THOMAS EDISON HAD IT RIGHT WHEN HE SAID THAT HIS NICKEL-IRON BATTERIES WOULD LAST 100 YEARS.

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ABSTRACT

This paper is going to report on the testing and results of following Thomas Edison's Nickel-Iron battery manuals that were published in 1916, 1924 and 1930. We will show how we followed his original instructions and were able to take Nickel-Iron cells that were manufactured between 1924 and 1931 (yes 80 – 87 year old cells) and return them to useful and reliable battery strings. We will show the as found and initial load test results, the results of various different steps and procedures used, and the final load test results. What is very interesting is that some of these cells actually had leaks from the bottom and had been empty for unknown years. Also interesting is that these Nickel-Iron cells do not suffer in any way if they are discharged into reversal or are left fully discharged for years. In fact, the Edison manual suggests discharging the cells to zero volts if they are to be stored extensively. Our only finding that went contrary to the Edison manual is that they caution to never let the cells set empty. Many of the cells we received were in fact empty or very nearly so but still recovered into useful cells.

INTRODUCTION

To say that Battery Research and Testing's experience with Nickel-Iron batteries was minimal would be overly generous. In fact, I had never even heard of that design, so a more appropriate term would be that we knew nothing about them when we first gained possession of a number of these cells.

One of our associates, Jim Miner, had noticed a listing on Craigslist for antique batteries and, when he showed me the wording, it piqued my curiosity. If it had not been for his curiosity, I never would have enjoyed this experience. As I mentioned above, I knew absolutely nothing about the technology. So it turned out that this was one of those things that drops into your lap out of nowhere. The remote hunting lodge in the Adirondack Wilderness Park that these cells came from had been using them for approximately the past 50 years for lighting of the lodge. The lighting system was made up of a 32 volt Delco Light Plant and parallel strings of these cells. The lodge had, through the years, upgraded to a central piped propane light system, and then to a new higher efficiency and quieter generator and a new battery system, but wanted to still keep the old Delco Light Generator. So they had this collection of old Nickel-Iron cells of two different amp hour cells in three different models that they wanted to get rid of, but did not want them to be trashed or disposed of improperly. In fact, their ad on Craigslist was very specific that they would not give these to someone that was going to just scrap them; they wanted them to go to someone who would use them in some sort of an antique type application. Their being environmentally conscious was a lucky break for us; otherwise, we never would have learned about the long life potential of Nickel-Iron cells. As you will see in the photograph in Figure 1, they were in less than pristine shape when we first arrived to pick them up.

To get to the lodge after you leave the paved, one lane road, you cross over a single lane, hand riveted bridge that crosses a beautiful trout stream. From there, you are on a very narrow dirt road. Not bad for a dirt road, you think, but then you reach the gate that allows you access to the path that takes you to the hunting lodge. My description of a path is two muddy ruts that wind around trees and large boulders, over smaller rocks and tree roots, and through some beautiful forest. I imagine if I had been in a small jeep, it might have been a smoother ride, but since I was in a crew cab dually four wheel drive, I felt every single bump and slide. Also, because of the extra width of the dually, it was, in some places, a close call between trees or obstacles. However, I made it into the lodge just as it was getting dark enough that, if it had been much longer, I would have had to turn on the headlights, which would have been an interesting drive.

I spent the night at the lodge with my hosts and, first thing the next morning, we loaded the cells into the dually, and I proceeded back out of the wilderness and back to the shop. The truck actually rode quite a bit better with the weight in it. I should mention that it was lucky for me that my hosts had used a tractor and a wagon to bring the cells to the top of a ridge where they kept a barn that housed the tractor and wagon. When I was there, the ground was wet and slick and there was no way that I could have taken the dually down to the building where the cells had been located and then made it back up that slope. Four wheel drive is nice, but I would have needed a bulldozer to make it back up. Going down would have been easy, as gravity does great things.

Figure 1. Cells as received in less than pristine shape in the Adirondack Wilderness Park.

These cells through their lives had sat in a small, uninsulated wooden building since their installation as used cells back in the early 1950's. They had experienced all sorts of discharges and recharges and often sat for months in various states of charge or discharge, sitting through the winter months where temperatures stay below freezing for weeks at a time. To say this is a hardy cell design is a massive understatement. As we later learned from different Edison brochures we found, before Edison brought these to market, the cells went through many different repeated tests. In one test, the cells were mounted on a cart securely, and then the cart was rammed into a brick wall at 15 MPH. The cells had to survive and function after 1,000 such impacts. Another test he created to prove the ability of the cell design to withstand shocks had a motor drive pendulum that raised a cell ½" and dropped it onto the solid wood stand repeatedly until 1,776,000 such drops had been achieved, then the cell was load tested again and it passed (2).

INITIAL ARRIVAL AND INSPECTION

Upon unloading and initial inspection at our facility, we discovered there were three different models. The A4H, which is a 150 AH model, and the A8, and A8H models, which are both 300 AH. Thomas Edison rated his cells at the five hour rate to 1.2 VPC. Constant current charging was the recommended technology back then, with an end voltage between 1.8 and 1.9 VPC. Just to clarify the model numbers, the H at the end of a model means that it has a taller head space so that it can hold more electrolyte; otherwise, the plates/cells are identical, and the capacity is the same. Since the same AH cells were used in so many different types of applications and usages (2), the extra electrolyte reservoir with the H design allowed for less frequent watering of the cells.

During our initial receipt inspection we discovered cell voltages that ranged from 0.06 volts to 1.38 volts, which is quite a spread. Of course, many cells had been off charge for years, some were empty, some were all over the place with electrolyte heights, and some had been taken off the generator just days before I arrived to pick them up and had not self discharged very much. In hindsight, we might have achieved better initial results if we had used some sort of open circuit voltage matching that might have reflected a grouping of cells that had about the same amount of charge, but who really knows.

We searched the Internet to find how to interpret the serial numbers stamped into the cover on each cell, but were having no luck, even though we contacted the Thomas Edison museum in NJ. Luckily, I reached out to Ole Vigerstol of Saft, and he was able to get help from their Railroad Group. They provided me with a copy of the serial number codes for the Thomas Edison cells. All of the cells in our possession that we have played with so far were built between 1924 and 1931. The Edison date codes give a serial number for the cell and a code for the year. They did not have a breakout for the month.

We selected different cells of each size, with no specific reason except that we wanted a wide range of voltages in each bank. After having the cells on a float voltage of 1.55 VPC for a week, we then proceeded to play with them. One interesting point noticed was that, with a number of the cells, when we infrared scanned them, there were hot spots in some of them, with no rhyme or reason. We attribute those to the sediment being moved around and creating mini-shorts inside the cell or cells. The photograph in Figure 2 shows the initial general condition of some of the cells.

Figure 2. Initial general condition of some of the cells.

The photograph in Figure 3 shows the carbonate buildup in one vent tube. Whenever we found a vent like this, we just broke it out. Parts of it dropped back into the cell, but this was not a concern, as we basically had little idea of what we were doing. This was a lot of trial and error, and a lot of fun.

What must be remembered is that, throughout this project, we were basically flying blind. We had no idea of what we could or could not do with these cells, nor did we understand how bulletproof they could be or how physically demanding some of the qualification tests that Edison required were before he brought the cells to market.

One of the first things that we learned was that we could not use a lead acid mindset on these Nickel Iron cells. Vented lead acid cells would not have taken kindly to sitting in a discharged state at less than half of a volt at below freezing temperatures for weeks at a time, nor would they have probably stood up well to being repeatedly run into reversal, and then recovered into usable cells.

This was not an exercise to prove anything, but was an attempt to learn if these cells could indeed function in some sort of application at their advanced years. That they indeed can still be utilized at 80+ years of age is a testament to both their design and to the manufacturing process that built them.

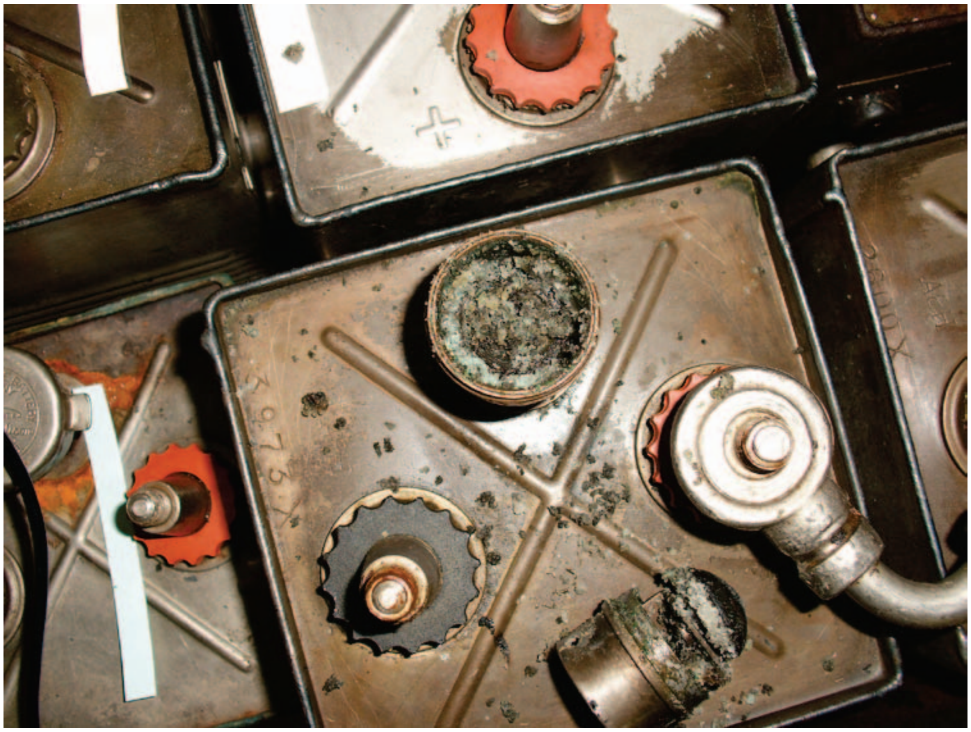


Figure 3. The carbonate build up in one vent tube

INITIAL LOAD TESTS

With each of the load tests we ran in the as-received condition, we encountered very early failure. With these tests, we tried to run the test at the full, published, five hour rate for the particular battery model. With many of the tests, the voltage collapsed within a few minutes of the start of the test. Even when we tried to randomly reduce the discharge rate, the end result was the same, but at a reduced rate of decline. They all failed quite miserably but they did not drop off instantaneously.

LOAD TESTS FOLLOWING ELECTROLYTE REPLACEMENT

Following the instructions in the Thomas Edison brochure (1), we obtained new electrolyte and replaced the electrolyte in a number of cells. We did not do this for all cells, as we have a long term plan and are waiting to replace the electrolyte in some of the other cells for that future project.

The Edison manual instructs that you first discharge each cell to zero volts, then pour out about half the electrolyte, shake the cell vigorously, then pour out the rest, pour in the new electrolyte, and place on charge. It cautions to not use water to rinse the cell. However, with some of the cells, we somehow missed (ignored) that caution and did rinse them with water. We can only assume that the statement to not use water to rinse the cell is because they did not want to have any excess of water inside the cell when the new electrolyte is added. Of course, there might very well be some other reason for their statements.

The statement to shake the cell vigorously did concern us, as it would seem, when we were doing the shaking, that some of the sediment would create shorts or get lodged in some of the spires, but it sure appears to have been the right thing to do. The old electrolyte that came out of the cells was black, but, of course, it should be, because we were able to get most or much of the sediment out of the bottom of the cells. In discussions with Jim McDowall of Saft, he thought that it would be better to carefully pour the electrolyte out and not attempt to remove the sediment, but we elected to follow Edison's instructions, and shook the heck out of them. I also should point out that we referenced the Saft Ni-Cad installation and operation manuals (3) quite frequently for guidance in our experiments.

With nothing more than following the Edison manual for the electrolyte replacement procedure, the follow-up load tests brought very improved results. What is important to understand is that we continued to test at the full published rate, which has a marked effect on the performance of the cells. As can be seen from Figure 4, with cell number 364X, there was an improvement in capacity due just to the replacement of the electrolyte and the accompanying discharges, but the real gain was not until later, when we used the IEEE 1106 (4) as a guide for de-rating of the discharge rate. Following the discharge test on September 16, 2010, we replaced the electrolyte and again retested with quite poor results. It was not until we had cycled the cell a number of times, with some down to almost zero volts, and recharged at 1.80 volts did we start to see improvements. It must be understood that we were still in the "playing" mode and just trying to learn as much as possible about these cells as compared to Thomas Edison's bold statements about a 100 year life battery. It was not until further along that we decided to try and test these to some sort of an IEEE Standard or Recommended Practice. The A8H model cell is rated at 60 amps for five hours to 1.2 volts.

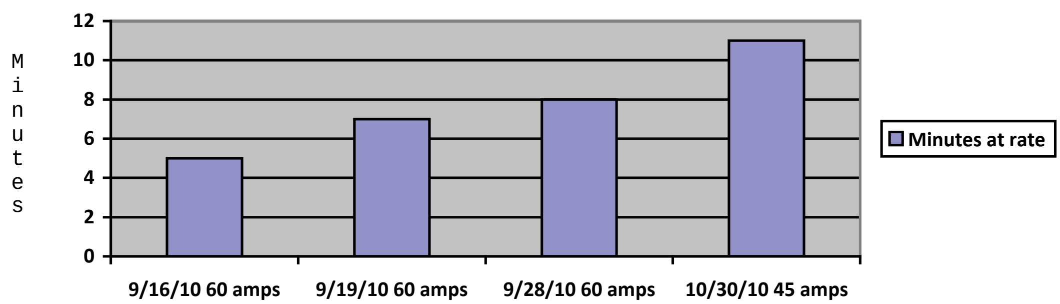


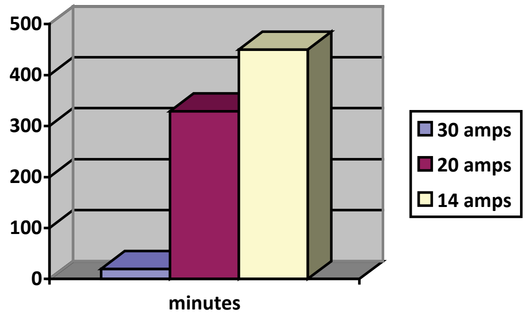
Figure 4. Cell number 364X capacity tests.
First column: 9/16/10, load 60 amps. Second column: 9/19/10, load 60 amps.
Third column: 9/28/10, load 60 amps. Fourth column: 10/30/10, load reduced to 45 amps.

LOAD TESTS FOLLOWING THE GUIDANCE OF THE IEEE 1106 RECOMMENDED PRACTICE

Now that we knew there was still some life left in these old cells, we decided to run some load tests that would more approximate their usage if there was some sort of an age related de-rating factor applied. The closest document that we felt would apply is the IEEE 1106 (4) for Nickel-Cadmium cells. Since they both use Nickel and Potassium Hydroxide, we felt this was the best source of information.

Following the IEEE 1106 guidance, we de-rated the cells by 1% per year for aging. For example, cell 364X, rated for 60 amps per hour for five hours and built in 1924 (now 86 years old), would have a de-rating factor of 86%, which would mean the cell should be load tested at 8.4 amps. We did not go to quite that extreme, but we did try various reduced rates of 30 amps, then 20 amps, and finally 14 amps. As can be seen in Figure 5, the 30 amp rate was still too much for the cell, but the 20 amp rate produced 329 minutes, and the 14 amp rate produced 450 minutes. Remember, this is an 86 year old cell. Also, please understand that these are not capacity test results as per any standard of any kind. They are just a way of proving that these Nickel-Iron cells have a useful life that is beyond any other technology used for any normal type stationary application that we are aware of. It would make sense that Nickel Cadmium cells would do the same.

Figure 6 is a set of 12 cells that were put together with one 1924 cell, three 1925 cells, four 1927 cells, three 1928 cells, and one 1930 cell. While it would have been nice to have had enough cells from the same year to make up a battery, we did the best we could with what we had.



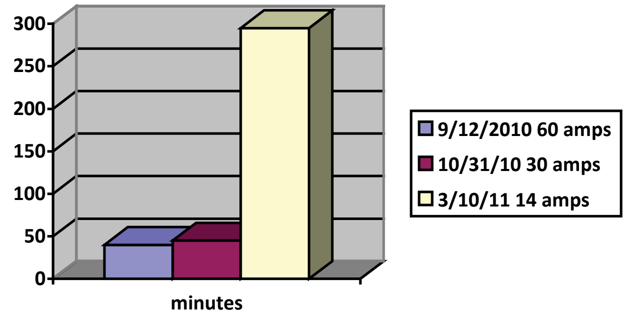


Figure 5. Testing of Cell 364X.

Figure 6. Results of testing 12 cells.

SUMMATION/CONCLUSION

This project has been quite an education for us, considering that, over the 34+ years that I have been in the industry and the 29+ years of Battery Research and Testing's existence, we have primarily worked on servicing lead acid batteries, with some work on Nickel-Cadmium strings, but never a Nickel-Iron design.

As we all understand, quality, vented lead acid stationary batteries typically have a useful life of between 15 and 20+ years, with some special batteries, such as the round cell and the extinct Exide Manchex models, having useful lives of 40+ years. So far, I personally have seen no other batteries like these Nickel-Iron that will still function in any way at 80+ years of age, nor that will take being left in a discharged state and spending weeks below freezing, or that can be discharged into reversal, and still be recovered back into a useful condition.

At the moment, the only manufacturers of Nickel-Iron batteries that we were able to locate are ChangHong Batteries out of China, and Kursk Accumulator from Russia. ChangHong was quite easy to communicate with, and they have models that are designed for what we would call a typical float type service, with a charger providing the normal loads and the battery as reserve, as well as ones that are designed for off grid applications, such as solar or wind only charging. We also utilized their Operation and Maintenance Manual (5) for guidance with these cells. Kursk Accumulator did not respond to any of our communications but, from their literature, we understood that their design was for traction applications, not float service. It appears that Nickel-Iron batteries, depending upon their design and construction, can be used for a wide a variety of services, just as lead acid can be. By this, I mean cycle service, motive power, typical full float stationary applications, and stationary applications with intermittent charging. The only real difference between the two types is that the Nickel-Iron batteries appear to have a substantially longer usable life. If the current manufacturing/production of Nickel-Iron cells actually follows the general formulas of Thomas Edison, then the only differences that would appear obvious between his cells and the current productions is that the current jars (as far as we know) are all plastics. I guess only time will tell if the current plastics will hold up without degradation or breakdown as well as the metal jars of Edison's time.

I would suggest that, since the similarities far outweigh any dissimilarities between Nickel-Cadmium and Nickel-Iron cells, that Nickel-Iron be included in the IEEE 1106 and the IEEE 1115 documents. This has been proposed to the IEEE BWG and it is under discussion.

Hopefully, those who control Battery Research and Testing Inc. in the future will continue to keep these strings as on-going test beds for data gathering, as this is a very interesting technology. For applications that require a very long life, this technology definitely has proven that it can do that. It surely would be interesting to see if these can still be functional when they actually reach 100 years of age.

I would like to extend a special thanks to Ole Vigerstol and Jim McDowall from Saft for their assistance and comments, as well as to Sam Zhow from Sichuan Changhong Battery Company for his answering my repeated questions. In addition, I want to extend a very special thank you to Weston Mitchell of the Fayetteville Hunting Club for providing us the opportunity to work with a piece of history. If it had not been for his environmental consciousness, we would not have our eyes opened to this very durable battery technology that was all but forgotten here in the US. And last but not least, I want to thank Bob Howland of Battery Research and Testing for providing the technicians to perform testing on these cells when I was not available to do so.

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