Household Batteries and the Environment

NEMA

Table of Contents

Introduction

"Household batteries" are the small portable batteries used daily by most people in devices such as radios, toys, flashlights and lanterns, games, watches, calculators, hearing aids, cameras, telephones and other communications devices, but do not include the larger batteries used in motor vehicles, commercial and industrial, military and other applications. They are called "dry cell batteries" because they contain no freestanding bodies or pools of liquid electrolyte. Household batteries are divided into two large categories, primary (meaning not rechargeable) and rechargeable (also called secondary) batteries.

This brochure is designed to provide answers to frequently asked environmental questions about household batteries, including battery contents, legislation, and recycling. The question of "Which battery should I select?" is reviewed from the perspectives of battery performance, costs, and environmental impact.

Section 1
Basic Factual Information

Basic factual information about household batteries includes:

- The names commonly used to describe them;
- Whether they are primary or rechargeable;
- Their voltage per cell;
- Their "chemistry," meaning the specific combinations of

TABLE 1

Names	Primary or Rechargeable	Voltage Per Cell
Alkaline, Alkaline Manganese	Primary	1.5
Zinc Carbon, Carbon Zinc	Primary	1.5
Zinc Air	Primary	1.4
Silver Oxide, Silver	Primary	1.5
Lithium	Primary	3.0
Lithium	Primary	1.5
Nickel Cadmium	Rechargeable	1.2
Nickel Metal Hydride	Rechargeable	1.2
Lithium Ion	Rechargeable	3.6
Small Sealed Lead Acid *Sold only as multicell batteries, with voltages being multiples of 2.0 volts.	Rechargeable	2.0*
Alkaline, Alkaline Maganese	Rechargeable	1.5

Note 1: Standard size alkaline batteries are not considered hazardous under U.S. federal regulations. Since alkaline manganese button cell size batteries do contain very small amounts of mercury; it is possible that certain of the larger size button batteries could fail the U.S. TCLP test and be defined as hazardous waste.

reactive constituents they contain;

- Whether they are hazardous under federal law;
- The geometric sizes and shapes in which the batteries are produced; and
- Frequent applications of the batteries.

A summary of the first five of these parameters is presented in Table 1. Discussion of the other three follows.

Chemistry	Hazardous Under U.S. Federal Law?**
Electrodes = manganese dioxide + zinc. Electrolyte = potassium hydroxide.	No (see Note 1)
Electrodes = manganese dioxide + zinc. Electrolyte = zinc chloride.	No
Electrodes = zinc + oxygen. Electrolyte = potassium hydroxide.	No (see Note 2)
Electrodes = silver oxide + zinc. Electrolyte = potassium hydroxide or sodium hydroxide.	No (see Note 2)
Electrodes = metallic lithium + manganese dioxide or carbon monoflouride. Electrolyte = mixture of organic materials.	No
Electrodes = metallic lithium and iron disulfide. Electrolyte = mixture of organics materials.	No
Electrodes = nickelic or nickelous hyrdroxide + metallic cadmium or cadmium hydroxide. Electrolyte = potassium hydroxide.	Yes
Electrodes = nickelic or nickelous hydroxide + metallic rare earth alloys. Electrolyte = potassium hydroxide.	No
Electrodes = compounds containing lithium ions + carbon materials. Electrolyte = mixture of organic materials.	No
Electrodes = lead or lead compounds (both electrodes). Electrolyte = sulfuric acid.	Yes
Electrodes = manganese dioxide + zinc. Electrolyte = potassium hydroxide.	No

Note 2: As explained in Section 3, button cells contain small amounts of mercury. A few of the larger sizes of button cells may fail federal TCLP tests for mercury.
**Readers should consult with state and local environmental officials to determine whether there are more restrictive laws or regulations in their jurisdictions.

Alkaline Batteries.

By far the most commonly used household batteries are alkalines, also referred to as alkaline manganese batteries. Cylindrical alkaline batteries are mainly produced in D, C, AA, AAA, AAAA, and N sizes (Figure 1), while rectangular (prismatic) alkalines are mostly produced in sizes to fit in 9-volt and lantern applications (Figure 2).

FIGURE 1 - Cylindrical Alkaline Batteries

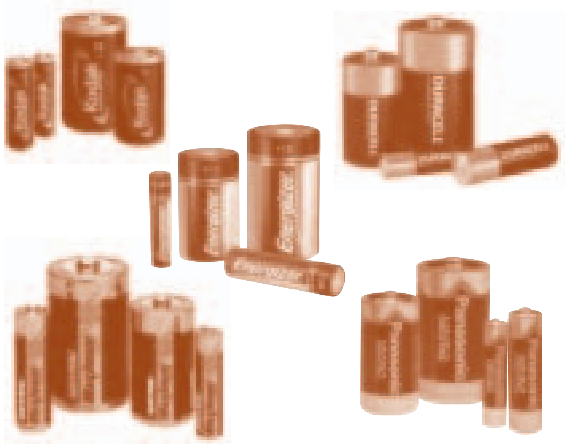

FIGURE 2 - Rectangular Alkaline Batteries

9V Alkaline Battery

Alkaline batteries are also produced in sizes and shapes known as "button cells" (Figure 3), which are given that name because of their similarity in appearance to buttons. Alkaline button cells are also combined in stacks to produce cylindrical batteries with higher voltages.

Alkaline batteries are used in radios, toys, flashlights, lanterns, games, watches, calculators, cameras, fire and smoke detectors, tape and compact disc players, portable stereos, telephones and other communications devices, and other products.

Alkaline batteries have high energy density (energy per unit of volume), high rate capability (ability to discharge rapidly), very long shelf life, and good performance over a wide range of temperatures.

At one time, small amounts of mercury were used as an additive in alkaline batteries to suppress formation of internal gasses which otherwise would lead to leakage, possible ruptures, and/or short shelf life. In response to environmental concerns, battery manufacturers developed new technologies that eliminated the need for mercury, except in button cells. (See Section 3, Mercury Reduction, for discussion of mercury in button cells.) Cylindrical and rectangular alkaline batteries have been produced in the United States, Europe, and Japan without the addition of mercury since at least 1993. The addition of mercury to these products was made illegal in the U.S. under 1996 federal battery legislation.

FIGURE 3 - Alkaline Button Cells

Zinc Carbon Batteries.

Known generically as zinc carbon or carbon zinc batteries, and sometimes bearing words such as “Heavy Duty” or “General Purpose” on their labels, these products were in widespread use before the development of alkaline batteries. Although still sold and used, zinc carbon batteries have largely been surpassed in the United States by the alkaline products. In general, they are manufactured in the same shapes and sizes (Figure 4), and are used in many of the same applications as alkaline batteries, except that there are no zinc carbon button cells.

As with alkaline batteries, small quantities of mercury were formerly used in zinc carbon batteries to suppress gassing. As a result of new technology, this practice had ended in the United States by 1992. The addition of mercury to zinc carbon batteries was prohibited by 1996 federal battery legislation.

FIGURE 4 - Zinc Carbon Batteries

Zinc Air Batteries.

Zinc air button cell batteries (Figure 5) are the dominant power source for hearing aids. Stacks of zinc air button cells are combined into a rectangular format (Figure 6) to produce batteries used in medical devices.

Oxygen, which reacts with the zinc electrode, is obtained from air that enters the battery through one or more small holes in the battery casing. Because of the need for a continuous supply of air, zinc air batteries cannot be used in watches and other tightly sealed products. A sealing tape is kept across the hole(s) to prevent entry of the air until the battery is to be activated. The battery will discharge continuously after the sealing tape is removed, meaning that it can be used most

FIGURE 5 - Zinc Air Button Batteries

FIGURE 6 - Zinc Air Button Batteries

efficiently in devices which are used continuously or for high percentages of the day (such as hearing aids).

Small amounts of mercury are used in zinc air button cells. (See Section 3, Mercury Reduction, for discussion of mercury in button cells.)

Silver Oxide Batteries.

Silver oxide (also known simply as silver) button cell batteries (Figure 7) are used in watches, calculators, hearing aids, and cameras.

Small amounts of mercury are used in silver oxide button cells. (See Section 3, Mercury Reduction, for discussion of mercury in button cells.)

FIGURE 7 - Silver Oxide Button Cells

Lithium Batteries.
Primary lithium batteries are produced in different shapes and sizes. Lithium coin cells (Figure 8), given that name because of their similarity in appearance to coins, are used in keyless remotes, personal digital assistants, watches, hand-held games, and other devices. These coin cells cannot be interchanged with button batteries of different chemistries because of different sizes and different voltages. Cylindrical lithium batteries, which come in 1.5-volt and 3.0-volt varieties, are produced in various sizes (Figure 9) and are primarily used in photographic, high-drain, and other applications. The 1.5-volt variety is interchangeable with standard "AA" batteries, whereas the 3.0-volt batteries are different shapes and sizes and are not interchangeable with AA and AAA sizes. Rectangular 9-volt lithium batteries (Figure 10 — next page) are used in fire and smoke detectors and in medical devices.

Lithium primary battery voltages remain essentially constant until all of the metallic lithium has reacted and the battery is fully discharged. In other words, there is no reactive lithium metal remaining in the batteries when they are replaced and disposed. For more information, see *Spent Consumer Lithium Batteries and the Environment* on the NEMA website at www.nema.org/batteryehs.

FIGURE 8 - Lithium Coin Cells

FIGURE 9 - Cylindrical Lithium Batteries

Lithium FeS_2 (1.5V)

Lithium MnO_2 (3.0 V)

Nickel Cadmium Batteries.

Nickel cadmium rechargeable batteries are produced in D, C, AA, and AAA cylindrical sizes, and in the 9-volt rectangular size (Figure 11), and in some applications can be used as alternatives to alkaline batteries. In addition, individual batteries are assembled into packs of whatever size and shape is needed for a particular device (Figure 12). Nickel cadmium battery packs are used in portable power tools and appliances, cordless telephones, personal care products, and other devices.

FIGURE 10 - Rectangular Lithium Battery

Compared with alkaline batteries, nickel cadmium batteries have only about one-third the energy density, but can discharge at higher rates. They also have a high internal self-discharge rate, making them a poor choice in certain applications such as smoke detectors and emergency flashlights. They are used in applications requiring high power and where frequent charging is possible, but not in applications where long periods of unattended storage will occur.

Nickel-Metal Hydride Batteries.
Like nickel cadmium batteries, nickel-metal hydride rechargeable batteries are produced in D, C, AA, and AAA cylindrical sizes, and in the 9-volt rectangular size, and are used in some applications as an alternative to alkaline batteries (Figure 13). They are also assembled into packs of various sizes and shapes (Figure 14 — next page).

FIGURE 11 - Nickel Cadmium Batteries

FIGURE 12 - Nickel Cadmium Packs

FIGURE 13 - Nickel-Metal Hydride Batteries

FIGURE 14 - Nickel-Metal Hydride Packs

Nickel-metal hydride battery packs are used in cellular phones, laptop computers, video cameras, power tools, and other devices requiring high power and premium performance.

Nickel-metal hydride batteries are similar to nickel cadmium batteries, except that metallic rare earth alloys are substituted for cadmium in the negative electrode.

Lithium Ion Batteries.

Lithium ion rechargeable batteries are produced in a variety of cylindrical and rectangular sizes (Figure 15). Many are designed with dimensions to fit into the battery compartments of specific small portable devices, such as cell phones, laptop computers, video cameras, and other portable equipment.

FIGURE 15 - Lithium Ion Batteries

Lithium ion batteries are not interchangeable with batteries of any other chemistry, even where the sizes and shapes would otherwise make them interchangeable. The voltage is different from any other battery and the charging requirements are different from other rechargeable batteries.

Small Sealed Lead Acid Batteries.

Small sealed lead acid batteries are manufactured in cylindrical and rectangular shapes. In consumer applications, these batteries are used in older video cameras.

Rechargeable Alkaline Batteries.

Rechargeable alkaline (also called rechargeable alkaline manganese) batteries are produced in D, C, AA, and AAA cylindrical sizes (Figure 16).

The chemistry of rechargeable alkalines is the same as that of primary alkalines. Certain modifications in the interiors of the batteries are necessary to make them rechargeable, and the modifications involve tradeoffs in battery performance. As a result of these tradeoffs, rechargeable alkalines may be satisfactorily used as substitutes for primary alkalines in some, but not all, applications.

FIGURE 16 - Rechargeable Alkaline

Section 2
Which Battery Should I Select?

With so many different batteries available, which one should I select for my application? The question can be answered by comparing the characteristics of each battery type with the requirements of the application.

First, select a battery having the needed size, shape, and voltage.

Second, consider the drain or power requirements of the application. Low drain applications include radios, clocks, and flashlights. Moderate drain applications, which include the majority of today's electronic products, include tape recorders, Game Boys, music and CD players, electronic toys, pagers, boom boxes, smoke detectors, remote controls, and flashlights that get lots of use. Products with high drain requirements include digital cameras, palmtops, remote-control toys, portable televisions, and photo flash units.

Third, consider the shelf life or storage requirements. If a battery-containing device can be easily recharged frequently, then a rechargeable battery may be a possible power source for the application. On the other hand, if the battery must be able to retain its power for long periods of inactivity, then a battery having a long shelf life should be selected.

Fourth, consider costs. For some applications, there are reasonable alternatives available and, in those cases, costs become a consideration.

Following this decision-making process will result in the selection of the best battery for a particular application and budget. It does not, however, address the environmental issues about battery disposal and recycling. The latter involves questions about whether the used batteries are hazardous, and whether a recycling option is available.

The choice of which battery to purchase should not be made mainly on the basis of battery disposal and recycling criteria, because it has a high chance of leading to the selection of a battery which does not meet an application's performance requirements. The selection of the wrong battery for a particular application represents a bad decision, regardless of what disposal and recycling options are available.

Section 3
Mercury Reduction

The use of mercury by the battery industry has been reduced dramatically. The U.S. Department of the Interior reports, "The use of mercury in electrical batteries has declined precipitously, from more than 1,000 (metric) tons annually in the early 1980s to a small fraction of 1 ton in 1996." See http://minerals.usgs.gov/minerals/pubs/commodity/mercury/430496.pdf.

Alkaline and Zinc Carbon Batteries. As mentioned earlier, small amounts of mercury were formerly used as an additive in alkaline and zinc carbon batteries to suppress formation of internal gasses which otherwise would lead to leakage, possible ruptures, or short shelf life. In response to environmental concerns, battery manufacturers developed new technologies that eliminated the need for mercury in cylindrical and rectangular batteries. In general, these new technologies reduced the rate of internal gassing by reducing impurities that cause gassing and using other formulations to suppress gasses. In addition, companies redesigned batteries as appropriate to allow gasses to escape at faster rates. Cylindrical and rectangular alkaline batteries have been produced in the United States, Europe, and Japan without the addition of mercury since 1993, and the addition of mercury to these products was made illegal in the U.S. under 1996 federal battery legislation.

Button Cells. The generation of gasses (see above) is a phenomenon associated with zinc electrodes, and therefore affects all batteries containing zinc electrodes — including alkaline manganese, zinc air, and silver oxide button cells.

The relatively large size of cylindrical and rectangular alkaline and zinc carbon batteries allows them to be packed less fully such that any small buildup of gasses will not lead to internal gas pressures that cause leaking or rupturing the battery sealing systems. In the case of button cells, however, this is not true. Because of their relatively small external sizes and of the need to provide maximum energy in their small interiors, there is little if any room for any internal gassing buildup before it affects the button cell. Such gas building up in button cells can cause bulging in the button cell and leakage and/or rupture of the button cell in a product. As a result, very small amounts of mercury continue to be used in button cells.

Zinc air button cells require the presence of one or more small holes in their casings so that air can enter and allow oxygen to react with the zinc electrode. These holes prevent the buildup of high internal pressures, but even a small internal gas pressure is sufficient to prevent the inflow of the outside air. Despite the holes in their casings, zinc air button cells are very sensitive to even small internal gas pressures, and therefore they continue to require very small amounts of mercury to suppress the internal gas generation.

In recognition of the unique problems facing button cells, 1996 U.S. federal battery legislation permits the inclusion of up to 25 milligrams of mercury per alkaline manganese button cell. The laws of some states apply the same limitation, 25 milligrams of mercury per button cell, to all button cell chemistries — alkaline manganese, zinc air, and silver oxide. All three of these button cell chemistries are manufactured to comply with these limits; the average mercury content of button cells is substantially below the 25-milligram limit.

Mercuric Oxide Batteries. A primary battery chemistry known as mercuric oxide, or simply as mercury, uses mercuric oxide and zinc electrodes and an alkaline electrolyte. Because the mercury in these batteries is used as an electrode rather than as an additive, it cannot be eliminated and it is inherently present in high concentrations, usually 35–40 percent of the total weight of the batteries. Mercuric oxide button cells, which were once widely used in hearing aids and watches, are now prohibited under the 1996 federal battery legislation. Larger sizes of mercuric oxide batteries, produced in rectangular and cylindrical shapes, have been replaced in many applications by alkaline and zinc air counterparts. To the extent that the larger sizes continue to be used, they are now allowed by the 1996 U.S. federal battery legislation to be sold only on the condition that the manufacturer identify a collection site for recycling and inform the purchasers about the site.

Declining Mercury Content in Batteries Entering Municipal Solid Waste (MSW). As a result of the changes described above, the number of mercury-containing batteries entering municipal solid waste streams has declined greatly in recent years, and will continue to decline further.

Since 1996, members of the NEMA Dry Battery Section have worked with state and local officials in New Jersey, Florida, and Minnesota to collect annual samples of batteries entering municipal solid waste, and to determine the average mercury contents in the batteries. The results of these sample analyses show that as of 2000, mercury levels in the battery waste stream have declined by over 90 percent. NEMA projects this mercury level will decline by 50 percent every two years. This would result in mercury levels from batteries in the waste stream falling to background mercury levels (less than 5 PPM) by the year 2008.

Section 4
Zinc and Manganese

Zinc and manganese, which are used as electrode materials in many primary batteries, are benign metals that do not pose a safety or environmental threat during normal use and disposal. For more information, see *Sound Environmental Management of Spent Primary Batteries*, at www.nema.org/batteryehs. The Food and Drug Administration lists compounds of zinc, and compounds of manganese, as “Substances Generally Recognized as Safe” for use as nutrients or dietary supplements (21CFR582).

The principal uses of zinc metal are as a coating to protect iron and steel from corrosion (galvanized metal), as alloying metal to make bronze and brass, as zinc-based die casting alloy, and as rolled zinc. See http://minerals.usgs.gov/minerals/pubs/commodity/zinc. United States pennies have a 97.6 percent zinc content. Zinc oxide is used as the active ingredient in diaper rash ointments and skin creams, where it may constitute 20 percent of the ointments and creams.

The principal use of manganese is in steel making. Manganese also is a key component of certain widely used aluminum alloys. As ore, additional quantities of manganese are used for such nonmetallurgical purposes as plant fertilizers, animal feed, and colorants for brick. See http://minerals.usgs.gov/minerals/pubs/commodity/manganese.

Section 5
1996 U.S. Federal Battery Legislation

The *Mercury-Containing and Rechargeable Battery Management Act* (Public Law 104-142; 42 USC 14301 et seq.) became law on May 13, 1996. The purposes of the law were to formalize, with legal requirements, the phase-out of the use of mercury in batteries; and provide for the efficient and cost-effective collection and recycling or proper disposal of used nickel cadmium batteries, small sealed lead acid batteries, and certain other batteries. The 1996 federal legislation followed the principles of battery legislation previously enacted in 18 U.S. states.

Title I of the law prohibits the sale of regulated rechargeable batteries or rechargeable consumer products unless specific labeling requirements are met and the rechargeable battery is either easily removable from the product or is sold separately.

Title II of the law prohibits the sale of alkaline manganese batteries containing added mercury (except button cells, where the use of mercury is limited to 25 milligrams per button cell); zinc carbon batteries containing added mercury; mercuric oxide button cell batteries; and larger mercuric oxide batteries (unless specified conditions are met). The law may be viewed at www.nema.org/batteryehs.

Pursuant to the 1996 federal legislation, and to facilitate the collection, storage, and transportation of hazardous waste batteries, the U.S. EPA has included batteries in its Universal Waste Regulations (see www.nema.org/batteryehs).

Section 6 Recycling

NEMA maintains a list of companies in the United States and Canada that claim to collect, recycle, or treat used batteries. See *List of Companies Claiming to Collect or Recycle or Treat Used Batteries* at www.nema.org/batteryehs. Inclusion on the list does not constitute an endorsement or recommendation by NEMA of the companies or their technologies, and NEMA reserves the right in its sole discretion to exclude companies from the listing. Persons contacting the listed companies should make their own investigations and determinations about the costs and appropriateness of the listed companies and their activities.

Alkaline and Zinc Carbon Batteries. When alkaline and zinc carbon batteries were first identified as contributors of mercury to municipal solid waste, proposals were made to collect and recycle the batteries as a way to minimize mercury pollution. The successful elimination of added mercury from alkaline and zinc carbon batteries removed the need to recycle these batteries as a way of diverting mercury from the solid waste stream. However, there is still the opportunity to develop recycling technologies for the purpose of resource conservation that could be both economical and environmentally beneficial.

Currently, the battery industries in the U.S., Europe, and Japan are working to develop improved recycling technologies. For example, the European and U.S. battery industries have demonstrated the technical feasibility of recycling alkaline and zinc carbon batteries in existing metal smelting furnaces and kilns. Although considerable progress has been made, environmentally beneficial and cost-effective recycling technologies are not universally available. In addition, the results of a life cycle analysis of various post-consumer collection systems commissioned by the U.K. government shows that systems for collecting and transporting primary batteries may have a greater detrimental environmental impact than the benefits gained from recycling these batteries, and carry a significant financial burden.

Any decision to recycle alkaline and zinc carbon batteries must carefully weigh several factors, including the low toxicity of the battery materials (e.g., steel, zinc, and manganese); the total energy requirements and environmental impacts associated with the collection, transport, and recycling of the batteries; the amount and value of the metals recovered; and the overall cost.

Button Cells. Used alkaline, zinc air, and silver oxide button cells are small and, in the aggregate, constitute a relatively small quantity of materials. Collecting them is difficult, and except for silver oxide batteries, they have little or no economic value. During the routine servicing of watches some jewelers collect silver oxide batteries for their silver content. For these reasons, few button cells are recycled.

Primary Lithium Batteries. The statements about button cells are, in general, also applicable to primary lithium coin cells. Recycling of larger primary lithium batteries is limited.

Rechargeable Batteries. Nickel cadmium and small sealed lead acid batteries are expected to be collected and recycled because of their high contents of cadmium and lead, respectively, and the Rechargeable Battery Recycling Corporation (RBRC) has been created for that purpose. The activities of RBRC have been extended to include nickel metal hydride and lithium ion batteries. For more information, contact RBRC at 1-800-8-BATTERY or visit its website, www.rbrc.org.

Important Cautions about Battery Collection Programs. Anyone intending to collect button cells, coin cells, and other miniature batteries should take precautions to avoid unintentional ingestions of the batteries, and to provide proper care if ingestions do occur. For further information see *Have You Swallowed a Button Battery* at www.nema.org/batteryehs. Also, anyone intending to start a collection program for standard size batteries must be aware that storing larger quantities of loose, unpackaged batteries can create a safety hazard. Used batteries may still contain small amounts of energy, and there is a possibility of that energy short circuiting creating heat and, in unusual cases, even fires if battery terminals remain in contact. RBRC has designed its collection system to ensure that they safeguard against this risk, as should any other special battery collection program.

Section 7
Sound Environmental Management of Spent Batteries

The landfill disposal of alkaline and zinc carbon batteries does not pose a significant health or environmental risk, based on over 20 years of battery industry experience and the results of various scientific studies. Modern alkaline and zinc carbon batteries do not contain materials that pose an environmental threat, and they are not regulated as hazardous waste by the U.S. federal government. Thus, *there is no basis to require the mandatory collection and recycling of household alkaline and zinc carbon batteries based on any alleged health or environmental risks.* In addition, effective recycling technology is not currently available for these batteries, and the negative environmental impacts of special collection systems including emissions from vehicles may be greater than the environmental benefit to be gained from recycling.

Governments should focus their current efforts on collecting and recycling batteries that contain significant quantities of hazardous materials, such as nickel cadmium, mercury, and lead acid batteries. This is the current approach of the United States, Japan, Brazil, and some European countries. Effective recovery or recycling technology is generally available for these types of batteries.

The Dry Battery Section of the National Electrical Manufacturers Association (NEMA) is the trade association for United States manufacturers of dry cell batteries. Members of the NEMA Dry Battery Section include:

Adva-Lite, Inc.
Duracell, Inc.
Eastman Kodak Company
Eveready Battery Company, Inc.
Panasonic Industrial Company
Polaroid Corporation
Rayovac Corporation
Saft, Inc.
Wilson Greatbatch, Ltd.

For additional information, contact:

NEMA
1300 North 17th Street, Suite 1847
Rosslyn, Virginia 22209
Telephone: (703) 841-3200
Fax: (703) 841-3300
Website: www.nema.org

Printed on recycled paper
June 2002