



Cochran Undersea Technology

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Batteries: Disposable Vs. Rechargeable

Introduction

Mike Cochran has been designing and producing battery powered products for over four decades. His first were at Texas Instruments where he invented TI's first Scientific Calculators. These early products were powered by rechargeable batteries because the power consumption was too high and hence, battery life too short for disposable batteries. These calculators used a Light Emitting Diode (LED) display which consumed energy and used a relatively high power processor. In the years since, the units were converted to a much lower power Liquid Crystal Display (LCD) and processor power consumption was reduced so the later units were designed with disposable batteries. Today, almost all Scientific Calculators are powered with disposable batteries that last for many years. This avoids all of the disadvantages of rechargeable systems.

In Richardson, Texas, Cochran Consulting designs and manufactures a number of uniquely different battery powered products. Some use rechargeable batteries and some use disposable batteries. Each battery type has its own advantages and disadvantages. This paper will focus on two of Cochran's products (Thermal Imagers and Dive Computers) and why one uses disposable batteries and the other uses rechargeable batteries.

For this discussion, within the category of Rechargeable Batteries are two basic types, Permanent and Replaceable.

Cochran Thermal Imagers

Cochran Thermal Imagers (www.CochranImagers.com) are small hand-held or helmet-mounted devices used by individuals for viewing thermal energy in a variety of applications. The microbolometer used in the imager consumes substantial energy as does the 3D LED viewers.

The relatively large total amount of energy consumed makes disposable batteries not a good choice as significant battery weight would need to be added to power the unit for a reasonable period of time. Furthermore, the added batteries size would increase the physical size of the Imager too much.

Therefore, for the Cochran Imager the decision was made to use rechargeable batteries. Instead of standard Lithium-ion batteries, Lithium-ion Polymer batteries (LiPol) were chosen because of their high ratio of power-density to physical size and weight. Also, certain LiPol batteries are not toxic or flammable and do not explode.

Cochran Dive Computers

For over twenty years, Cochran has been designing dive computers for itself and others. In addition to recreational and commercial units, Cochran is the exclusive provider to the U.S. Navy and other international Navies including NATO. Cochran designs the products it produces and markets with a continuing effort focused on providing the diver with a reliable, cost-effective, and trouble-free, state-of-the-art product. Intense effort has been placed on reducing power consumption because the dive computers are battery powered and Cochran wants to give the diver very long battery life. *Worrying about battery life should not be a factor while diving.*

The choice of a display for a dive computer is the most critical factor when considering battery life. Organic Light Emitting Diode (OLED) displays have extremely high power requirements. LED displays that require a continuous backlight also have high power requirements. Typically, the relatively high power required of these displays forces some of those products into using rechargeable batteries regardless of the disadvantages. Transflective Liquid Crystal Displays with on-demand color backlight like those used in Cochran products have a near zero power requirement.

It is important to note that a new, fresh, Disposable Battery contains substantially more energy than a new, fresh rechargeable battery, assuming the same physical size. For the Cochran dive computers, transflective LCD Displays with disposable batteries continue to be the strategy.

Batteries

When using disposable batteries it is important to use only name-brand products that are known to be new or fresh. Only use Lithium-ion or Alkaline as the dive computer manufacturer recommends.

There are a number of issues with any rechargeable battery system that require careful and challenging considerations:

Exploding Batteries

As evidenced by a recent (March 2013) dive computer recall, some rechargeable batteries particularly the cylindrical type, can explode. One should take great care when using them.

Sudden Shutdown

Rechargeable batteries have an extremely sharp discharge curve when reaching the end of its charge. This can result in an unexpected and sudden shutdown of your dive computer. There have been numerous reports of this occurring and unfortunately, on live-aboard dive trips it can be very expensive and frustrating. Should this occur, some dive computers require the diver to stay out of the water for 48 hours.

Because of the typically very long life of disposable battery dive systems (like Cochran) multiple low battery warnings are issued long before any shutdown.

Finite Recharge Half-life

From the very first time a rechargeable battery is charged it begins to age a little with every recharge. Typically, the half-life of a rechargeable battery is 300 recharges. For example, if a new battery lasts 5 hours on a recharge, after it has been recharged 300 times it will last only 2.5 hours. (Those of us with cell phones have experienced this problem.) However, continuing research indicates this half-life will continue to be increased.

Disposable batteries like those in Cochran products do not have this issue.

User Replaceable

The Finite Half-life problem implies that rechargeable batteries should be user replaceable. Sending a product back to the factory or service center to have its batteries replaced is simply unacceptable. Cochran solved this problem in its Imagers by supplying an independent battery pack that is easily user replaceable. Cochran Imagers also come with two batteries. This way, the Imager can be continuously used by successively connecting freshly charged batteries.

All of Cochran dive products have user replaceable long-life batteries.

Rechargeable Battery: Unpredictable Remaining Charge

As a rechargeable battery inexorably ages, the time it will last between charges becomes unpredictable. Temperature also plays a role in the unpredictability. Furthermore, some display systems that modulate the brightness based on ambient light also contribute to unpredictability.

Disposable batteries can also have an unpredictable life. However, systems using them are typically extremely low power and battery life is typically very long. All of Cochran dive products have battery life typically over two years.

Self-discharge Rate

As soon as the charger is removed from a system the batteries begin to discharge on their own. This rate of self-discharge depends on the battery and its temperature. While this rate is typically small, it can be significant in low power systems such as a dive computer.

Disposable batteries like those in Cochran dive products do not have this issue.

Zero-charge Life

Permanent damage can occur any time a rechargeable battery is discharged to zero. Sophisticated systems like the Cochran Imagers do not allow the batteries to be discharged below 20%.

Disposable batteries like those in Cochran dive products do not have this issue.

Over-charge Life

In simpler systems, serious, permanent damage can occur any time a rechargeable is allowed to remain on the charger for extended periods of time. Sophisticated systems like the Cochran Imagers monitor the state of charge and cut off the charging system when the batteries are fully charged.

Disposable batteries like those in Cochran dive products do not have this issue.

Long-term Storage Life

A rechargeable battery half-life can be shortened by leaving it fully charged or discharged for long-term storage. Cochran Imagers are shipped at the optimum 80% of charge. Cochran recommends that prior to storage, to fully charge the battery and then discharge it by around 20%.

Disposable batteries like those in Cochran products do not have this issue.

Degradation

One source states: "Lithium ion batteries start to degrade from the moment they are made, and, in fact, will become inoperable after two to three years even if they aren't used."

High Initial Parts Cost

Typically, rechargeable systems cost more than systems with disposable batteries. The more comprehensive battery management cost in properly designed systems coupled with the battery cost itself and its charging system cost are the main factors.

Replacement Battery and Related Cost

The battery cost per dive is small whether disposable or rechargeable batteries are used. The most significant battery cost factor is not the cost of the battery, but the cost of replacing a rechargeable battery at the factory.

Bulky Charger and Cable

Rechargeable systems require always having the charger available. They are prone to be lost or damaged which may leave the product unusable. Finding adequate power to recharge a system can be problematic while travelling or on a boat.

Relative Reliability

A poorly designed system is usually less reliable than a properly designed system. However, all things being equal, rechargeable systems can be less reliable than systems with disposable batteries because of the increased complexity and increased number of components including the charging system.

Battery Fuel Gauge, Coulomb Counter, and Warnings

Some products claim to have "Battery Fuel Gauge" while in fact, they do not. Assume:

- that the gas tank in your car got a little smaller with every fill-up,
- the temperature affected the size of the gas tank,
- your gas consumption changed with temperature,
- your gas consumption changed with your driving style.

Then a Gas Gauge that indicates a half full tank will not always give you the same driving time.

To be useful, a true Battery Gas Gauge MUST consider all of these factors. The Gas Gauge in Cochran's imagers is also called a Coulomb Counter and accurately tells the user how much time in hours and minutes are remaining while considering ALL of the above factors.

In addition to a battery voltage reading, Cochran Dive Computers have an audible and visual warning when the battery is low and changing it is recommended. Furthermore, because of their very long battery life, Cochran units will give the diver adequate warnings to finish a dive and then change the battery. If the battery becomes too low during a dive the backlight cannot be turned on, thereby conserving battery energy. The diver can then use his dive light if necessary to see the display. When the unit is turned on, if inadequate battery life exists for several dives, the unit will turn back off.

Planned Obsolescence

"With today's technology, when a product is designed with rechargeable batteries, it is a fact that the product will eventually become unusable due to the limited lifetime of the batteries. The only acceptable solution is to allow the user to replace the batteries when the life becomes too short. Permanent, rechargeable batteries are simply unacceptable to us."

"On a rechargeable system with a user replaceable battery, if the battery life is too short then the diver may need to carry a number of spare batteries to last a full week of diving on a live-aboard. The risk of not being able to conveniently and quickly recharge batteries and losing days diving is simply unacceptable to us."

For more information:

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- See Cochran Tech Pub: **Batteries: Caveat Emptor**