

A SHORT HISTORY OF EVERYTHING BATTERIES

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Batteries have been around for centuries, whether or not they were recognized as such. The Parthian batteries from Mesopotamia were found in the Baghdad Museum archives and described in 1938 by Dr. Wilhelm Kong, an Austrian archaeologist. These artifacts, dating back nearly two millennia, may have been used in early electroplating. They have the basic elements of batteries: two different metals that can create a flow of electrons when immersed in an acidic solution (Figure 1). In a battery, the cathode terminal is the source of the electrons that flow to the anode terminal. The movement of the electrons provides the current that does the work required of the battery.

One definition of the word “battery” refers to a grouping or series of similar items. The usage of the nomenclature for power supply cells undoubtedly came from the stacking of multiple layers of copper and zinc electrodes separated by acid-electrolyte soaked wafers that created the first “modern” battery, which was invented by Alessandro Giuseppe Antonio Anastasio Volta in 1800. Batteries were invaluable in the early development of electrical and electronic devices, such as the electric light, phonograph, telephone and, yes, hearing aids.

Early electric hearing aids with substantial amplification used vacuum tubes, which presented a daunting problem. Vacuum tube amplifiers need a low-voltage, high-current power supply to heat up a cathode to stir up electrons and “boil” them off the cathode. The anode needs a high-voltage power supply to create a positive charge to attract the negatively charged electrons across a grid, or control surface. This flow of electrons is modulated according to variations in current that originate at the microphone (or telephone coil).

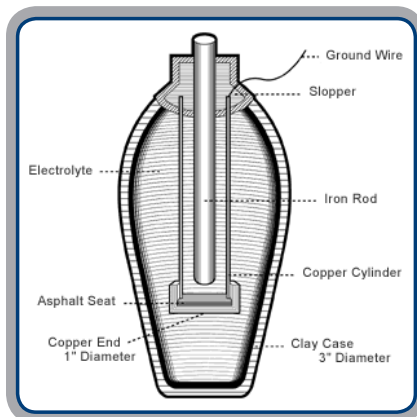


Figure 1: Estimated to be about 2,000 years old, the Parthian batteries produce an electrical current when filled with an electrolyte solution. As no written records exist, their use in ancient times can only be speculated on.

The only solution for the early hearing aids was to employ two batteries that needed to be worn on the body of the user. The body-worn vacuum tube hearing aids of the 1930s and 1940s were powered by two batteries — an A battery (from 1.5 to 3 volts) for the cathode and a B battery (22.5, 45, 90 volts (or greater)) that provided the amplifying power at the anode of the tube. The batteries were inefficient zinc-carbon types and were quite large (Figure 2). Some weighed more than two pounds, and the two together were sometimes larger than the hearing aid itself. Despite two batteries, gain, output and good battery life remained compromised.

It's hard to believe the size of the earliest hearing aid batteries; by today's standards, they were huge. For example, in the early 1920s, lead-acid storage batteries, especially in rural America, were used to start a farmer's Model T or tractor or were hooked up to provide lighting in the home or barn. These same batteries (Figure 3) could also be used to run early vacuum tube hearing aids, some of which were so large they were built into desks, built into cabinets or mounted on a table.

To deal with the limitations of the batteries, the engineers adapted a very successful audio amplifier circuit called the Class A amplifier for use in hearing aids. The Class A amplifier has two salient characteristics: the current drain remains constant no matter where the volume control is set, and it only requires a small number of components to operate, resulting in smaller designs. But the Class A circuit had a serious downside for use in portable applications requiring batteries: the steady current requirement used up battery reserves very quickly unless the design of the circuit prevented high current drain. Unfortunately, highly amplified output signals would become distorted when the demands exceeded the limited current available. When the amplified output was comparatively low, the aids worked beautifully, but at high levels of output, signal quality and clarity were seriously compromised. The outcome was that signal excellence was sacrificed in order to guarantee adequate battery life and keep consumer expenses manageable.



Figure 2: A typical body-worn vacuum tube hearing aid of the 1940s. The two batteries together are larger than the hearing aid itself.

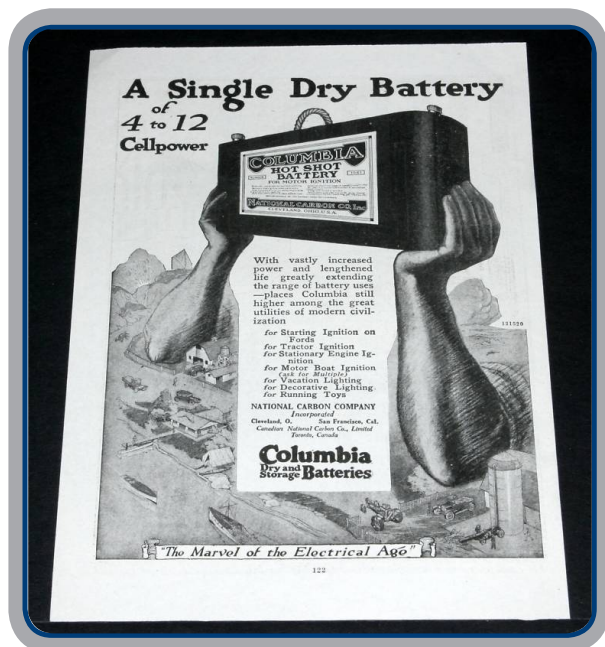


Figure 3: The type of battery that was used in the early 1920s to provide power for lighting, engine ignition, radios and, yes, even hearing aids.

The introduction of transistors in the 1950s was a breakthrough for hearing aids because the solid-state devices require much lower voltage requirements and a single, much smaller battery. Following WWII, the silver-oxide battery (1.55 volts) and the mercury battery (1.4 volts), both button-type batteries, were perfected. The discharge characteristics of silver oxide and mercury were suitable for hearing aids because of a relatively stable operation voltage over the life of the battery. Other types of batteries, such as the previously used zinc-carbon cells common for flashlights and other consumer products at the time, did not produce a stable voltage and weren't suitable for consistent hearing aid performance.

The reduced size of the transistor and batteries allowed for great strides in miniaturization of hearing aids. Although reduction in size and greater

efficiency was afforded by transistor circuitry, reengineered Class A circuitry remained the workhorse circuitry used in hearing aids. However, the lower battery voltages of the smaller batteries were often not enough to overcome the problems of distortion and battery life when higher gain and output levels were demanded. Parenthetically, silver oxide was the battery of choice for power behind-the-ear (BTE) aids because of the higher operating voltage. The cost of silver in the late 1970s and early 1980s nearly quadrupled, making the use of silver in a high-consumption battery unaffordable (Figure 4). The loss of silver-oxide batteries for power hearing aids disrupted the market temporarily, because the lower voltage of the mercury batteries that were substituted resulted in loss of gain and output. Although the voltage differences between the mercury and silver batteries appeared small on the surface, each required different circuit designs. Mindful of the need to provide high-power, economical, low-distortion hearing aids for patients with severe losses, engineers employed Class B circuits that had more components, but when not engaged in amplifying high-output signals, the circuit "idled" at a very low level, thereby lessening average current drain. Although these "push-pull" circuits provided the power with reduced distortion, they still pushed the limits of battery life whenever high input/output levels were present. One patient explained having to turn off his hearing aid when driving his noisy car, or his battery would be dead at the end of his trip after amplifying all the engine noise!



Figure 4: Speculation quadrupled the price of silver in the late 1970s and early 1980s, effectively removing silver-oxide batteries from the hearing aid market.

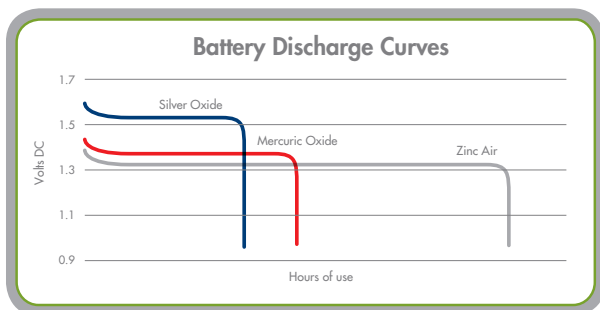


Figure 5: Relative battery discharge curves: silver oxide, mercuric oxide and zinc air.

In the late 1970s and early 1980s, a new battery appeared in the market: the zinc-air cell. This new hearing aid battery offered about twice the battery life of mercury or silver-oxide cells. This, concurrent with environmental and toxicity concerns emerging over mercury cells, led to a decline of mercury batteries as a viable power source for hearing aids. Zinc-air cells are currently the undisputed primary power source for hearing aids. Zinc-air batteries require a constant source of oxygen and dry out if activated but left unused, giving them a very short shelf life after activation. They do have a long shelf life prior to breaking the seal that activates the batteries. Their performance characteristics are such that they are very well matched with the needs of hearing aid users if used properly (Figure 5).

What's the future of hearing aid batteries?

Although hearing aid batteries are relatively inexpensive in the big picture of hearing aid cost, replacement of batteries is a constant irritant to hearing aid users. There is continuing development and improvement in rechargeable batteries. It is likely that we will see significant developments that allow rechargeable battery systems to be deployed in hearing aid systems within the next five years.

Battery tips:

How long will a battery last for your patient?

The best way to determine battery life is to measure the current drain of a complete hearing aid in operation in your test box or to use a battery drain meter to determine the typical current in milliamperes. The battery manufacturer should publish standard ANSI test routines and high-power test routines for each battery type. Use your measured data to determine which test routine is appropriate for your patient.

Care and safety tips:

Batteries in cold weather

Batteries cannot deliver much power when they are cold. Extreme cold temperatures may affect the performance of hearing aid batteries. Let the batteries warm up to normal temperature and try them again before you decide to replace the batteries.

Storage

Store batteries in a cool, dry location. Refrigeration is not necessary.

Remember, batteries are like any other chemical system. Heat will accelerate the chemical reaction and shorten cell life. Avoid storing batteries in extremely warm places or at other temperature extremes.

Keep batteries in their original packages until you are ready to use them. Storing new batteries together with coins or other batteries outside of the

original packaging may short circuit the cells and reduce their useful lives.

Disposal

NEVER dispose of batteries in a fire. They may rupture, releasing internal ingredients.

Local regulations may vary, but the safest route is to always recycle. Follow your local guidelines for collection and disposal.

Medical Emergencies

If a battery is swallowed, please call the Capital Poison Center Hotline, collect, at 202-625-3333, immediately. For more information, please visit the National Capital Poison Center web site at www.poison.org.



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