Alkaline Batteries and Powering Vintage Clocks

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Based on the alkaline D battery, the Model 1900L has been considered the direct No. 6 replacement product for self-winding clocks. As time has gone on, quite a bit has been learned about effectiveness and issues associated with the alkaline battery for powering vintage self-winding electric clocks. Some things were predictable, others were a bit of a surprise. Technical data sheets for alkaline batteries can confound one's ability to predict aging, what characteristics matter, etc. when powering vintage clocks. Yes, performance graphs and curves do provide some insights. Unfortunately, these curves can be confusing when evaluating battery performance in vintage clocks. Much of what we have learned has come from experience.

Powering ATO Clocks with Alkaline Cells. With ATO's, much depends on the specific clock style. In general, when powering ATO clocks (such as Bulles, ATO, electronic balance wheel clocks, etc.), shelf life and battery voltage sag compete with each other to determine battery life. This is because the actual current drawn from the battery is minimal, typically hovering in the 100uA range (average). These clocks have very high coil resistances on the order of 1-3k ohms, and impulse for perhaps 100ms out of every second or so. For this application, alkaline batteries perform fairly well. As the battery voltage droops with use, the timekeeping of the clock may vary, but the clock will generally continue to perform down to perhaps 1.2V cell voltage or so. For this reason, good lifetime is achieved, which begins to compete with the shelf life of the cell. These two effects which taken together act to limit the run time of the battery, despite the theoretical lifetime one would expect based on calculations from the A-hr capacity of the cell.

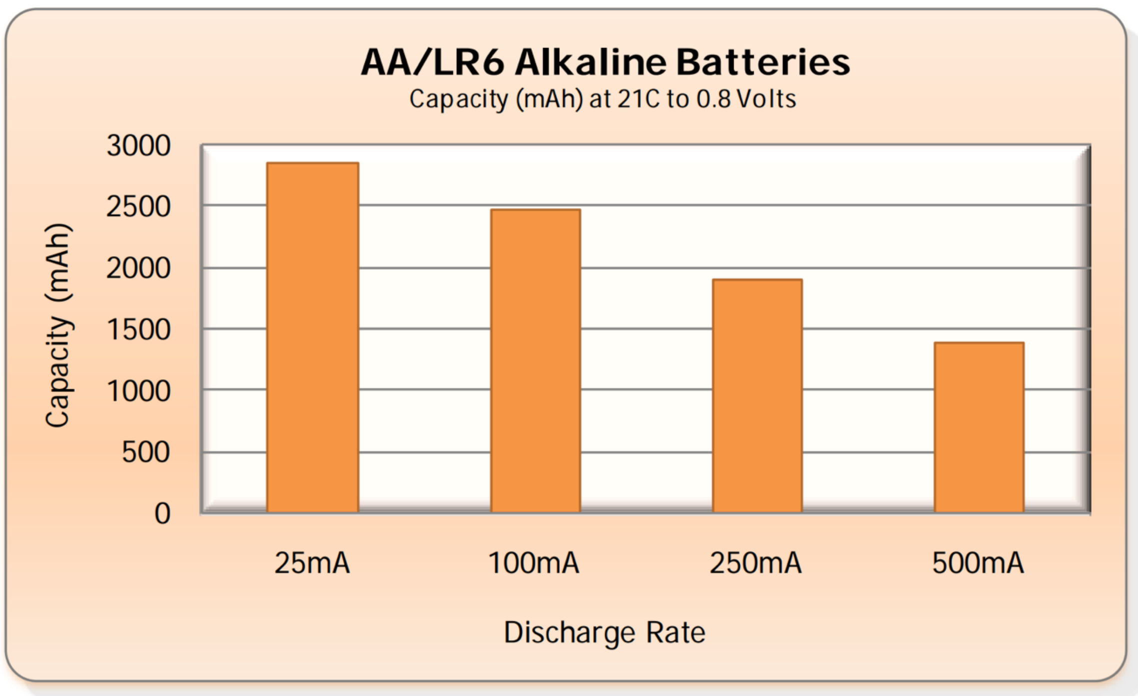
Nonetheless, ATO style clocks are the least demanding of a cell's performance parameters related to run time, and so alkaline cells often prove adequate albeit not perfect—**as long as they don't leak chemicals into the clock**. And this very serious issue with alkaline batteries (recently, especially Duracells) cannot be neglected! We have seen many battery holders destroyed by battery leakage. It is very possible that you have, too.

Powering Vibrating (Style F) and Rotary (A, B, C) Clocks. Self-Winding Clock Co. clocks with vibrating (or rotary) motors are more demanding. The coil resistance is roughly 5-6 ohms, which means that when our 3V alkaline battery is connected, there will be almost 0.5 amps needed to start the motor. To illustrate, every hour (or perhaps every 5 minutes when powering 37-SS style clocks with vibrating motors) the battery must output a fairly high level of current in the 0.5A range which subsequently settles into the 200-400mA range while the motor is running (usually 4-10 seconds), and then recovering until the next winding. This might at first seem like a condition that would easily fall within the cell's capability, since it averages out over time to the equivalent of perhaps 2-4mA continuous. However, these motors must be started and run, requiring substantial energy. What does this do to alkaline battery life?

Consider the graph below (their Figure 13) taken directly from the Energizer technical data sheet for an LR6 cell (commonly known as the AA cell—same chemistry and behavior as other sizes).

Referring to their Figure 13 (shown below) the battery's capacity on the vertical axis is expressed in mA-Hr. The higher the number, the longer the lifetime of the cell. When drawing low continuous currents such as 25mA, the best lifetime is achieved. But as the current is increased to the 200-400mA region, the mA-Hr lifetime of the cell diminishes towards ½ its optimal level, as shown. **Even though our clock averages out over time to only perhaps 2-4mA, the clock motor's demand on the cell peaks at much higher levels, and these periodic "peaks" disrupt the alkaline cell chemistry in measurable ways which dramatically reduce cell life and (as we have observed) GREATLY increase likelihood of battery leakage (especially with Duracells).**

So, which of these bars do we use to estimate battery life?



(fig. 13) AA/LR6 alkaline battery capacity to 0.8 volts
https://data.energizer.com/pdfs/alkaline_appman.pdf

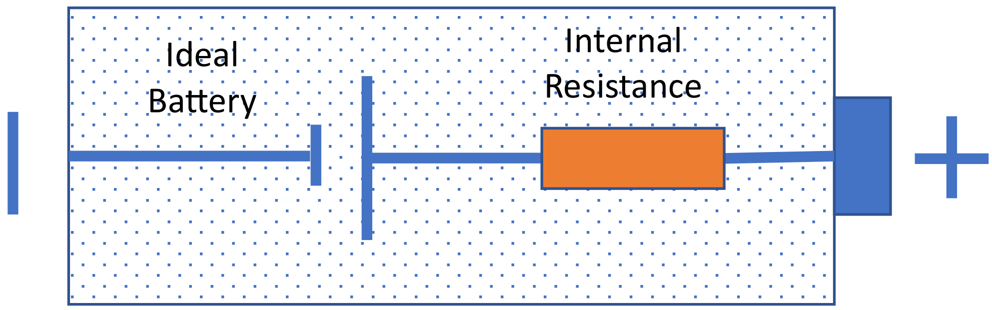
What we have learned is that the available A-Hr (or mA-Hr) capacity of the cell must be estimated from the bar on the right; not the averaged, much better value (left) which reflects the A-Hr capacity. And the difference isn't subtle—it's ½ the battery capacity we would expect! We have also found that the battery internal resistance has a great deal of influence on the cell's ability to power clocks. And, these two effects work together to make matters worse—especially when powering **impulse-wound clocks**.

Powering Impulse Wound Clocks. An Impulse-would clock is one which winds perhaps once per minute, once per 3 minutes, or once per 7 minutes, etc. At each wind cycle, impulse-wound clocks demand substantial current from the battery, but for only a short amount of time.

Examples are clocks from Gregory, American Clock Co., Hip-Toggle clocks from New York Standard Watch Co., Seth Thomas 86A, Imperial models, among others.

What is meant by "internal resistance" and how does it affect battery life? To understand this effect, consider Figure 1 below. A "real" battery consists of an "ideal" battery in series with some internal loss, shown in Figure 1 as "Internal Resistance" (measured in ohms). When the battery supplies current, this internal resistance absorbs some of the energy from this current passing through it. This loss can cause heating within the battery in extreme cases. But most of the time it is simply troublesome in powering devices, such as impulse wound vintage clocks.

Figure 1: Internal Resistance of Battery Cell



When alkaline batteries are used to power impulse wound clocks, we have seen many batteries end up in the trash bin after only a few weeks or months run time due to the degradation of internal cell resistance. Let's explore this, as a re-cap of our Model 1900G White Paper.

According to the specification sheet for alkaline batteries, the manufacturer indicates around 200 milliohms (0.2 ohms) fresh—each cell, regardless of the cell's size (AAA, AA, C, D, etc). Put two in series to obtain the required 3 volts and now we have conservatively 400 milliohms total internal resistance when the cells are fresh. That means that when the clock's contacts close connecting the motor to the batteries, we are going to lose up to 0.2 volts across the cell internal resistances with fresh batteries (0.5A x 400 milliohms). You'll likely get by, at least at first.

The problems occur when the cells have been used for a few weeks or months in the clock and these above effects start to play together. We know from the curves that alkaline batteries do not maintain a constant voltage. After a few months use under modest load, the voltage drops from 1.65V fresh to 1.3V (each cell). In addition, the cell's internal resistance increases—sometimes as much as 3x its "fresh" level!

Voltage drop internal to the alkaline cells in response to the clock's coil can extend well over 0.6 volts. This voltage is lost to the clock. Subtracted from the 2.6 volts we measure at 1/3rd the service life, we now have 2 volts applied to the clock, which in many cases will not be enough to initiate a wind. Hopefully this provides a rough idea of the problem we face using alkaline cells to drive impulse-wound clocks.

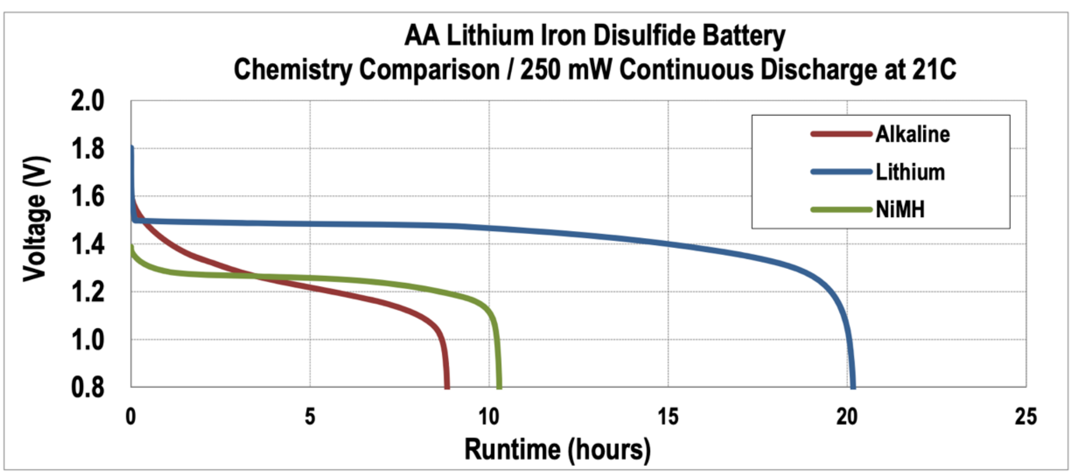
At this point, 1/3rd or so into the service life of fresh batteries, you'll likely remove them from the clock and throw them away, thinking they are dead! Yet most of the cell life remains, if we can find a way to extract it from the battery.

Our Model 1900G extends the life of the internal alkaline cells by buffering the output with ultra-capacitors (which addresses the internal resistance issue) while at the same time regulating the output voltage to 3.3V with a special energy-harvesting boost regulator (which addresses the voltage droop issue). The results are quite fabulous, but require electronic assemblies and components. Nonetheless, the Model 1900G has turned out to be the premier choice for powering self-winding clocks, performing much better than anything else available, anywhere.

By contrast, the original Model 1900L improved on the alkaline cell life by having two cells in parallel within each No. 6 unit, reducing the effect of internal cell resistance by half. But it still does not help with the chemistry disruption caused by powering vintage self-winding clocks. In fact, we see no improvement in leakage or series resistance effects.

Until now, there was no way to completely work around the vulnerabilities of the alkaline cell chemistry to impulses. Regardless of how it is done, the cells would under-perform in self-winding clocks—**with the very, very dark cloud of potential leaks always present.**

Within the last decade, Energizer introduced a brand-new non-rechargeable (primary) AA battery called the **Energizer Ultimate Lithium** (the internal chemistry is called Lithium Iron Disulphide). Again, while this is a lithium battery, it is NOT rechargeable. But what it delivers is nothing short of revolutionary. It outperforms the alkaline battery in every application, including powering self-winding clocks. In fact, despite the lower specified A-Hr energy capacity due to its AA size (vs. the alkaline D cell), the **Energizer Ultimate Lithium** technology can be configured to power a self-winding clock more efficiently, more powerfully, and with longer life than the alkaline D solution in almost all cases.



(Fig. 6) Relative Constant Power Performance of an AA Size Battery (different chemistries)

https://data.energizer.com/pdfs/lithiuml91l92_appman.pdf

To understand why, let's consider the curve above, this time from the Energizer Ultimate Lithium Applications Manual.

From the curve in Fig. 6 above, the contrast between the blue (the Energizer Ultimate Lithium chemistry) and red (the alkaline chemistry) curves is staggering! While both AA batteries have similar A-Hr ratings (specified at light loads), the AA Energizer Ultimate Lithium far outperforms the AA alkaline equivalent in run time comparison (more than 2x!) under loads representative of powering vintage battery clocks. This is unprecedented performance. In addition, the Energizer Ultimate Lithium battery internal resistance actually IMPROVES as the cell is used—from 0.2 ohms initial to just over 0.1 ohms under actual use! **All of these factors together greatly improve watt-hour capacity far beyond what is possible with alkaline cells. And "watt-hours" relates directly to energy, and thus run time.**

Bottom line, Energizer Ultimate Lithium batteries have a highly resilient and superior chemistry—hands down—for powering vintage self-winding clocks. While they don't offer the A-Hr capacity to do the job with long life, we can almost always configure them into products for you that will. We have already converted our Model 1900L2 and Model 1900G2. But what about powering the 1900W-UNV series?

Powering Minute Impulse Master and Secondary Clocks. Unfortunately, the A-Hr requirements to get long run times from minute impulse master and secondary clocks using the 1900W-UNV series would require strings of quite a few Energizer Ultimate Lithium cells, and that might prove impractical. But there is another solution for minute impulse-wound clocks. Our new Model 1900W-UNV-UC (with ultra-capacitor technology) solves the problem and allows us to still recommend four alkaline D batteries to power that product. That's because the ultracapacitor technology softens that impulse load experienced by the battery, and immunizes the 1900W-UNV-UC from series resistance effects within the alkaline battery. The battery doesn't experience the impulses, so the disruption to the cell chemistry is minimized, and battery life is optimized.

Inclusion of ultra-capacitor technology also lowers the chance of battery leakage caused by chemistry disturbances inside the batteries. All that said, **our recommendation has shifted back to Energizer Alkaline D batteries, given recent issues we have experienced with Duracell alkaline AA and D battery leakage. It has become literally epidemic level.**

By the way, while we have replaced the original ultra-capacitor based Model 1900G with the Model 1900G2 (Energizer Ultimate Lithium based), we have never observed any leakage or problem performance from the alkaline D batteries (even Duracells) used in that product! What absolute testimony to the value of how ultra-capacitors can help with powering vintage clocks!