# White Paper: The NEW Model 1900L2 No. 6 Battery

## A breakthrough new era in No. 6 Replacements

Ken Reindel, 6/9/23

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.

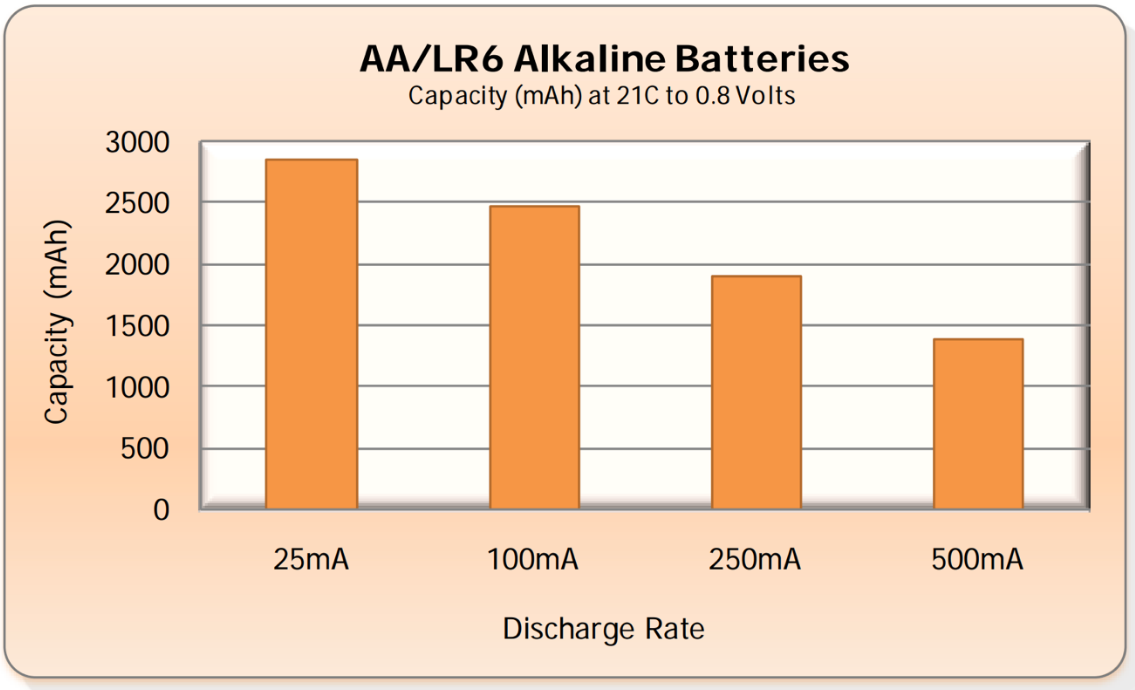
**Powering ATO Clocks with Alkaline Cells.** With ATO's, much depends on the specific clock style. In general, when powering ATO clocks (such as Bulles, ATO, electronic balance wheel clocks, etc.), shelf life and battery voltage sag compete with each other to determine battery life. This is because the 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 probably 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 cannot be neglected!

**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" upset the cell chemistry in measurable ways which dramatically reduce cell life.**

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




(fig. 13) AA/LR6 alkaline battery capacity to 0.8 volts

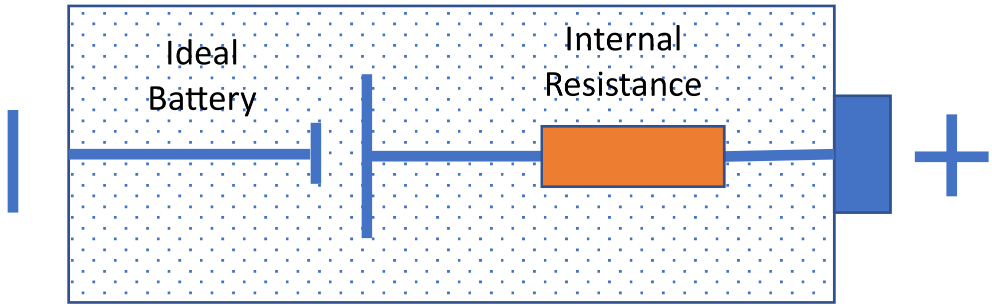
https://data.energizer.com/pdfs/alkaline_appman.pdf

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.

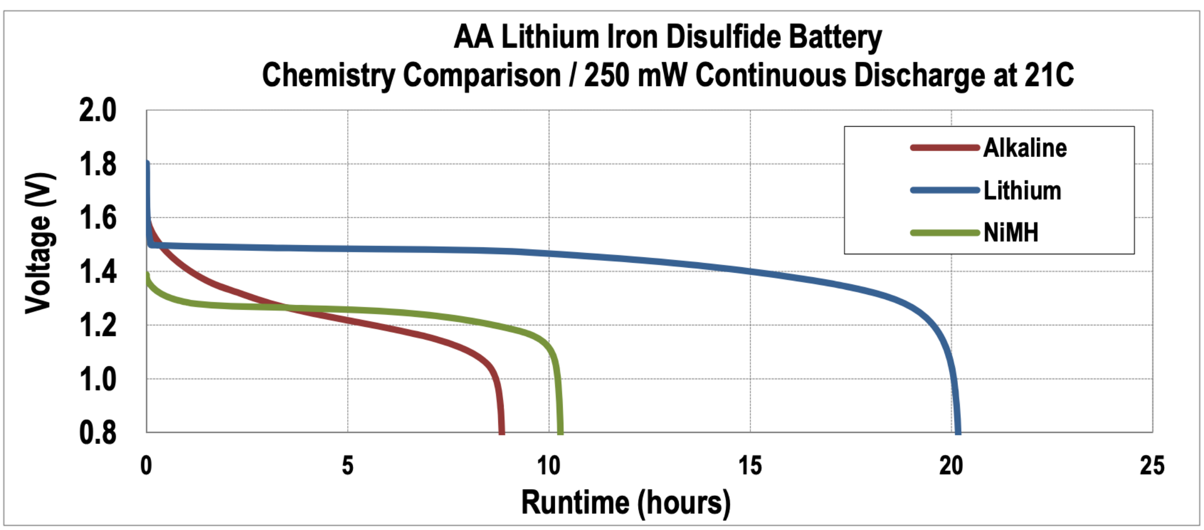
At this point, 1/3rd or so into the service life of fresh batteries, you'll likely remove them from the clock and throw them away, thinking they are dead! Yet most of the cell life remains, if we can find a way to extract it from the battery.

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, and has performed much better and more reliably 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. This helps somewhat, but the effects are still felt when powering impulse-wound clocks, which are the most difficult of all to wind. Cutting the battery life nearly in half (due to alkaline chemistry's sensitivity to impulsing) works against our effort of having two cells in parallel in each No. 6 unit and the clock soon experiences trouble winding even with the Model 1900L configuration.

Until now, there was no way to completely work around the vulnerabilities of the alkaline cell. 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.




(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! Again, in the world of readily-available replaceable cells, this is absolutely unprecedented.

For these reasons, the new Model 1900L2 is supplied with (2) Energizer Ultimate Lithium cells in parallel with appropriate series protection, with space to increase this to 4 cells if the user desires. Two Model 1900L2 units in series can power ANY self-winding clock, from the simple ATO to the very difficult impulse-wound units. The voltage curve is virtually flat, and doesn't drop below 1.3V (where alkalines spend the majority of their life) until the battery is near end of life.

The following table compares No. 6 battery solutions with theoretical vs. actual lifetime powering a typical restored rotary or Style F clock, and clearly shows the advantage of the new Model 1900L2 (with all 4 holders per unit utilized) using this exciting new AA Energizer Ultimate Lithium technology. It also compares our new Model 1900G2 (utilizing Energizer Ultimate Lithium technology) to the original Model 1900G.

Battery Performance with Style A, B, C, and F movements

| Product | Theoretical Run Time based on A-Hr Capacity Model | Theoretical Run Time Based on 500mA Model | Actual Measured Lifetime (typical) |
|---|---|---|---|
| (2) Model 1900L | 5 years | 2.3 years | 2.3 years |
| Model 1900G | 2.85 years | 1.42 years | 1.4 years |
| (2) Model 1900L2 in series | 2.3 years | 2.3 years | Predicting 2.3 years |
| Model 1900G2 (3V) | 1.3 years | 1.3 years | Predicting 1.3 years |

The above table (out of necessity) assumes 10% lifetime degradation lost per cell due to continuously increasing internal resistance for alkaline cells, which does not occur with the new Energizer Ultimate Lithium cells (1900L2) because of this new, breakthrough chemistry.

The following table summarizes performance when powering an impulse-wound clock winding once every 7 minutes. Here we see the dramatic effect of the new Energizer Ultimate Lithium technology.

| Product | Theoretical Run Time based on A-Hr Capacity Model | Theoretical Run Time Based on 500mA Model | Actual Measured Lifetime (typical) |
|---|---|---|---|
| (2) Model 1900L | N/A | 6-9 months | 6-9 months |
| Model 1900G | 5.4 years | 3 years | 3 years |
| (2) Model 1900L2 in series | 6 years | 6 years | Predicting 6 years |
| Model 1900G2 (3V) | 3.4 years | 3.4 years | 3.4 years |

Impulse-wound clocks are tremendously demanding of the voltage applied to them. Experience has shown that as long as 2.6V or greater (1.3V per No. 6 unit) is applied, they usually wind fairly reliably. Unfortunately, this is not the strength of alkaline batteries, which deliver this voltage only when fresh. Including internal cell resistance losses, we are left with an unreliable power source for impulse-wound clocks if we use a pair of Model 1900L. Up to now, this is why we have been very meticulous about steering customers to the Model 1900G for powering impulse-wound clocks. Indeed, the Model 1900G performs with at least 4x improvement in lifetime!

Some folks astutely ask, "Can we use three Model 1900L in series to power an impulse-wound clock? This would overcome the poor battery effects." The problem with this approach is that it also applies a higher voltage to the clock's winding electromechanics than it was designed to tolerate for the majority of the run time. While it would wind better, it will also accelerate wear and damage to the clock movement. Secondarily, many clocks do not have space for the additional cell.

**German Die Cast and Miniature Desktop SWCC.** Although these models are quite rare, SWCC did produce clocks powered by high-speed miniature DC motors. They used these motors to provide the whisper-quiet winding 37-SS Broadcast Studio clock as well as multiple quiet, jeweled lever escapement desktop models such as the Ogden. The motors used in these special clocks require very demanding startup current, on the order of 2-3 amps, and run at perhaps 1 amp or so for a few brief seconds, once per hour. These can cause disastrous problems for alkaline batteries. The new Model 1900L2, powered by the new Energizer Ultimate Lithium, will power these with ease. Expected battery life will hover in the 2.5 years range.

**Cost.** Of course, as with all of our battery products, the new 1900L2 and 1900G2 are renewable. This means at some point when the batteries are exhausted you will be able to change them out for new internal cells. Energizer Ultimate Lithium cells are more expensive than alkaline batteries. While there is more cost associated with replacing them, this cost will hopefully be offset by improved performance, absence of a tendency to leak (saving the cost and inconvenience of replacing the entire No. 6 unit), as well as longer run time requiring fewer replacements.

There are lower cost off-brand "versions" of this new Lithium Iron Disulphide available. We have not evaluated them fully, so we are NOT recommending them as a first choice. But they may be worth considering if cost becomes a concerning factor. Consider this link if interested, but use at your own discretion/risk in realization that reviews are mixed:

https://www.amazon.com/RUIHU-AA-Batteries-Flashlight-Non-Rechargeable/dp/B09XBH2T9V/ref=sr_1_10?crid=2BYCPEUR8WG0N

**Conclusion.** With a flat voltage profile, extremely low internal resistance, literally leak-proof assurance, and of course a shelf life of 20+ years, the predicted long run time of the 1900L2 or 1900G2 powering impulse-wound clocks can be realized. Results will be published once actual data has been measured, but there is no doubt we will be impressed. Your clock will require lubrication and other maintenance *long* before the batteries need to be serviced.

Please do not ignore the potential leakage issues of alkaline cells. It seems that over time, this issue is getting worse. We've witnessed leakage where the batteries were still functional, practically new. This leakage permanently damages the battery holders. Over time, we are phasing alkaline batteries out of ALL our offerings and replacing them all with units based on the Energizer Ultimate Lithium cells. Based on this study, the benefits are crystal clear.