradually phased out and replaced by zinc chloride batteries utilizing paper separators. This results in increased volume available for active materials and increased capacity. In spite of these conversion efforts by manufacturers, a number of third world countries still continue the demand for pasted Leclanche´ product because of its low cost. The size of that market has prevented a complete conversion. It appears that this situation will continue for the near future. During this transitional phase, the zinc-carbon batteries can be classified into two types, Leclanche´ and zinc chloride. These can, in turn, be subdivided into separate general purpose and premium battery grades, in both pasted and paper-lined constructions:



1. Leclanche´ Batteries

General Purpose. Application: Intermittent low-rate discharges, low cost. The traditional, regular battery, which is not too different from the one introduced in the late nineteenth century, uses zinc as the anode, ammonium chloride (NH_4Cl) as the main electrolyte component along with zinc chloride, a starch paste separator, and natural manganese dioxide (MnO_2) ore as the cathode. Batteries of this formulation and design are the least expensive and are recommended for general-purpose use and when cost is more important than superior service or performance.

Industrial Heavy Duty. Application: Intermittent medium- to heavy-rate discharges, low to moderate cost. The industrial “heavy-duty” zinc-carbon battery generally has been converted to the zinc chloride system. However, some types continue to include ammonium chloride and zinc chloride (ZnCl_2) as the electrolyte and synthetic electrolytic or chemical manganese dioxide (EMD or CMD) alone or in combination with natural ore as the cathode. Its separator may be of starch paste but it is typically a paste-coated paper liner type. This grade is suitable for heavy intermittent service, industrial applications, or medium-rate continuous discharge.

2. Zinc Chloride Batteries

General Purpose. Application: Low-rate discharges both intermittent and continuous, low cost. This battery has replaced the Leclanche´ general-purpose battery in all Western countries. It is a true “zinc-chloride” battery and possesses some of the “heavy-duty” characteristics of the premium type. The electrolyte is zinc chloride; however, some manufacturers may add small amounts of ammonium chloride. Natural manganese dioxide ore is used as the cathode. Batteries of this formulation and design are competitive in cost to the Leclanche´ general-purpose batteries. They are recommended for general-purpose use on both continuous and intermittent discharges and when cost is an important consideration. This battery exhibits a low leakage characteristic.

Industrial Heavy Duty. Application: Low to intermediate-continuous and intermittent heavy-rate discharges; low to moderate cost. This battery has generally replaced the industrial Leclanche´ heavy-duty battery. It is a true “zinc-chloride” cell and possesses the heavy-duty characteristics of the premium zinc chloride type. The cell electrolyte is zinc chloride; however, some manufacturers may add small amounts of ammonium chloride. Natural manganese dioxide ore is used along with electrolytic manganese dioxide as the cathode. These cells use paper separators coated with cross-linked or modified starches, which enhance their stability in the electrolyte. Batteries of this formulation and design are competitive in cost to the Leclanche´ heavy-duty industrial batteries. They are recommended for heavy-duty applications where cost is an important consideration. This battery also exhibits a low leakage characteristic.

Extra/Super Heavy Duty. Application: Medium and heavy continuous, and heavy intermittent discharges; higher cost than other zinc-chloride types. The extra /super heavy-duty type of battery is the premium grade of the zinc-chloride line. This cell is composed mainly of an electrolyte of zinc chloride with perhaps a small amount of ammonium chloride, usually not exceeding 1% of the cathode weight. The ore used for the cathode is exclusively electrolytic



manganese dioxide (EMD). These cells use paper separators coated with cross-linked or modified starches, which enhance their stability in the electrolyte. Many manufacturers use proprietary separators in almost all their zinc-carbon type batteries. This battery type is recommended when good performance is desired but at higher cost. It also has improved low-temperature characteristics and reduced electrolyte leakage. In general, the higher the grade or class of zinc-carbon batteries the lower the cost per minute of service. The price difference between classes is about 10 to 25%, but the performance difference can be from 30 to 100% in favor of the higher grades depending upon the application drain.

CONSTRUCTION

The zinc-carbon battery is made in many sizes and a number of designs but in two basic constructions: cylindrical and flat. Similar chemical ingredients are used in both constructions.

1. Cylindrical Configuration

In the common Leclanche' cylindrical battery (Figures 1 and 2), the zinc can serves as the cell container and anode. The manganese dioxide is mixed with acetylene black, wet with electrolyte, and compressed under pressure to form a bobbin. A carbon rod is inserted into the bobbin. The rod serves as the current collector for the positive electrode. It also provides structural strength and is porous enough to permit the escape of gases, which accumulate in the cell, without allowing leakage of electrolyte. The separator, which physically separates the two electrodes and provides the means for ion transfer through the electrolyte, can be a cereal paste wet with electrolyte (Figure 1) or a starch or polymer coated absorbent Kraft paper in the "paper-lined" cell (Figure 2). This provides thinner separator spacing, lower internal resistance and increased active materials volume. Single cells are covered with metal, cardboard, plastic or paper jackets for aesthetic purposes and to minimize the effect of electrolyte leakage through containment. Construction of the zinc chloride cylindrical battery (Figure 3) differs from that of the Leclanche' battery in that it usually possesses a resealable, venting seal. The carbon rod serving as the current collector is sealed with wax to plug any vent paths (necessary for Leclanche' types). Venting is then restricted to only the seal path. This prevents the cell from drying out and limits oxygen ingress into the cell during shelf storage. Hydrogen gas evolved from corrosion of the zinc is safely vented as well. In general, the assembly and finishing processes resemble that of the earlier cylindrical batteries.

2. Inside Out Cylindrical Construction

Another cylindrical cell is the "inside-out" construction shown in Figure 4. This construction does not use the zinc anode as the container. This version resulted in more efficient zinc utilization and improved leakage, but has not been manufactured since the late 1960s. In this cell, an impact-molded impervious inert carbon wall serves as the container of the cell and as the cathode current collector. The zinc anode, in the shape of vanes, is located inside the cell and is surrounded by the cathode mix.

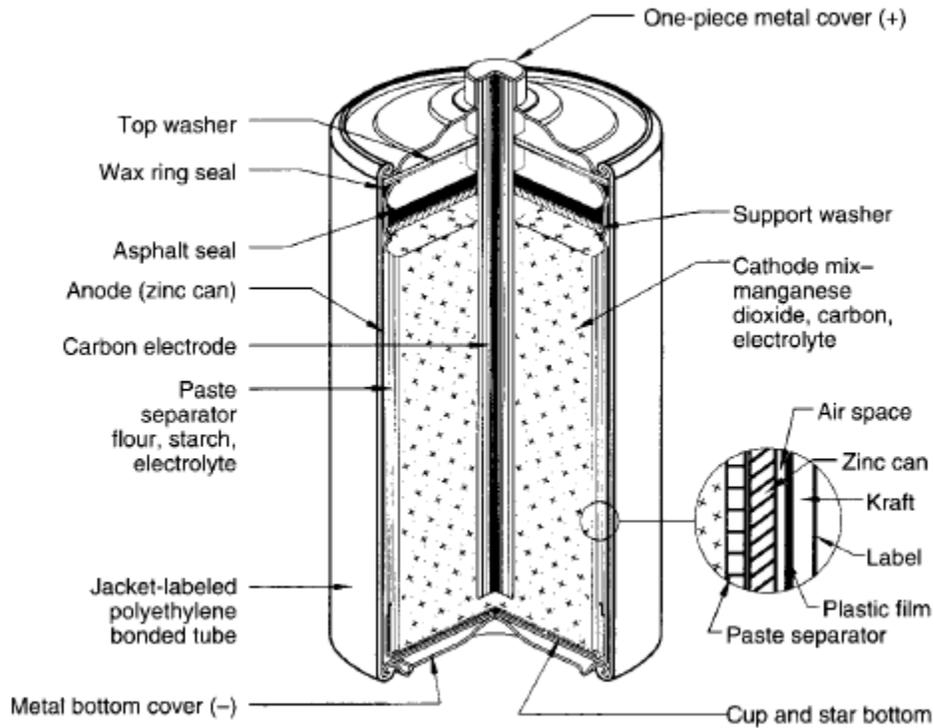


Figure 1: Typical cutaway view of cylindrical Leclanche' battery ("Eveready") paste separator, asphalt seals.

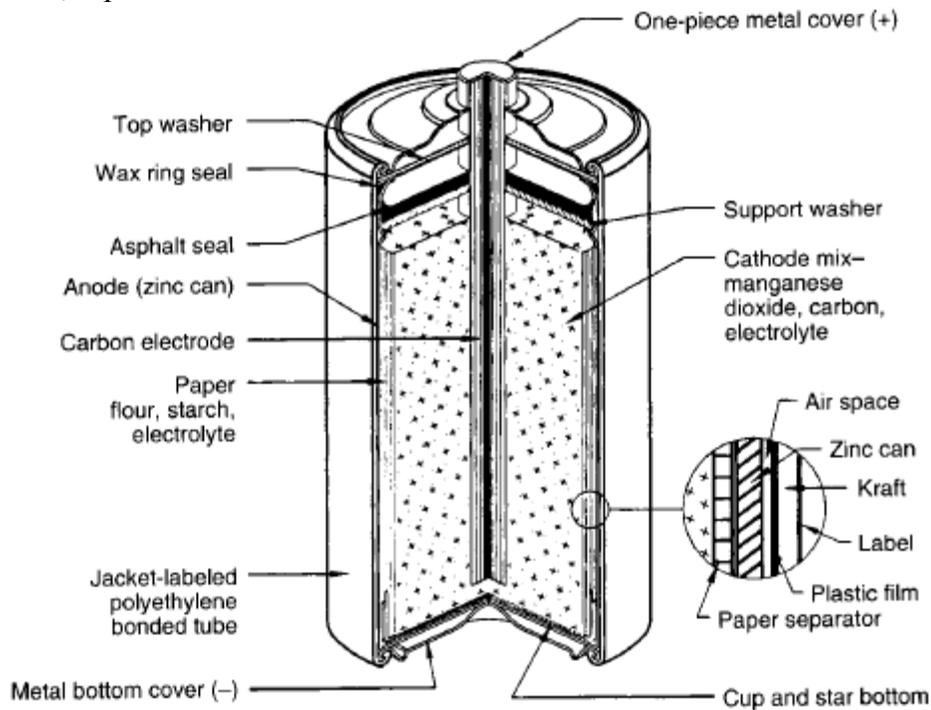


Figure 2: Typical cutaway view of cylindrical Leclanche' battery ("Eveready") paper liner separator, asphalt seal.

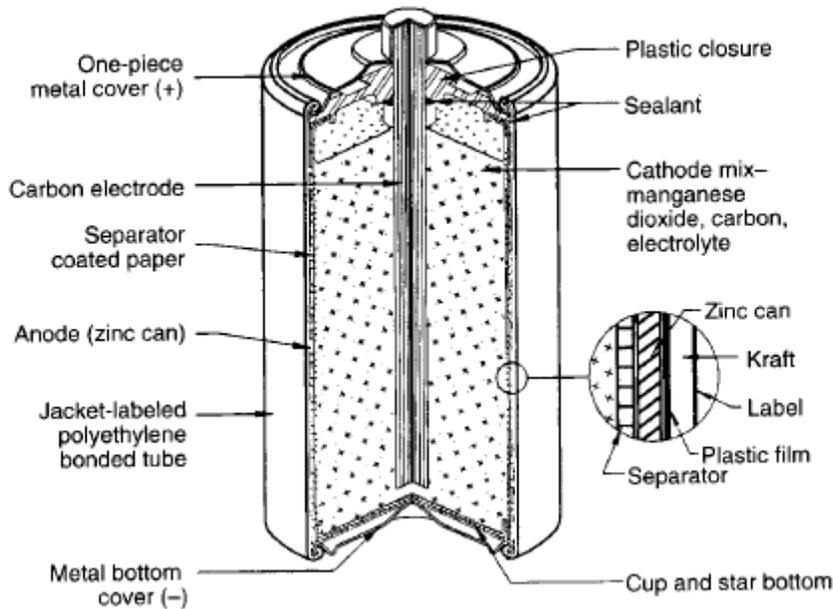


Figure 3: Typical cutaway view of cylindrical zinc chloride battery (“Eveready”) paste separator, plastic seal.

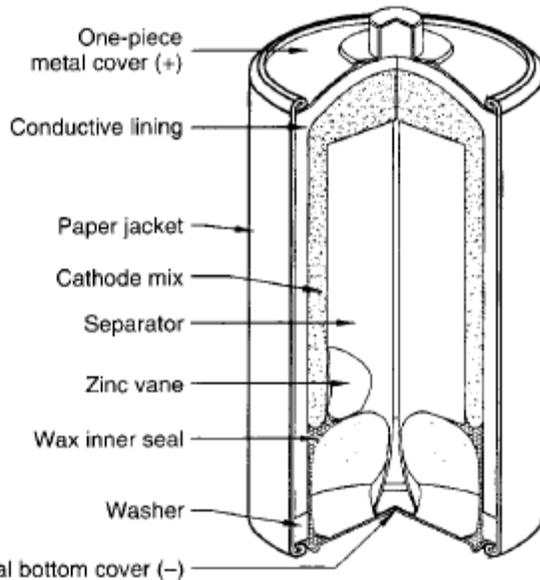


Figure 4: Typical cutaway view of cylindrical Leclanche ‘ battery (“Eveready”) inside-out construction.

3. Flat Cell and Battery

The flat cell is illustrated in Figure 5. In this construction, a duplex electrode is formed by coating a zinc plate with either a carbon-filled conductive paint or laminating it to a carbon filled conductive plastic film. Either coating provides electrical contact to the zinc anode, isolates the zinc from the cathode of the next cell, and performs the function of cathode collector. The collector function is the same as that performed by the carbon rod in cylindrical cells. When the

conductive paint method is used, an adhesive must be placed onto the painted side of the zinc prior to assembly to effectively seal the painted surface directly to the vinyl band to encapsulate the cell. No expansion chamber or carbon rod is used as in the cylindrical cell. The use of conductive polyisobutylene film laminated to the zinc instead of the conductive paint and adhesive usually results in improved sealing to the vinyl; however, the film typically occupies more volume than the paint and adhesive design. These methods of construction readily lend themselves to the assembly of multi-cell batteries.

Flat cell designs increase the available space for the cathode mix because the package and electrical contacts are minimized, thereby increasing the energy density. In addition, a rectangular construction reduces wasted space in multi-cell assemblies, (which is, in fact, the only application for the flat cell). The volumetric energy density of an assembled battery using flat cells is nearly twice that of cylindrical cell assemblies.

Metal contact strips are used to attach the ends of the assembled battery to the battery terminals; (e.g., 9-V transistor battery). The orientation of the stack subassembly (cathode up or anode up) is only important for each manufacturer’s method of assembly. The use of contact strips allows either design mode. The entire assembly is usually encapsulated in wax or plastic. Some manufacturers also sleeve the assembly in shrink film after waxing. This aids the assembly process cleanliness and provides additional insurance against leakage. Cost, ease of assembly, and process efficiencies usually dictate the orientation during the assembly process.

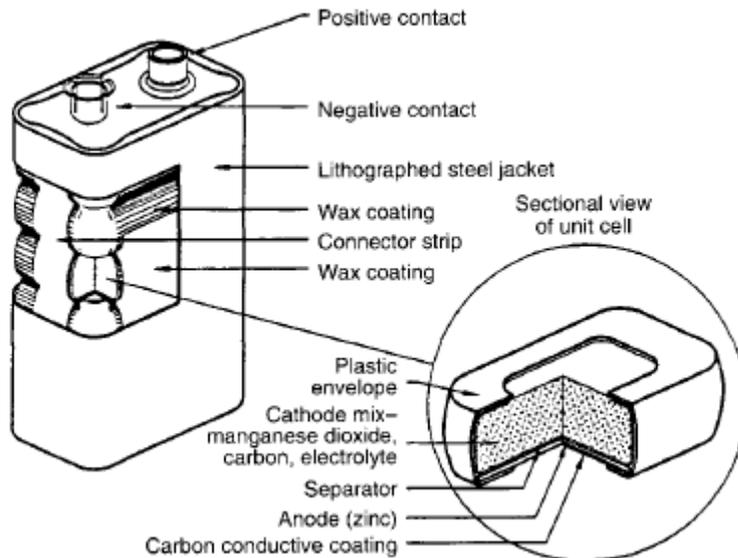


Figure 5 : Typical cutaway view of Leclanche’ flat cell and battery. (e.g. “Eveready” #216).

4. Special Designs (Flat-Pack Zinc/Manganese Dioxide P-80 Battery)

Designs for special applications are currently in use. These designs demonstrate the levels of innovation that can be applied to unusual application and design problems. In the early 1970s, Polaroid introduced a new instant camera-film system, the SX-70. A major innovation in that system was the inclusion of a battery in the film pack rather than in the camera. The film pack contained a battery designed to provide enough energy for the pictures in the pack. The concept



was that the photographer would not have to be concerned about the freshness of the battery as it was changed with each change of film.

CELL COMPONENTS

Zinc

Battery grade zinc is 99.99% pure. Classical zinc can alloys contained 0.3% cadmium and 0.6% lead. Modern lubrication and forming techniques have reduced these amounts. Currently, zinc can alloys with cadmium contain 0.03% to 0.06% cadmium and 0.2% to 0.4% of lead. The content of these metals varies according to the method used in the forming process. Lead, while insoluble in the zinc alloy, contributes to the forming qualities of the can, although too much lead softens the zinc. Lead also acts as a corrosion inhibitor by increasing the hydrogen overvoltage of the zinc in much the same manner as does mercury.

Cadmium aids the corrosion-resistance of zinc to ordinary dry cell electrolytes and adds stiffening strength to the alloy. For cans made by the drawing process, less than 0.1% of cadmium is used because more would make the zinc difficult to draw. Zinc cans are commonly made by three different processes:

1. Zinc is rolled into a sheet, formed into a cylinder, and, with the use of a punched-out zinc disk for the bottom, soldered together. This method is obsolete except for the most primitive of assemblies. Last use of this method in the U.S. was during the 1980s in 6 inch cells.
2. Zinc is deep-drawn into a can shape. Rolled zinc sheet is shaped into a can by forming through a number of steps. This method was used primarily in cell manufacturing in the U.S. prior to the relocation and consolidation of U.S. zinc-carbon manufacturing overseas.
3. Zinc is impact extruded from a thick, flat calot. This is now the method of choice. Used globally, this method reshapes the zinc by forcing it to flow under pressure, from the calot shape into the can shape. Calots are either cast from molten zinc alloy or punched from a zinc sheet of the desired alloy.

Metallic impurities such as copper, nickel, iron, and cobalt cause corrosive reactions with the zinc in battery electrolyte and must be avoided particularly in “zero” mercury constructions. In addition, iron in the alloy makes zinc harder and less workable. Tin, arsenic, antimony, magnesium, etc., make the zinc brittle.

U.S. federal environmental legislation prohibits the land disposal of items containing cadmium and mercury when these components exceed specified leachable levels. Some states and municipalities have banned land disposal of batteries, require collection programs, and prohibit sale of batteries containing added cadmium or mercury. Some European have similarly prohibited the sale and disposal of batteries containing these materials. For these reasons, levels of both of these heavy metals have been reduced to near zero. This impacts directly upon global zinc can manufacture due to importation of battery products to the U.S. and Europe. Manganese is a satisfactory substitute for cadmium, and has been included in the alloy at levels similar to that of cadmium to provide stiffening. The handling properties of zinc, alloyed with manganese or cadmium are equivalent; however, no corrosion resistance is imparted to the alloy with manganese as is the case with cadmium.

**Bobbin**

The bobbin is the positive electrode and is also called the black mix, depolarizer, or cathode. It is a wet powder mixture of MnO_2 , powdered carbon black, and electrolyte (NH_4Cl and/or ZnCl_2 , and water). The powdered carbon serves the dual purpose of adding electrical conductivity to the MnO_2 , which itself has high electrical resistance. It also acts as a means of holding the electrolyte. The cathode mixing and forming processes are also important since they determine the homogeneity of the cathode mix and the compaction characteristics associated with the different methods of manufacture. This becomes more critical in the case of the zinc-chloride cell, where the cathode contains proportions of liquid that range between 60% and 75% by volume. Of the various forming methods available, mix extrusion and compaction-then-insertion are the two used most widely. On the other hand, there is a wide variety of techniques for mixing. The most popular methods are “Cement”-style mixers and rotary mullor mixers. Both techniques offer the ability to manufacture large quantities of mix in relatively short times and minimize the shearing effect upon the carbon black, which reduces its ability to hold solution. The bobbin usually contains ratios of manganese dioxide to powdered carbon from 3:1 to as much as 11:1 by weight. Also, 1:1 ratios have been used in batteries for photoflash applications where high pulses of current are more important than capacity.

Manganese Dioxide (MnO_2)

The types of manganese dioxide used in dry cells are generally categorized as natural manganese dioxide (NMD), activated manganese dioxide (AMD), chemically synthesized manganese dioxide (CMD), and electrolytic manganese dioxide (EMD). EMD is a more expensive material, which has a gamma-phase crystal structure. CMD has a delta-phase structure and NMDs the alpha and beta phases of MnO_2 . EMD, while more expensive, results in a higher cell capacity with improved rate capability and is used in heavy or industrial applications. The polarization is significantly reduced using electrolytic material compared to the chemical or natural ores. Naturally occurring ores (in Gabon Africa, Greece, and Mexico), high in battery-grade material (70% to 85% MnO_2), and synthetic forms (90% to 95% MnO_2) generally provide electrode potentials and capacities proportional to their manganese dioxide content. Manganese dioxide potentials are also affected by the pH of the electrolyte. Performance characteristics depend upon the crystalline state, the state of hydration, and the activity of the MnO_2 . The efficiency of operation under load depends heavily upon the electrolyte, the separator characteristics, the internal resistance and the overall construction of the cell.

Carbon Black

Because manganese dioxide is a poor electrical conductor, chemically inert carbon or carbon black is added to the cathode mix to improve its conductivity. This is achieved by coating the manganese dioxide particles with carbon during the mixing process. It provides electrical conductivity to the particle surface and also serves the important functions of holding the electrolyte and providing compressibility and elasticity to the cathode mix during processing. Graphite was once used as the principal conductive media and is still used to some extent. Acetylene black, by virtue of its properties, has displaced graphite in this role for both Leclanche' and zinc chloride cells. One great advantage of acetylene black is its ability to hold more electrolyte in the cathode mix. Caution must be used during the mixing process so as to



prevent intense shearing of the black particles as this reduces its ability to hold electrolyte. This is critical for zinc-chloride cells, which contain much higher electrolyte levels than the Leclanche' cell. Cells containing acetylene black usually give superior intermittent service, which is the way most zinc-carbon batteries are used. Graphite, on the other hand, serves well for high flash currents or for continuous drains.

Electrolyte

The ordinary Leclanche' cell uses a mixture of ammonium chloride and zinc chloride, with the former predominating. Zinc-chloride cells typically use only $ZnCl_2$, but can contain a small amount of NH_4Cl to ensure high rate performance. Examples of typical electrolyte formulation for the zinc-carbon battery systems are listed in Table 2.

Table 2: Electrolyte Formulations

Constituent	Weight %
Electrolyte I	
NH_4Cl	26.0
$ZnCl_2$	8.8
H_2O	65.2
Zinc-corrosion inhibitor	0.25–1.0
Electrolyte II	
$ZnCl_2$	15–40
H_2O	60–85
Zinc-corrosion inhibitor	0.02–1.0

Corrosion Inhibitor

The classical zinc-corrosion inhibitor has been mercuric or mercurous chloride, which forms an amalgam with the zinc. Cadmium and lead, which reside in the zinc alloy, also provide zinc anode corrosion protection. Other materials like potassium chromate or dichromate, used successfully in the past, form oxide films on the zinc and protect via passivation. Surface-active organic compounds, which coat the zinc, usually from solution, improve the wetting characteristic of the surface unifying the potential. Inhibitors are usually introduced into the cell via the electrolyte or as part of the coating on the paper separator. Zinc cans could be pretreated; however, this is ordinarily not practical. Environmental concerns have generally eliminated the use of mercury and cadmium in these batteries. These restrictions are posing problems for battery manufacturers in the areas of sealing, shelf storage reliability, and leakage. This is critical for zinc-chloride cells in that the lower pH electrolyte results in the formation of excessive hydrogen gas due to zinc dissolution. Certain classes of materials considered for use to supplant mercury include gallium, indium, lead, tin and bismuth either alloyed into the zinc or added to the electrolyte from their soluble salts. Other organic materials, like glycols and silicates, offer protection alternatives. Additional restrictions on lead use, which are already stringent, may also be imposed in the future.



Carbon Rod

The carbon rod used in round cells is inserted into the bobbin and performs the functions of current collector. It also performs as a seal vent in systems without a positive venting seal. It is typically made of compressed carbon, graphite and binder, formed by extrusion, and cured by baking. It has, by design, a very low electrical resistance. In Leclanche' and zinc-chloride cells with asphalt seals, it provides a vent path for hydrogen and carbon dioxide gases, which might build up in and above the cathode during heavy discharge or elevated temperature storage. Raw carbon rods are initially porous, but are treated with enough oils or waxes to prevent water loss (very harmful to cell shelf-life) and electrolyte leakage. A specific level of porosity is maintained to allow passage of the evolved gases. Ideally, the treated carbon should pass internally evolved gases, but not pass oxygen into the cell, which could add to zinc corrosion during storage. Typically this method of venting gases is variable and less reliable than the use of venting seals. Zinc-chloride cells using plastic, resealable, venting seals utilize plugged, non-porous electrodes. Their use restricts the venting of internal gas to only the designed seal path. This prevents the cell from drying out and limits oxygen ingress into the cell during shelf-storage. Hydrogen gas evolved from wasteful corrosion of the zinc is safely vented as well.

Separator

The separator physically separates and electrically insulates the zinc (negative) from the bobbin (positive), but permits electrolytic or ionic conduction to occur via the electrolyte. The two major separator types in use are either the gelled paste or paper coated with cereal or other gelling agents such as methycellulose. In the paste type, the paste is dispensed into the zinc can. The preformed bobbin (with the carbon rod) is inserted, pushing the paste up the can walls between the zinc and the bobbin by displacement. After a short time, the paste sets or gels. Some paste formulations need to be stored at low temperatures in two parts. The parts are then mixed; they must be used immediately as they can gel at room temperature. Other paste formulations need elevated temperatures (60°C to 96°C) to gel. The gelatinization time and temperature depend upon the concentration of the electrolyte constituents. A typical paste electrolyte uses zinc chloride, ammonium chloride, water, and starch and/or flour as the gelling agent. The coated-paper type uses a special paper coated with cereal or other gelling agent on one or both sides. The paper, cut to the proper length and width, is shaped into a cylinder and, with the addition of a bottom paper, is inserted into the cell against the zinc wall. The cathode mix is then metered into the can forming the bobbin, or, if the bobbin is preformed in a die, it is pushed into the can. At this time, the carbon rod is inserted into the center of the bobbin and the bobbin is tamped or compressed, pushing against the paper liner and carbon rod. The compression releases some electrolyte from the cathode mix, wetting the paper liner to complete the operation. By virtue of the fact that a paste separator is relatively thick compared with the paper liner, about 10% or more manganese dioxide can be accommodated in a paper-lined cell, resulting in a proportional increase in capacity.

Seal

The seal used to enclose the active ingredients can be asphalt pitch, wax and resin, or plastic (polyethylene or polypropylene). The seal is important to prevent the evaporation of moisture



and the phenomenon of “air line” corrosion from oxygen ingress. Leclanche’ cells typically utilize thermoplastic materials for sealing. These methods are inexpensive and easily implemented. A washer is usually inserted into the zinc can and placed above the cathode bobbin. This provides an air space between the seal and the top of the bobbin to allow for expansion. Melted asphalt pitch is then dispensed onto the washer and is heated until it flows and bonds to the zinc can. One drawback to this method of sealing is that it occupies space that could be used for active materials. A second fault is that this type of seal is easily ruptured by excessive generation of evolved gases and is not suitable for elevated temperature applications. Premium Leclanche’ and almost all zinc-chloride cells use injection molded plastic seals. This type of seal lends itself to the design of a positive venting seal and is more reliable. Molded seals are mechanically placed onto a swaged zinc can. Many manufacturers have designed locking mechanisms into the seal, void spaces for various sealants and resealable vents. Several wrap the seal and can in shrink wrap or tape to prevent leakage through zinc can perforations. It is very important to prevent moisture loss in the zinc-chloride system, and to vent the evolved gases generated during discharge and storage. The formation of these gases disrupts the separator surface layer significantly and affects cell performance after storage. Use of molded seals in the zinc-chloride cell construction has resulted in the good shelf storage characteristics evidenced by this design.

Jacket

The battery jacket can be made of various components: metal, paper, plastic, polymer films, plain or asphalt-lined cardboard, or foil in combination or alone. The jacket provides strength, protection, leakage prevention, electrical isolation, decoration, and a site for the manufacturer’s label. In many manufacturers’ designs, the jacket is an integral part of the sealing system. It locks some seals in place, provides a vent path for the escape of gases, or acts as a supporting member to allow seals to flex under internal gas pressures. In the inside-out construction, the jacket was the container in which a carbon-wax collector was impact molded (Figure 4).

Electrical Contacts

The top and bottom of most batteries are capped with shiny, tin-plated steel (or brass) terminals to aid conductivity, prevent exposure of any zinc and in many designs enhance the appearance of the cell. Some of the bottom covers are swaged onto the zinc can, others are locked into paper jackets or captured under the jacket crimp. Top covers are almost always fitted onto the carbon electrode with interference. All of the designs try to minimize the electrical contact resistance.

TYPES AND SIZES OF AVAILABLE CELLS AND BATTERIES

Zinc-carbon batteries are made in a number of different sizes with different formulations to meet a variety of applications. The single-cell and multicell batteries are classified by electrochemical system, either Leclanche’ or zinc chloride, and by grade; general purpose, heavy duty, extra heavy duty, photoflash, and so on. These grades are assigned according to their output performance under specific discharge conditions. Table 3 lists the more popular battery sizes with typical performance at various loads under a two-hour per day intermittent discharge, except for the continuous toy battery test. The performance of these batteries, under several intermittent discharge conditions, is given in Table 4. The AA-size battery is becoming the



predominant one and is used in penlights, photoflash and electronic applications. The smaller AAA-size is used in remote control devices and other small electronic applications. The C and D-size batteries are used mainly in flashlight applications and the F-size is usually assembled into multicell batteries for lanterns and other applications requiring these large batteries. Flat cell are used in battery assemblies, in particular, the 9-volt battery used in smoke detectors and electronic applications. Table 5 lists some of the major multicell zinc-carbon batteries that are available commercially. The performance of these batteries can be estimated by using the IEC designation to determine the cell compliment (e.g. NEDA 6, IEC 4R25 battery consists of four F-size cells connected in series).

Table 3: Characteristics of Zinc-Carbon Batteries

Size	IEC	ANSI, NEDA	Weight g	Maximum dimensions, mm		Typical service, 2 h/d*			
						Leclanché		Zinc-chloride	
				Diameter	Height	Drain mA	Service h	Drain mA	Service h
N	R1	910	6.2	12	30.2	1	480		
						10	45		
						15	20		
AAA	R03	24	8.5	10.5	44.5	1	—	1	520
						10	—	10	55
						20	—	20	26
AA	R6	15	15	14.5	50.5	1	950	1	1200
						10	80	10	110
						100	4	100	8
C	R14	14	41	26.2	50	300	0.6	300	1
						5	380	5	800
						25	75	20	150
D	R20	13	90	34.2	61.5	100	6	100	20
						300	1.7	300	5.5
						10	400	10	700
F	R25	60	160	34†	92†	50	70	50	135
						100	25	100	55
						500	3	500	6
G No. 6	R26	—	180	32†	105†	25	300	25	400
	R40	905	900	67	170.7	100	60	100	85
						500	5.5	500	9
						—			
						5	8000		
						50	700		
						100	350		
						500	70		

*Typical values of service to 0.9-V cutoff.
 †Typical values.



Table 4: ANSI Standards for Zinc-Carbon and Alkaline-Manganese Dioxide Batteries

Size	Use	Ohms	Schedule	Cutoff voltage	Specification requirements	
					Zinc-carbon batteries	Alkaline-manganese dioxide batteries
					Initial*	Initial*
N					910D	910A
	Portable lighting PAGER then	5.1 (10.0 then 3000.0)	5 min/d 5 sec/hr, 3595 sec/h)	0.9 0.9	NA NA	100 min 888 hr
AAA					24D	24A
	Pulse test	3.6	15 sec/min 24 hr/d	0.9	150 pulses	450 pulses
	Portable lighting	5.1	4 min/hr 8 hr/d	0.9	48.0 min	130.0 min
	Recorder Radio	10.0 75.0	1 hr/d 4 hr/d	0.9 0.9	1.5 hr 24.0 hr	5.5 hr 48.0 hr
AA					15D	15A
	Pulse test	1.8	15 sec/min 24 hr/d	0.9	100 pulses	450 pulses
	Motor/toy	3.9	1 hr/d	0.8	1.2 hr	5 hr
	Recorder Radio	10.0 43.0	1 hr/d 4 hr/d	0.9 0.9	5.0 hr 27.0 hr	13.5 hr 60 hr
C					14D	14A
	Portable lighting	3.9	4 min/hr 8 hr/d	0.9	350 min	830 min
	Toy	3.9	1 hr/d	0.8	5.5 hr	14.5 hr
	Recorder Radio	6.8 20.0	1 hr/d 4 hr/d	0.9 0.9	10.0 hr 30 hr	24.0 hr 60.0 hr
D					13D	13A
	Portable lighting	1.5	4 min/15 min 8 hr/d	0.9	150 min	540 min
	Portable lighting	2.2	4 min/hr 8 hr/d	0.9	120 min	950 min
	Motor/toy	2.2	1 hr/d	0.8	5.5 hr	17.5 hr
	Recorder Radio	3.9 10.0	1 hr/d 4 hr/d	0.9 0.9	10 hr 33 hr	26.0 hr 90.0 hr
9 Volt					1604D	1604A
	Calculator	180	30 min/d	4.8	380 min	630 min
	Toy	270	1 hr/d	5.4	7 hr	14 hr
	Radio	620	2 hr/d	5.4	23 hr	38 hr
	Electronic Smoke detector	1300 Currently under consideration.	24 hr/d	6.0	NA	NA
6 Volt					908D	908A
	Portable lighting	3.9	4 min/hr 8 hr/d	3.6	5 hr	21 hr
	Portable lighting Barricade	3.9 6.8	1 hr/d 1 hr/d	3.6 3.6	50 hr 165 hr	80 hr 300 hr

*Performance after 12 month storage
zinc-carbon batteries: 80% of initial requirement
alkaline-manganese dioxide batteries: 90% of initial requirement



Table 5: ANSI/NEDA Dimensions of Zinc-Carbon Batteries

ANSI	IEC	Diameter, mm		Overall height, mm		Length, mm		Width, mm	
		Max	Min	Max	Min	Max	Min	Max	Min
13C	R20S	34.2	32.3	61.5	59.5				
13CD	R20C	34.2	32.3	61.5	59.5				
13D	R20C	34.2	32.3	61.5	59.5				
13F	R20S	34.2	32.3	61.5	59.5				
14C	R14S	26.2	24.9	50.0	48.5				
14CD	R14C	26.2	24.9	50.0	48.5				
14D	R14C	26.2	24.9	50.0	48.5				
14F	R14S	26.2	24.9	50.0	48.5				
15C	R6S	14.5	13.5	50.5	49.2				
15CD	R6C	14.5	13.5	50.5	49.2				
15D	R6C	14.5	13.5	50.5	49.2				
15F	R6S	14.5	13.5	50.5	49.2				
24D	R03	10.5	9.5	44.5	43.3				
903	—			163.5	158.8	185.7	181.0	103.2	100.0
904	—			163.5	158.8	217.9	214.7	103.2	100.0
908	4R25X			115.0	107.0	68.2	65.0	68.2	65.0
908C	4R25X			115.0	107.0	68.2	65.0	68.2	65.0
908CD	4R25X			115.0	107.0	68.2	65.0	68.2	65.0
908D	4R25X			115.0	107.0	68.2	65.0	68.2	65.0
915	4R25Y			112.0	107.0	68.2	65.0	68.2	65.0
915C	4R25Y			112.0	107.0	68.2	65.0	68.2	65.0
915D	4R25Y			112.0	107.0	68.2	65.0	68.2	65.0
918	4R25-2			127.0	—	136.5	132.5	73.0	69.0
918D	4R25-2			127.0	—	136.5	132.5	73.0	69.0
926	—			125.4	122.2	136.5	132.5	73.0	69.0
1604	6F22			48.5	46.5	26.5	24.5	17.5	15.5
1604C	6F22			48.5	46.5	26.5	24.5	17.5	15.5
1604CD	6F22			48.5	46.5	26.5	24.5	17.5	15.5
1604D	6F22			48.5	46.5	26.5	24.5	17.5	15.5