Engineering Technology

Electrochemical devices

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TABLE OF CONTENTS

0> SUMMARY

This papers presents information regarding electrochemical devices. First explain that every battery has the same basic construct. This includes have a casing, electrodes, separator, and a connector. These items all come to together to create a consistent current at some voltage. Our everyday use devices utilize the dry cell design and heavier applications then can use the rechargeable well cells. The original invention made in the late 1700's did not actually have the ability hold a consistent current with voltage. Made by Benjamin Franklin was a device that could release large spikes of voltage but not for prolonged amount of time. Today such a device is known as a capacitor but at the time coined as a battery. There were following designs that were improved with longer sustainability within the next decade. What is now known as Energizer Battery Company, was one of the first companies in the US for battery distribution in the late 1800's, early 1900's and is still using similar designs from way back when. During the technology boom, that we are still experiencing even now, they started re-evaluating the materials used in batteries because people were demanding longer battery life. This battery life would be for the many portable gadgets and implanted medical devices. There have been some improvements but we are always looking for smaller and longer lasting designs.

1> INTRODUCTION

If you take a moment to realize how often you interact with batteries on a day-to-day basis, you would realize that they are everywhere: in the laptop that you are using, the phone in your hand, the watch that you're wearing, the car you took to work or even in the tooth brush that you used this morning. There are so often used, that we do not even think about how they work or where they came from. There are many applications across the world that use these seemingly simple devices. Now batteries are becoming a hot topic across the world because of the automotive industry and electric cars that are looking like our future as well as advances in other fields, such as medical devices. This will take you into the history and original designs for batteries, to the updates that we have or have not changed over the years and how we utilize the electrochemical equipment today.

2> COMPONENTS & OPERATION

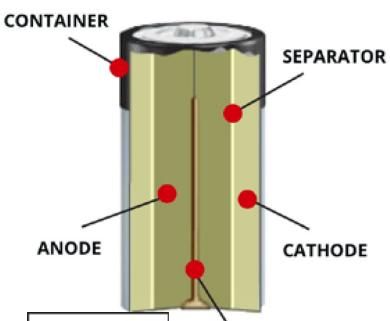

Figure 1

Every battery has six basic components that are explained in this section. As labeled in *Figure 1*, there is a container, terminals, electrodes (anode and cathode), separator, electrolyte, and the collector. To hold all the elements together we have our first component, the container. The container is a basic metal or plastic case that can last through and not interrupt the chemical reactions inside. Also, on the outside, are the terminals. They are not labeled in the figure, but they are on the top and bottom of this particular design but can be various orientations in other designs. These are generally labeled as negative and positive to determine the direction of flow of electricity to be connected within a circuit.

Now let's venture to the inside, where the magic happens. The two electrodes: the cathode which is deemed the positive side of the battery and the anode which is the negative. They are the items that create the flow of electrons. The separator keeps the two electrodes from interacting with each other. This generally is a fibrous material such as paper or cardboard that has been used in many designs. The electrolyte is a liquid or paste substance that carries ions and electrons to and from the electrodes. The collector is a rod placed in the middle of the cathode that carries out the electrons to the terminal. With all of this, we can now see how each element will react with one another. First, starts with what is known as an oxidation reaction between the anode and the electrolyte once the battery is connected to a load. In this process, compounds are formed but electrons are released to the electrolyte. The electrolyte then carries these free electrons through the separator, or around depending on the design, to the cathode. During which, the cathode is experiencing a reduction reaction with the electrolyte which attracts the electrons and some ions to be combined. This is when the collector gathers all the free electrons before they can combine with anything, to release them into the given circuit through the positive terminal. These internal reactions will progress until there are no longer materials left to react. This brings us to the different types of electrochemical devices. There are primary batteries which are the single-use disposable batteries that everyone thinks of when you mention them such as AA. These generally use the dry cell design which consists of a moist paste as the electrolyte, making them more portable and less likely to agitate the reaction within. Secondary battery types are the rechargeable batteries, which mostly uses a wet cell design. The most common wet cell design is the one that sits in your

garage. The oldest and most common secondary battery is the lead-acid batteries are used in combustion engine vehicles. This uses a liquid electrolyte that has a powerful reaction but must stay upright to operate properly and is easily recharged.

3> HISTORY

1749, the word "battery" was coined by Benjamin Franklin. He realized that there were differences between insulators and conductors. While that was his real discovery, Franklin managed to create a series of capacitors out of jars and metal plates that would discharge electrical power. The material used for this experiment from the research conducted on the subject was very vague, stating only that it was metal. These capacitors were created by two other men in 1745 which was called a "Leyden Jar" at the time. At the turn of the century, the actual battery was created by Alessandro Volta. In an attempt to disprove a colleague's theory Volta built what was known as the "voltaic pile". This colleagues name was Luigi Galvani and he was experimenting with frogs. During these experiments, Galvani hooked up a series of metals to the muscles of the frog to observe that there was movement in the frog's leg. Then claiming the dead frog spawned electricity. Volta's invention was the first known electrochemical device to generate continuous current, along with a measurable voltage. Hence the name voltage, in honor of his discovery. In this experiment, Volta used stacked copper and zinc plates with a cloth material in between them. All this was soused in saltwater. The next electrochemical device came to light 36 years later. This device was created by a chemist name John Frederick Daniel, naming the device the "Daniel Cell". This design also included a jar, similar to the capacitors from Franklin's era, with metal

plates but this time we have a couple of electrolytes evolved. The bottom of the jar contained a copper plate the hung from the side of the jar. This plate sitting in the copper sulfate that occupied the bottom half. The top half had zinc sulfate. This worked because the two liquids being different density could stay separated. Within the zinc sulfate the set a zinc plate, also hanging from the side. This design was often used for immobile applications because it was fairly efficient for the time but could not be moved around without disturbing the chemical reaction. A design that most people still use to this day is the Lead-Acid battery. This electrochemical device was invented by a man named Gaston Plante in 1859. This design was considered one of the first rechargeable designs using lead plates as the anode, which were separated by rubber strips. The cathode was a lead dioxide all immersed in the electrolyte, sulfuric acid. Much more compact designs were soon to come, in 1866 George Leclanche started using a crushed mixture of manganese dioxide and carbon, for the cathode, within a container with a zinc rod through the middle, as an anode. The electrolyte that he used was an ammonium chloride solution. This and all the previous designs were considered "wet cells" but Leclanches' design was still used for large applications, such as the telegraph. The first dry cell was not invented until 1880's by a gentleman named Carl Gassner. Held within a zinc container, which also served the purpose of the anode, was the same cathode from Lachances' design but with a copper rod inserted in the middle. Gassner also used a different electrolyte, which made a huge difference in the shelf life of the product. By using zinc chloride, the zinc container did not erode as fast as previous designs.

Figure 2

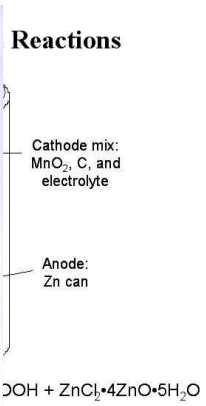

Figure 3

In the 1890's batteries became commercially available for industrial and consumer applications. The company that originally started distributed these products was called National Carbon Company. This company today is known as the Energizer Battery Company. Originally distributed designs such as Leclanches' wet cell then soon moving on to using dry cell design such as in *Figure 2* and *Figure 3*. This Columbian Dry Cell was very similar to the Gassner's design. From this point forward, the design continued to improve and change for various given applications. One of the most common batteries used today was not invented until 1980, by John Goodenough. This was the lithium-ion battery, which has led to increasing innovation in the battery industry. There was evidence found by Wilhelm Konig, whilst he was digging at an archaeology site in Iraq, of battery like devices dating back to 200 BC so this may not be the first time the human kind has made such discoveries.

4> APPLICATIONS & ELEMENTS

Now we know how electrochemistry works and who had their hand in the original designs, we can get into how things are done today. You may

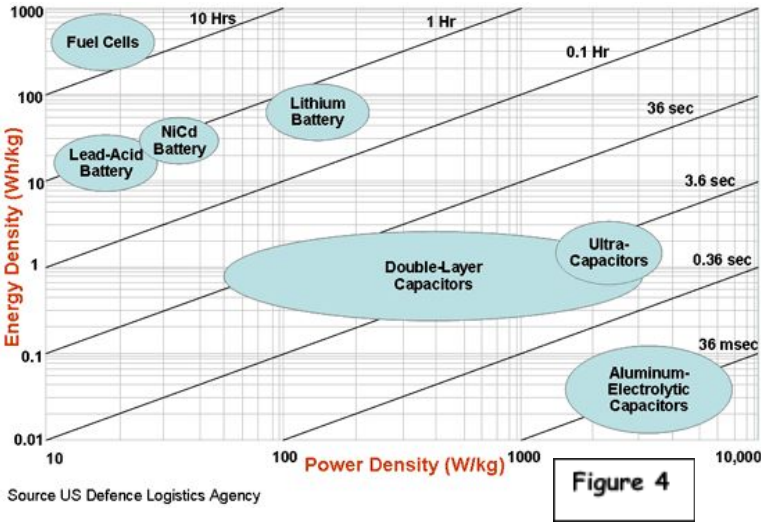

Figure 4

have noticed the first battery company started over 100 years ago. The design at some time was very stagnant because there was no reason to improve the idea. It worked for what was needed for the times. With the recent boom of portable devices and advances in the medical field the consumer market for better, longer lasting batteries has risen substantially. Another large difference now is the world is becoming environmentally aware. The main hurdle for this industry to overcome is the power density versus the energy density. This basically means how heavy and bulky the device is compared to how much power it can supply in how so much time. This can be observed *Figure 4*, known as a "Ragone Plot". This diagram has an x-axis of power density, measured in Watts per kilogram. The y-axis is the energy density, measured in Watt Hour per kilogram and there is a diagonal axis of time. As you can see, the capacitors have very high-power density but a low energy density. This is due to their ability to provide extensive amounts of power, but they generally are very hefty in size. In the top left corner, you can see our fuel cells and some batteries that have been mentioned. These last longer but have less Watts per kilogram. There are various ways that electrochemical devices are compared but this is one of the most common ways. This comparison makes it easy to understand what device works for which application best. The next part of this section includes a table some common modern designs of our batteries and what we generally use them for. There are many variations of materials used in mixtures with others.

Electrochemical Application table:

Battery	Sizes	Materials	Applications
Alkaline	AAA, AA, C, D, 9 Volt	Alkaline, Manganese, Dioxide	Clocks, toys, Remotes, Consumer products
Lead Acid	Stationary	Lead-dioxide, Sulphuric Acid, Lead	Vehicles, Submarines, Emergency Power
Lithium Primary	Wide Variety (Replacing many designs)	Manganese Dioxide, Sulphur Dioxide, Oxygen	Pacemakers, Car Keys, Security transmitters, Aerospace
Lithium Secondary	Rechargeable	Carbon, Lithium Cobalt Dioxide or Manganese	Communication Equipment, Cameras, Electrics Razors, Phones
Nickel Cadmium	Wide Variety	Nickel Hydroxide, Cadmium, Potassium Hydroxide	Power tools, Two-way Radios, Toys
Nickel Hydrogen	Large, Specialized	Hydrogen (Same as Previous)	Aerospace, Hubble Space Telescope
Nickel Iron	Large, Specialized	Iron (Same as Previous)	Traction applications, Fork lift trucks
Nickel Zinc	Specialized	Zinc (Same as Previous)	Scooter, Lawnmowers
Silver Zinc	Small	Sodium Hydroxide or Potassium Hydroxide, Silver oxide	Hearing aids, instruments, low power devices
Zebra	Large, Specialized	Sodium Nickel Chloride	Electric and Hybrid Vehicles, Railway

The items listed on this table are not limited to what is stated and in battery applications many items overlap but are not listed. This is at the discretion of the manufacturer and application purpose, as well as consumer choice. All the

information listed on this table comes directly from *Battery and Energy Technology* website.

5> CONCLUSION

Sometimes more than we realize, batteries have an impact to almost every part of our lives, from work to home to the products we purchase. These electrochemical devices can be any variety of size and chemical composition. The original device that was named the "battery" ended up being a capacitor by Benjamin Franklin. The created more compact and mobile in the late 1800's by Leclanche, whose design was used for commercial use in one of the biggest battery distributors in America. With every battery made with the same basic components of anodes, cathodes and an electrolytes that react with one another to create a consistent stream of current at some voltage. Look around you and see the world of power, variety and with many recent improvements and always more to come.

6> REFERENCES

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