The Changing Landscape of Hearing Aid Batteries

BY BARRY A. FREEMAN, PH.D., VP BUSINESS DEVELOPMENT, ZPOWER LLC.

Has there been a time in recent years where so much has been written about batteries?

Probably not since transistors replaced vacuum tubes and the size of batteries and their current drains were drastically reduced. It appears we are entering a time when the hearing aid industry is moving *"to more differentiated solutions such as rechargeable hearing aids... rechargeability was a focus at AAA (2017), with most manufacturers now offering the silver-zinc battery solution from ZPower, which enables the user to recharge their hearing aid every night, with the battery lasting for c.400 charges (i.e., over a year). In the medium- to long-term, we believe it is likely that most hearing aids will be rechargeable"* (Goldman Sachs, 2017).

Understanding Hearing Aid Batteries: Chemistry, voltage and capacity

Batteries are defined by three main characteristics: chemistry, voltage, and energy or capacity (Battery University, 2017). The capacity of the battery represents its specific energy and is measured in Ampere-hours (Ah) or for hearing aid batteries, mAh. This is the amount of discharge current used by the battery over time. In an automobile, fuel tank capacity is the number of gallons of gas the tank can hold when it is full, e.g., 20 gallons. In a car, this partially determines how far you can drive on a single tank of gas. Similarly, in a hearing aid, the battery's capacity (e.g., 160-180mAh for a 312 zinc-air or 37 mAh for a 312 silver-zinc rechargeable) partially determines how long the hearing aid will operate.

Additionally, driving distance is also determined by driving habits and the mileage performance of the automobile. These contribute to the miles per gallon used by your vehicle. Some cars may get higher MPG than others and some drivers may have driving habits that result in better miles per gallon than others. Hearing aids work in the same manner. Batteries have defined capacities that may vary by the chemistry or the amount of energy placed in the cell by the manufacturer (Penteado and Bento (2013) (Freeman, 2017). Even though battery packaging and size may look the same, the actual battery capacity could differ quite substantially depending on the amount of energy placed in the cell by the manufacturer. Similarly, hearing aids use different algorithms to manage their features such as noise or feedback management, some companies and products use different streaming strategies such as NFMI or 2.4GHz, and hearing aid consumers have different operational or wear habits. These all contribute to different battery drain rates.

Disposable Primary Batteries

In the 1970s, research led to the miniaturization of disposable zinc-air batteries that were adapted for the hearing aid industry. These batteries have the proper 1.2-1.4 volts to operate the signal processing systems of hearing aids and sufficient capacity to run hearing aids to accommodate the typical wear-times of consumers. In recent years, however, the power demands of hearing aids have increased with the introduction of numerous features like wireless programming, feedback algorithms, and noise management. In addition, the majority of hearing aids fit in the U.S. have wireless streaming capabilities (Hearing Industries Association, 2017).

Wireless technology in hearing aids could be near-field magnetic induction (NFMI), 900 MHz, or 2.4 GHz (Galster, 2011). Each of these approaches to streaming have their unique advantages and listening strategies. NFMI, for example, requires an intermediary device that has its own battery and battery life while 2.4GHz hearing aids do not require a streamer and depend entirely on the battery in the hearing aid for power. Streaming, regardless of strategy, increases battery drain and in studies of consumers, they report a gap between hearing aid satisfaction scores and satisfaction with battery life. In fact, rechargeable hearing aids or batteries would be among the leading features that would motivate consumers to purchase new hearing aids (Abrams and Kihm, 2015)

Throughout the years, efforts to bring rechargeable hearing aids to the market have met with mixed results. Today, three different rechargeable battery chemistries are commercially available in hearing aids—Nickel Metal Hydride (NiMH), Lithium-ion (Li-ion), and Silver-Zinc (AgZn). Each of these chemistries are characterized not only by their different chemistries, but also by differences in their voltages and capacities.

Rechargeable Hearing Aid Batteries

In the last decade, attention focused on nickel-metal hydride (NiMH) batteries for rechargeable hearing aids. These batteries were originally developed for the automobile industry with research sponsored by Daimler-Benz and Volkswagen AG. They are the batteries used by Toyota in the Prius and Lexus hybrid automobiles and were widely used in early versions of mobile phones and consumer electronics. They continue to be used in some hearing aids but as the power demands of new hearing aids have increased, the average 18-20mAh capacity of NiMH batteries may be insufficient to operate a full day on a single charge. (Freeman, 2017).

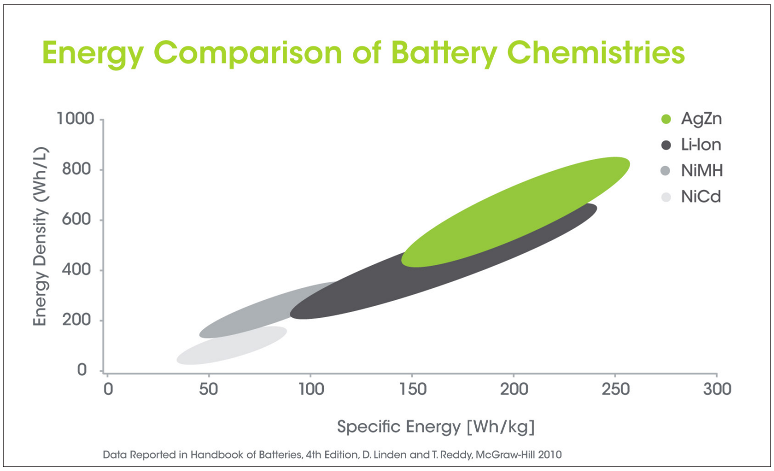

Figure 1. Comparison of energy density by size of various battery chemistries. As the size of the battery is reduced, silver-zinc has energy advantages over other rechargeable battery chemistries.

Today, many consumer electronics have replaced NiMH batteries with Lithium-ion (Li-ion) cells. Commercially, Li-ion batteries were introduced by Sony around 1991 and, today, they are widely used in consumer electronics and the automobile industry. The first hearing aids using Li-ion batteries were introduced by Phonak and Signia in 2016. While these perform better than NiMH in terms of capacity, cycle life, and operating time, Li-ion have voltages of 3.6-3.7v requiring a voltage regulator in the hearing aid circuitry to manage the DSP of hearing aids; have size limitations with the smallest Li-ion battery slightly larger than a #13 battery and Li-ion batteries must be sealed in the hearing aid case preventing access to the battery compartment. In a recent consumer survey (Hearing Tracker 2016), hearing aid users reported a preference for “the flexibility to use disposable batteries with their rechargeable hearing aids when needed” rather than a quick charge. Consumers using hearing aids with Li-ion batteries, must remove the hearing aid and place it in the charger if the battery does not have sufficient capacity to operate the hearing aid. Also, to replace the battery, it must be returned to the manufacturer for repair or battery replacement in labeled boxes complying with the federal requirements for shipping or mailing products with Li-ion batteries (UPS, 2017).

As noted by Goldman-Sachs (2017), “most hearing aid manufacturers are now offering a rechargeable solution with the silver-zinc battery.” Silver-zinc batteries were first invented by Volta in 1800 when he reported the first voltaic cell using silver and zinc. Many consider this the very first battery (Buchmann, 2016). Silver-zinc is a battery chemistry that has been widely used by the military and in the space industry. NASA successfully deployed rechargeable silver-zinc batteries without any incidents in launch systems beginning with the Mercury manned space flight missions. The military has used silver-zinc batteries in missiles, torpedoes and submarines for more than 50 years (Dueber, 2008). "The battery chemistry that was used by NASA and the military has now been moved to the commercial sector for consumer electronics and hearing aids" (Dueber, 2016).

The favorability of silver-zinc is that it uses a water-based electrolyte that is non-flammable. The stability of the silver-zinc battery materials and the complete nonflammability of the silver-zinc electrolyte make it an intrinsically safe battery technology. In addition, when compared to other rechargeable battery chemistries, silver-zinc does not have size limitations and has a higher energy density when compared to other chemistries. As shown in Figure 1, as the size of the battery decreases through miniaturization, silver-zinc maintains the highest amount of energy while being cost-effective for small hearable and wearable devices.

Rechargeable silver-zinc batteries are a perfect match for hearing aids. They can be produced in the small sizes required for hearing aids with current products using #312 and #13 batteries; they offer enough capacity to operate wireless streaming hearing aids for a full day; and, despite a slightly higher voltage than zinc-air batteries, the 1.6-1.8v silver-zinc batteries can operate current and next generation hearing aid DSPs with minimal voltage regulation. They also do not require the hearing aid to be sealed and can be used interchangeably with zinc-air batteries. Silver-zinc, unlike the estimated 1.6b other hearing aid batteries that go to landfills every year, are fully recyclable and a green source of energy.

Relationship Between Battery Chemistry, Capacity, and Battery Life

Hearing aids can vary widely in the amount of energy required for operation. Figure 2 shows data on the battery current drains of hearing aids from five leading manufacturers using their own proprietary feature algorithms and approaches to wireless streaming. Included in this figure is the data reported by the manufacturers on their technical sheets. However, there is little correlation between what is reported on the manufacturer's technical sheets and the actual current drain of hearing aids (Jorgensen, Baekgaard, Bendtsen (2013); Freeman, 2016). Manufacturers follow ANSI standards for reporting technical information and ANSI requires all adaptive features to be turned off (ANSI, 2003). Products A-E were programmed for individuals with moderate hearing losses and were electro-acoustically evaluated using the manufacturer's first fit. In the "No Stream" conditions, current drains were measured with ICRA input signals with 1.4v input to the hearing aids.

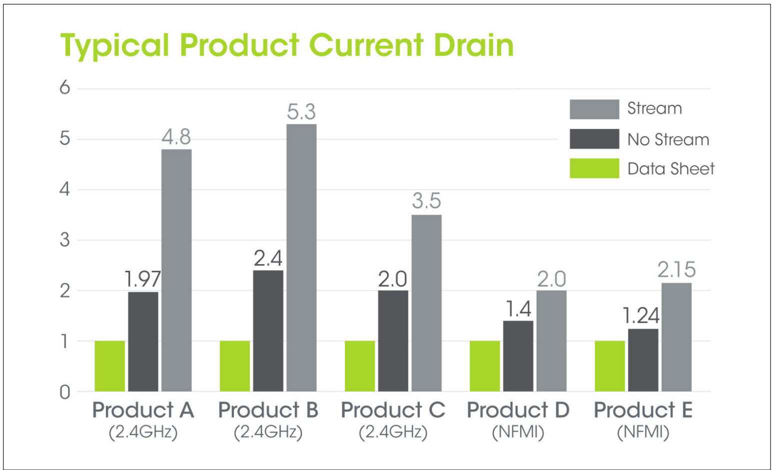

Figure 2. Typical Hearing Aid Current Drains. This figure shows the hearing aid current drain of five hearing aids. The first bar (Data Sheet) represents the current drain using ANSI specifications where all features are disabled and reported on the manufacturer's technical sheet; the second set of bars (No Stream) represent current drain with features activated but without streaming; and the final bars (Stream) in the graph represent the current drain while the hearing aid is streaming.

The average non-streaming current drain for hearing aids operating with 2.4GHz capabilities ranged between 1.97mA-2.4mA current drain. The non-streaming drain was lower for hearing aids using NFMI with current drains averaging between 1.2-1.4mA. When streaming was introduced by playing music from a phone, the current drains increased for all products with the 2.4GHz devices ranging from an average low of 3.5mA to an average high of 5.3mA.

Hearing aids using NFMI required the use of an intermediary device for streaming (Products D and E). As expected, the streaming current drains were lower (average 2.0-2.1 mA) for these products. These latter devices required an intermediary device that has its own battery for streaming whereas Products A-C depended on the hearing aid battery for its power needs. It's important to remember that hearing aids using the 2.4GHz band do not use an intermediary device and depend on the hearing aid battery to power all their features and streaming while NFMI hearing aids use two

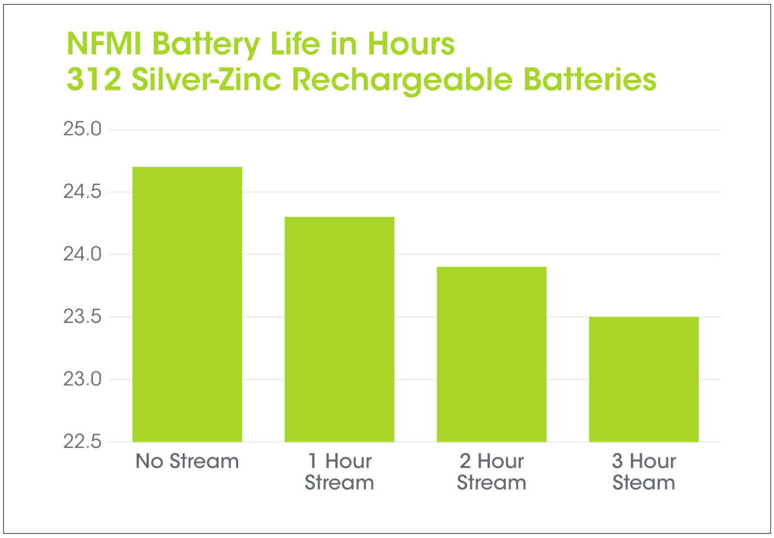

Figure 3. Comparison of battery life with silver-zinc rechargeable 312 battery operating a wireless streaming hearing aid using NFMI. Even with three hours of streaming, the hearing aid will work 23.5 hours on a single charge of the 312 battery.

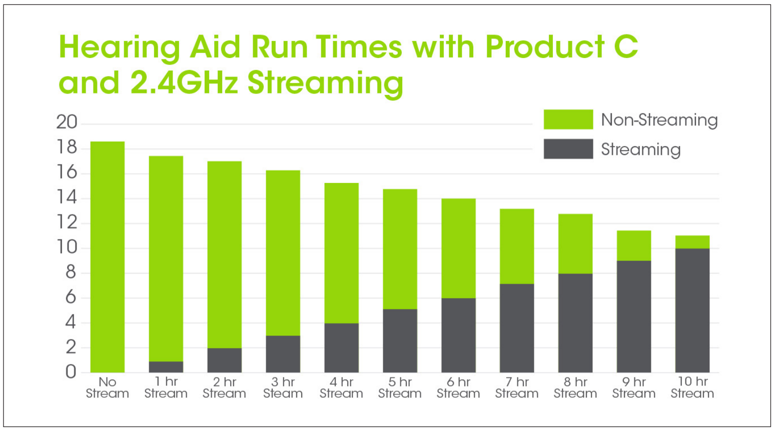

Figure 4. Example of Product C operating with a silver-zinc rechargeable 312 hearing aid battery with various levels of streaming. With no streaming, the hearing aid will operate approximately 19 hours before requiring a charge. The same hearing aid will operate more than 10 hours with full-time streaming using 2.4GHz.

battery sources to power their products—the battery from the accessory streamer plus the battery to power the hearing aid.

The implications of the different current drains become quite apparent considering the different wear times available to patients. The data in Figure 3, for example, reveals that patients wearing the NFMI Product D hearing aids with a #312 rechargeable silver-zinc battery (37mAh effective capacity) could wear the hearing aids for almost 25 hours on a single charge if they were not streaming and 23.5 hours if they streamed 3 hours per day. In this example, the amount of streaming and wear-time would not be limited by the silver-zinc rechargeable hearing aid battery but by the battery life of the intermediary streaming device which may only last 3-4 hours.

Similarly, as shown in Figure 4, patients wearing Product C with 2.4GHz streaming and a silver-zinc rechargeable battery (37mAh effective capacity) could use the hearing aids without streaming for almost 19 hours on a single charge, approximately 17 total hours when streaming for 3 hours, and for more than 10 hours if all they did was stream.

Math and chemistry will provide a guide for minimum and maximum hours of use but patients can dictate whether their days can be longer or shorter by simply how they manage, or do not manage, their power consumption.

Take Away: Counseling

In the past few decades, the hearing industry reduced the size of hearing aids; transitioned from analog to digital technology; and integrated wireless streaming capabilities into products. We are at the precipice of a new disruption with the adoption of rechargeable batteries replacing billions of disposable cells.

In a traditional model of patient centered care, the practitioners will evaluate patient lifestyles to understand the individual needs of their patients. Lifestyle questions would be asked about how patients hear in restaurants or understand their grandchildren. We may evaluate a patient's motivation to wear amplification to manage their expectations. We also may evaluate their ability to communicate in various listening situations like church or at home watching television. While all of these factors are an important part of lifestyle assessment, now we must also learn more about the daily listening habits of patients. Today, we must also understand how many hours per day they listen to music, talk on the telephone, and watch TV. These are streaming activities and successful patient management requires an understanding of the typical listening day including streaming and non-streaming activities. This information will help professionals make the right product selection for their patients. Of course, it is equally important to understand the performance of devices in these situations. As we are learning, hearing aids have different performance characteristics based on their algorithms and streaming strategies. It is critical to match the communication and listening needs of our patients with the right technology.

As hearing aid consumers become more comfortable with the capabilities of wireless streaming hearing aids and as more features and capabilities are added to these products, there will be increased expectations and demand by consumers to operate their hearing aids for a full day. Now is the time to meet that challenge by having a deep understanding of the lifestyle needs of our patients and matching these to appropriate technology.

REFERENCES:

Abrams HB, Kihm J. An introduction to MarkeTrak IX: A new baseline for the hearing aid market. Hearing Review. 2015;22(6):16.

ANSI S3.22-2003. Hearing aid evaluation standards.

Battery University (2017). http://batteryuniversity.com/learn/article/battery_definitions

Buchman, I. (2016). Batteries in a portable world. Second Edition, Cadex Electronics, Inc. Canada.

Freeman, B.A. (2017). Rechargeable systems for hearing aids. Presentation at the Annual Conference of the American Academy of Audiology. Indianapolis April 2017.

Goldman Sachs (2017). Europe: Healthcare Medical Technology. Global Investment Research on Hearing Aids: AAA 2017. April 10, 2017.

Hearing Industries Association, Annual Report on Hearing Aid Sales in the United States. January 2017.

Hearing Tracker (2016). https://www.hearingtracker.com/

Joergensen, H., Baekgaard, L., Benedikte, B. (2013). Battery consumption in wireless hearing aid products. Audiology Online, June 3, 2013.

Penteado, S. and Bento, R. Performance analysis of ten brands of batteries for hearing aids. Int Arch Otorhinolaryngol. 2013 Jul; 17(3): 291–304.

Dueber, R. (2008). Silver-zinc battery tech outshines Li-ion on the safety front. J. of Military Electronics and Computing (May, 2008).

Dueber, R. Rechargeable hearing aid batteries draw from NASA research. Spinoff Magazine. December 2016.

Galster, J. (2011) Awash in a stream of wireless solutions. Audiology Practices, Vol 3, No. 2 p 28-29.

UPS (2017). U.S. lithium battery regulations. https://www.ups.com/media/news/en/us_lithium_battery_regulations.pdf