

came out to inform any of us about the cancellation.

Because we weren't in their computer, LIAT refused to put us up in a hotel for the night or pay our cab fare, despite the fact that they reluctantly did so for the other 11 people holding tickets for the same flight (who *were* in their computer). We tried begging, pleading, and threatening, but nothing got the attention of the counter personnel. We were repeatedly told that there was "nothing they could do." Each time they made that statement, the next step was to avoid eye contact and completely ignore us. I have never been treated so poorly by an airline, and I will never fly on LIAT again. Eventually the ticket agents actually closed up the counter and went home, despite the fact that we were still pleading with them to acknowledge us. Luckily, after paying for our own cab fares, hotel, and dinner, we did eventually get to Dominica at about noon the next day (an-

other half day of vacation shot).

The return trip was nearly as bad — while waiting at the departure gate at noon, we were informed that Canefield airport was closing due to high winds, so our flight to Antigua that afternoon was canceled. LIAT personnel informed us about an hour later that there would be a flight to Antigua leaving from the other airport on Dominica (Melville Hall), which was about an hour away by car. Again we had to pay our own cab fare, since LIAT's policy doesn't include paying for "natural disasters"! We dutifully took out our wallets and paid \$20 to get to the other Dominican airport, where a LIAT plane eventually did take us to Antigua late that day.

Unfortunately, by the time our flight arrived in Antigua at about 7 p.m., we had missed the last American flight from Antigua to San Juan, so we had

to find and pay for a cab and a hotel in Antigua, buy our own dinner and breakfast, and pay our own cab fare to return to the airport the next morning. We killed the entire day sitting in the Antigua airport waiting for our American flight, because Antigua's airport was crowded with British cricket enthusiasts who had come to see a tournament, and they had completely filled the two earlier American flights. We did get seats on the last flight out of Antigua, so we finally got home at 11 p.m., completely exhausted.

We're in the process of attempting to get reimbursed through LIAT's customer service office and the travel agent who booked our flights, but the mental anguish and wasted time involved in this trip nearly spoiled our memories of the good time we had on Dominica.

— Greg & Nancy Earle
Sterling, VA

Batteries Not Included

Portable Power to the People

As divers, we're used to dealing with consumables. We work hard to get the most out of a tank of air — sometimes to the extent of concocting special gas mixtures. We mark our dive time against the incessant clock of no-decompression limits. But there's one consumable that gives most of us fits: batteries! I, for one, find it far easier to calculate multilevel mixed-gas no-decompression limits than to try to calculate

my battery needs on a long dive trip. This is complicated somewhat by the fact that I seem to carry yet another piece of power-hungry gear on every trip.

And things are not likely to improve in even the distant future. Even Captain Kirk seems to drain his phaser batteries on every episode. Knowing that the portable power problem is likely to be

with us for some time, we should examine our options.

Measuring Up

One factor that determines the suitability of a battery to a particular application is its voltage output over the life of its charge. A nickel-cadmium battery, for example, delivers a relatively constant 1.2 volts until it suddenly quits. Alkaline voltage output declines more

steadily over the life of the charge (see figure).

A battery is generally operated not to zero voltage but to some arbitrary cutoff voltage determined by the equipment it powers. A Walkman may be able to squeeze a lot of useful life out of batteries that are useless in a strobe (see table).

Simple voltage measurements are not particularly useful in determining remaining battery capacity. The only reliable method of determining remaining capacity with a voltmeter is to put a load on the battery. The thermal battery testers that Duracell places in their newer packaging do properly simulate load (and they're free!)

The Choices

Current battery choices available for consumer equipment include

- Zinc chloride
- Silver oxide
- Alkaline
- Nickel cadmium
- Nickel metal hydride
- Lithium

In addition, industrial gelcells are available for a growing array of dive lights and underwater video lighting systems.

Let's look at the pros and cons of various battery types. Zinc-chloride "heavy duty" batteries have only one real advantage: they're cheap and reasonably cost effective on low-cutoff devices like transistor radios and kid's toys. But their shelf life is short, as is their capacity. They're generally ignored in diving applications. Silver-oxide batteries are typically special-purpose devices that we can ignore in our discussion as well.

Alkaline batteries, especially in their AA size, are the most popular consumer batteries sold, accounting for 70% of the 4 billion batteries sold in the U.S. last year. Over the past several years, competition between manufacturers has brought great improvements in alkalines. Five years ago a AA alkaline was rated about 1,400 mAh. Today most are in the 2,500-mAh range. In terms of performance on a single charge, alkalines win hands

Cutoff Voltages of Typical Products

Product	Cutoff Voltage
Autofocus 35-mm camera w/flash	1.3
Underwater strobe	1.3
Halogen flashlight	1.3
Regular flashlight	1.2
Portable CD player	1.2
Portable LCD color TV	1.2
Nintendo Game Boy	1.1
Walkman cassette player	1.0
Digital AM/FM radio	1.0
Portable electric shaver	1.0
Quartz analog clock	1.0
AM/FM transistor radio	0.8

Values given are per cell (AA cells)

down. Six AA alkalines represent about 22 watt-hours of power. A good set of six nicads, on the other hand, yields only 3.75 watt-hours. For a large number of battery-using divers, alkalines are the obvious choice. If you need the longest possible run time, especially on low-cutoff-voltage devices, choose alkalines. But their cost is relatively high, in terms of both purchase cost and environmental impact. It is estimated that over 2.5 billion alkalines ended up in landfills last year.

Within the past year or so, Duracell alkalines have begun to carry the boast "Environmentally Improved Now 99.9% Mercury Free." Other brands make a similar claim. Batteries that a decade ago contained about 1% mercury now contain less than 0.1%. Matsushita Battery Industrial Co., has a new line of alkalines that it claims are 99.999% mercury-free. That's 1 part per million (ppm), which is half the amount of mercury that may be present in a single human hair follicle.

This represents the industry's response to growing concern about the disposal of household batteries. Heavy metals contained in batteries, particularly mercury and cadmium, can leach out of landfills and contaminate groundwater supplies. Batteries incinerated with other municipal waste spew heavy metals into the air and contaminate the ash. Several states are considering proposals to restrict the disposal of batteries.

An obvious solution to the high cost and environmental impact of disposable batteries is the use of rechargeables. Nickel-cadmium rechargeables are especially attractive due to their consistent voltage output and low internal impedance. The 2,500-mAh alkalines that are so popular are rated down to 0.8 volts. This means that much of that 2,500-mAh capacity goes unused in equipment with higher cutoff voltages. If your application requires high current, or if you're planning an extended trip, then nicads are the hot ticket. They're especially good at low temperatures.

But nicads are not without their down side. All nicads exhibit a memory effect to some degree. A nicad battery should be fully discharged before being recharged. Recharging a partially discharged nicad battery will ultimately weaken the battery's memory, reducing charge capacity. This can often be corrected by repeatedly discharging and recharging the battery fully to expand the battery's memory to its original capacity, but it is better to avoid this condition altogether.

It is important not to discharge nicads too deeply, especially when discharging multiple cells in one device. If one cell is weaker than the others, it will be completely discharged first. This will

cause the other cells to charge it in reverse as they discharge. This condition, known as cell reversal, ultimately causes excessive current and failure of the remaining cells. Many a nicad has been killed by intentionally running a dive light completely flat in an attempt to prevent memory effect. The best way to handle nicads is to keep one group of cells together at all times and discharge them fully, until the light is very dim. Deep discharge nicad chargers (Cool-Lux LCD and others) are also available that monitor each battery individually as they are being cycled.

Keep in mind that nicads have a nominal output voltage of 1.2 volts — a full 20% less than alkalines. This is below the cutoff voltage of many types of equipment. Many quartz-halogen lights specifically advise against the use of nicads since the lower filament temperatures generated by the lower voltage nicads tend to reduce lamp life. Underwater Kinetics and other manufacturers offer lower-voltage halogen lamps specifically for use with nicads.

Once nickel-cadmium batteries are spent, they present even more of a disposal problem than alkalines. Cadmium is a particularly dangerous heavy metal. For this reason, many nicad manufacturers have begun to accept their batteries back for recycling.

Several leading dive-light manufacturers use 6-volt lead-acid gelcells. These special-purpose batteries are usually composed of three 2-volt cells. They are a good deal more expensive and somewhat heavier than nicads, but can be charged from any discharge level without memory effect. Gelcells are even more susceptible to cell reversal than

nicads. The best practice is not to deep-discharge gelcells, since it is of little benefit.

Care must also be taken when charging gelcells. Overcharging can damage the charger, which may subsequently cause damage to the battery. Restrict the charging times to those recommended by the manufacturer, and use only a charger meant specifically for the light or strobe and rated for the local outlet voltage. Oceanic suggests using an electrical appliance timer for their gelcell chargers, preset to the correct charge time. It is also critical to allow adequate ventilation during charging. Gelcells generate combustible hydrogen gas during charging.

Cool Runnings

Between dives, both nicads and gelcells should be stored fully charged. As with most batteries, it's best to keep them cool. The easiest way to damage a nicad or gelcell is to subject it to heat above 95°F. Gelcells also need adequate ventilation during storage to prevent accumulation of hydrogen.

What's New

There's been a great deal of press lately about recharging alkalines. Ray-O-Vac has introduced its Renewal rechargeable alkaline battery and charger system. The Renewal charger and batteries must be used together. The system has shown promise in several independent tests, especially on high-current, high-cutoff devices like strobes. While nicads may cycle your strobe faster, Renewal alkalines will probably last longer — and may be recharged up to 100 times. Expect to see other manufacturers introduce competing products in the near future.

Also active on the rechargeable alkaline front is SLM Corp's Buddy L charging system. SLM claims it can charge *any* alkaline — but unlike Renewal, it will not bring batteries back up to full charge. It can give your drained alkalines a second life in low-cutoff devices, however. Some divers retire alkalines from their strobes after every dive and charge them in a Buddy L for use in dive lights.

Lithium cells have been very popular for several years due to their extremely long shelf life. Until recently, lithium cells have been available only in 3- and 6-volt designs in unique configurations. As a result, they were seldom used as replacement batteries except in devices built to use them. Last year Eveready introduced a lithium AA battery that shows some promise. Be forewarned, however, that the nominal output voltage of this battery is 1.7 volts. Nikon and other manufacturers are specifically advising against its use pending further testing. Many divers report outstanding results with this battery in halogen flashlights.

Notebook computer manufacturers have been promoting the development of higher-performance, memory-free, environmentally friendly replacements for the nicad battery. The most likely candidate is nickel metal hydride (NiMH). Now available in AA and C sizes, these do indeed have higher capacity than nicads and are completely free of heavy metals. Charging times are rather long, however, and the few AA models presently on the market have outsized terminals that don't properly fit many chargers and battery holders. As a new product with limited distribution, NiMH batteries are also quite expensive. In

time, however, NiMH batteries may see widespread use.

As divers, we have one additional complication that most topside battery users don't have: salt water. As batteries are built to yield higher and higher current, they become more and more of a risk under water. A leaking dive light can cause some batteries, like high-current gelcells, to generate enough heat during a saltwater-induced short circuit to cause an explosion. Check those O-rings!

On the Horizon

Touted by some as the next great portable power source, lithium-based batteries have, so far, failed to live up to their potential. Over time, lithium electrodes become unstable, making the batteries unsafe to recharge. Chemists at the University of Nantes, France, feel they have solved that problem in a new, recharge-

able, "rocking-chair" lithium battery. To charge and discharge the battery, lithium ions "rock" back and forth between the battery's two electrodes. Lithium-polymer batteries also show promise.

Air Energy Resources in Atlanta plans to introduce new zinc-air batteries this year. Using oxygen from the air to fuel a power-generating chemical reaction, the batteries should provide more energy per pound than conventional batteries. Zinc-air batteries have been shown to last four times longer than heavy-metal batteries and are significantly lighter.

The lesson to be learned about batteries today is that there is no single solution for all applications. By matching the available batteries to your needs, though, you can keep your dive lights bright and your strobes cycling quickly.



Readers Report

Sharks, Galapagos, and Tonga

They Still Have Sharks

The long-line fishermen have come through Stuart Cove's shark-feeding area a couple of times. However, longtime In Depth reader Bob Mugford, Chelsea, Massachusetts, reports that they still have sharks to spare.

Stuart Cove and his crew did their usual outstanding job providing us with some terrific photo opportunities. Sharks

and more sharks — bull, reef, nurse, and a cameo from an 8-foot scalloped hammerhead. Hand feeding silky sharks at the buoy. Will definitely go back.

Galapagos Aggressor

We've been hoping to hear from readers about the new Galapagos Aggressor. Readers Graeme and Kathy Eisenhofer, who were on board in May 1994, report on their experience.