Nickel-Iron

This all but forgotten technology has a very important place to occupy with users that desire very long life and the ability to suffer abuse in their battery systems

Peter J. DeMar
Battery Research and Testing, Inc.
Oswego, NY, USA
pjd@batteryresearch.com

Abstract—**This paper is going to look at real life aged 80+ year old Nickel-Iron cells that are still functional and will explain the simple recovery techniques that were documented in an original Edison Alkaline Storage Battery brochure from the 1920's. Some of the cells had been charged intermittently, many had sat off charge for many years, and some had sat off charge and all but empty, but all made very substantial recoveries, and when subjected to discharge testing that followed the guidelines of the IEEE 1115 they all were able to pass load tests at their applicable rate.**

I. INTRODUCTION

The aim of this paper is to introduce this very old battery technology, which is over 100 years old, to those that have no idea that such a battery exists, or ever did exist. The majority of us are most familiar with various forms of lead acid, or nickel-cadmium as they were and still are the batteries of choice for most stationary applications, with Lithium Ion (in various forms) and other technologies gaining acceptance in many stationary applications.

The cells that are reported on in this paper are real life aged cells with an average age of 85 years, and the conditions that they were operated in and stored in were less than ideal. They spent the last approximately 60 years in a wooden shed, at a hunting lodge in the Adirondack Mountains, with temperatures from below -18C to above 32C. They were charged intermittently and often sat in a partial or full discharged state for weeks or months or years, at a time. Their function was to provide lighting to the lodge.

Waldemar Jungner of Sweden created the first Nickel-Iron battery in the late 1890's and has multiple patents on the design. However he found that by substituting Cadmium instead of Iron that he could improve the performance and efficiency of the cells, and he abandoned the development of the Nickel-Iron cell in favor of Nickel-Cadmium. There are two patents for the Ni-Fe technology and one for the Ni-Cd technology in his name from 1899.

Thomas Edison believed that Ni-Fe could displace lead acid as the battery of choice and in 1901 obtained both a US and a European patent for his version of the technology. Edison performed some very extensive testing on his cell designs to verify their hardiness for usage in RR applications, or electric automobiles (which he thought would replace internal combustion engines), or material handling (tuggers and such). Two of my favorite tests that he created to demonstrate the durability of his Ni-Fe batteries are as follows.

He mounted a battery system on a cart and then the cart was rammed into a brick wall at 15 MPH and the battery had to survive 1,000 such shocks, which it did. My favorite test though was where he hooked a cell to a motor driven pendulum and the device raised the cell ½" and dropped the cell onto a wooden platform. The cell survived 1, 776,000 such drops and then following that it passed a load test. (1)

The Thomas Edison battery factory in West Orange New Jersey USA produced cells from 1903 to 1972 when it was sold to the Exide Battery Company (name at that time), which continued production until 1975 when the factory was closed. Presently there are two companies that are still manufacturing Ni-Fe cells and they are Kursk Accumulator in Russia, and ChangHong Battery in China.

It is our belief that this very old technology still has a place in the current market, where the user has a need for a very long life battery that can stand frequent cycling and abusive conditions. In America these are being offered for usage in the off grid market due to their long life and ability to withstand the daily repeated cycling, and setting in a partial state of discharge for extended periods.

II. THE BOAST

It has been stated that Thomas Edison boasted of a 100 year battery with his Nickel-Iron design, but I have not been able to successfully locate those exact words. Now that sounds like a pretty bold marketing statement, sort of like the original marketing words "Maintenance Free" when referring to VRLA cells. However our experience in testing these old Nickel Iron cells convinced us that it may not have been just boldness or marketing on his part.

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III. The opportunity to prove or disprove

With our gaining access to a substantial number of Thomas Edison Alkaline cells in two different amp hour sizes (150 and 300AH) at the five hour rate, we had an opportunity to find out if there was any validity in a 100 year life statement.

Our first task was to locate documentation on these cells, and we turned to the Internet to locate manuals, documents, specifications, etc (1,2). While locating different manuals was easy enough, we could not determine the serial number code that was stamped into the top of each cell, so we did not know the age of any of the cells. Luckily we finally reached out to Ole Vigerstol of Saft who contacted their Railroad Group people, who then provided us with the original Edison Date codes. And yes we did have cells that were all built between 1924 and 1931.

We also utilized installation and maintenance manuals from both Saft (3) and ChangHong (5) as guides or comparison purposes, to see if there were any major differences in their instructions from the Edison manuals. While there were some differences none of the differences were of any great concern.

When we received the cells they were in various conditions of charge, or fill, or just plain cleanliness. It must be understood the majority of these cells had been setting off charge in various states for many years.

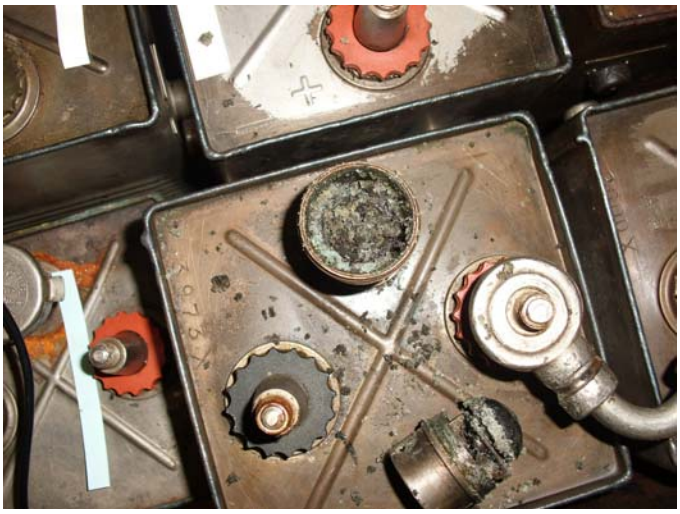
Picture 1. This shows the general condition of some of the cells as we received them.

The following shows the three size cells that we received. These originally were coated with a rubber like paint compound which was named Esbalite which is described in the Edison manuals as a special insulating paint. This coating covered the sides and the bottom, but none was on the top of any cell. However during the cleaning process of the cells, the coating which came off and we have not yet determined what we will use as a coating, so for our experiments we used wood spacers to maintain separation between the cells.

As can be seen in the following picture of the three different cell sizes the two on the left are the A4H and the A8H, and the one on the right is an A8 cell.

Picture 2. The three cell sizes.

The following picture shows the carbonate build up that we found in some of the cells, which of course has a severe impact on the cells performance.



Picture 3. Carbonate build up we found in some cells.

IV. Recovery procedures

We randomly took cells of the same AH rating and made up different battery strings, and in some cases we took single cells and with each we boost charged and then float charged at the voltages that were stated in a 1916 Thomas Edison manual and then followed up with load testing at the full published five hour rate. All of the cells or battery strings failed miserably.

Our as found individual cell voltages ranged from 0.06 of a volt to 1.36 volts. We attributed this wide of a voltage spread to the fact that some cells had been on charge just prior to our receiving them and some had been off charge for months or years. Some were filled with electrolyte and some were empty or nearly so.

The following is from one string of A8 cells and is an example of the age of the cells, and the as found open circuit voltages. As can be seen in this battery the age of the cells range from 1926 to 1930 with a voltage spread from 0.005 to 1.356. It is easy to see which cells have been setting around the longest and which ones were recently on charge.

Serial Number	year built	as found voltage 8/4/10
3404X	1930	1.344
1587X	1930	1.341
4101P	1926	0.105
1089R	1927	0.005
499W	1929	1.353
1595X	1930	1.356
565T	1928	0.856
2164R	1927	0.720
2050R	1927	1.279
1610X	1930	1.250
2080R	1927	0.051
7330P	1926	0.044

While experimenting with these cells we realized that even though the voltage would rapidly drop off in a matter of minutes when we tried to run a load test at the full published rate of the particular cell or battery, that if we lowered the discharge rate, the battery would hold voltage for a substantially longer amount of time, even though the best string would only support a 10 amp load for 22 minutes to an end voltage of 12.0 volts.

Throughout our testing we followed the instructions in the Edison manuals, and following those instructions we decided to replace the electrolyte. We obtained new electrolyte from Saft as they are a major supplier of Nickel-Cadmium batteries and the Potassium Hydroxide that they use is the same as what is utilized in the Nickel-Iron batteries. Both Saft and ChangHong also provide instructions that explain that when the capacity drops off and boost charging does not return desirable results, that the electrolyte needs to be replaced.

A discrepancy that we discovered between the three manufacturers (Edison, Saft, and ChangHong) is that during the electrolyte replacement procedures, Edison states to pour out about half of the old electrolyte then to shake the cell vigorously and then to pour out the remaining electrolyte, but to not rinse with any water, and then to fill with new electrolyte. Changhong says to pour out the old electrolyte and to shake it, and if the electrolyte is dirty in color to rinse it with distilled water two or three times, and then to fill with new electrolyte. Saft says to carefully pour out the old electrolyte and then to fill with new. This was the only real difference that we found between the three manufacturers. Of course Saft manufactures Nickel-Cadmium cells, ChangHong manufacturers both Nickel-Cadmium and Nickel-Iron, and of course the Edison cells are all Nickel-Iron. The common denominators are the Nickel and the Potassium Hydroxide electrolyte. We decided to follow Edison's procedure since the cells were Edison cells.

After the electrolyte replacement we placed the cells back on float and then boost charged at 1.65 VPC followed by a return to float at 1.49 volts per cell and then further load tests. The following shows the same cells as the previous chart, but with the respective float voltages following 100 hours of boost charging, and then being on float charge for about six weeks.

Serial Number	float voltage 9/26/10
3404X	1.473
1587X	1.477
4101P	1.482
1089R	1.469
499W	1.477
1595X	1.471
565T	1.467
2164R	1.463
2050R	1.470
1610X	1.469
2080R	1.470
7330P	1.443

V. PUBLISHED RATINGS

There were three different model cells that we had received and played with. There were models A4H, A8, and A8H cells. The H in any model just means that the cell is the same AH rating but it has more electrolyte reservoir and is approximately 7.6 Centimeters taller than the cells that do not have the H in their model number. The H designated cells were to be used in applications where there longer time periods between maintenance intervals.

With the three battery strings that we are reporting on here, we utilized the five hour rating from the Edison manual, and we used the end voltage of 1.0 VPC, also from the Edison manual.

The published rate for the A4H cells is 30 amps for five hours to an end voltage of 1.0 volt.

The published rate for the A8 and A8H cells is 60 amps for five hours to 1.0 volt.

VI. WHAT WERE WE TRYING TO UNDERSTAND

We are trying to learn if the Edison Alkaline cells that we had would indeed function at their advanced ages. But there is no existing standard to follow as a guide, so we decided to utilize the IEEE 1106 (4) since it is for Nickel-Cadmium cells and the only primary difference between the two types is the Cadmium content in place of the Iron, otherwise they are Nickel and Potassium hydroxide.

With our main goal being to determine if these cells or batteries would work reliably at their extended ages, and not to prove a specific capacity we decided to utilize the 1% per year aging factor from annex E of the IEEE 1106 .

With cell ages ranging from 80 to 87 years of age and an average of 85 years we decided to be conservative and used an aging factor of 0.2 which would reflect a 1% per year de-rating factor for an 80 year old cell. With that decision made we made we settled on the following discharge rates. As you will notice we used the same five hour rate for the two different models, even though one was a 150 AH model and two were 300 AH models. We do not yet understand why the A4H cells performed so much better than the A8 and A8H cells. We are suspecting that it was due to the fact that the A4H string had many more discharge/recharge sequences than either of the other strings, but only time will tell if the A8 and A8H strings continue to improve over time and cycling.

A8 and A8H cells used a 15 amp rate to 1.0 VPC

A4H cells used a 15 amp rate to 1.0 VPC, where as if we used a 0.2 aging factor the rate would have been 6 amps.

We made up one twelve cell string from the A8 cells, another twelve cell string from the A8H cells and an 18 cell string from the A4H cells. Each was placed upon its own charger. We utilized a varying range of float voltages at different times as part of this experiment. Primarily we kept the voltage between 1.47 and 1.5 but did sometimes go up to 1.57 volts per cell and 1.65 up to 1.85 when we equalized or boost charged. These voltages came out of the Edison manual and the float voltage corresponds to that recommended by both ChangHong and by Saft.

The following charts show the load test results at various times over the past approximately twelve months on all three of the strings. All of the load tests were run at the five hour rates to 1.0 VPC. As can be seen, the load tests that were run before we replaced the electrolyte were somewhat dismal, however as you will see in the load tests that were run after the electrolyte had been replaced were substantially improved, and then by the last load tests which were all performed in July 2011there was further improvement.

VII. Test Results

As can be seen in the following charts, with each battery string there was some amount of run time under load but it was not until we replaced the electrolyte and then ran a number of discharge and recharge scenarios that the run time really returned. While we could not get any strings to recover to a level where they could support their full published rates, it was encouraging that they could support an age related reduced discharge rate for a full five hours.

In each chart the left hand column is the original as found run time, with boost and float charging but no electrolyte replacements. The middle column is after electrolyte replacement and boost charging and from float voltage. The green line is after some number of discharges and boost charges and also is from a float condition.

Chart 1 is comprised of A4H cells.

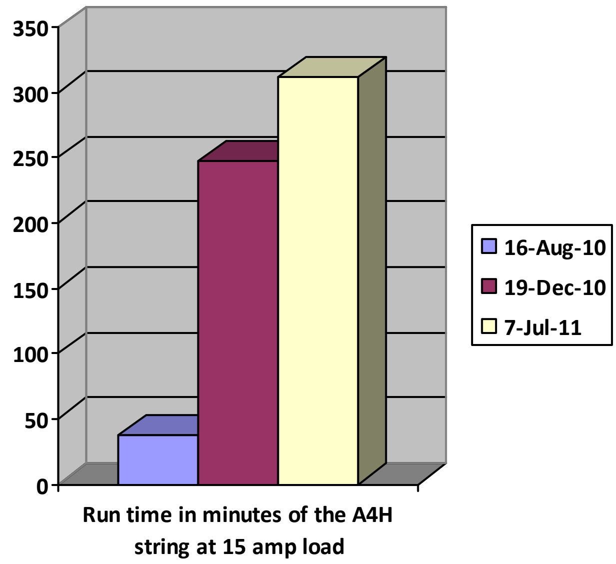


Chart 1. This chart shows the increase in run time with this battery with a 15 amp load.

Chart 2 is the string that is made up of A8 cells.

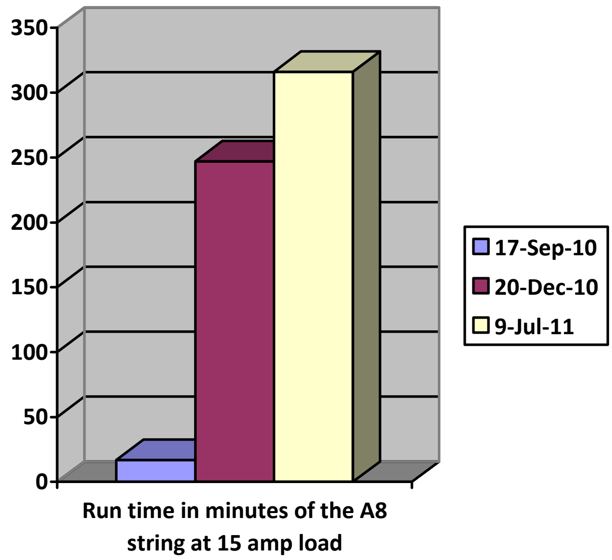


Chart 2. This chart shows the increase in run time with this battery with a 15 amp load.

Chart 3 is the string that is made up of the A8H cells.

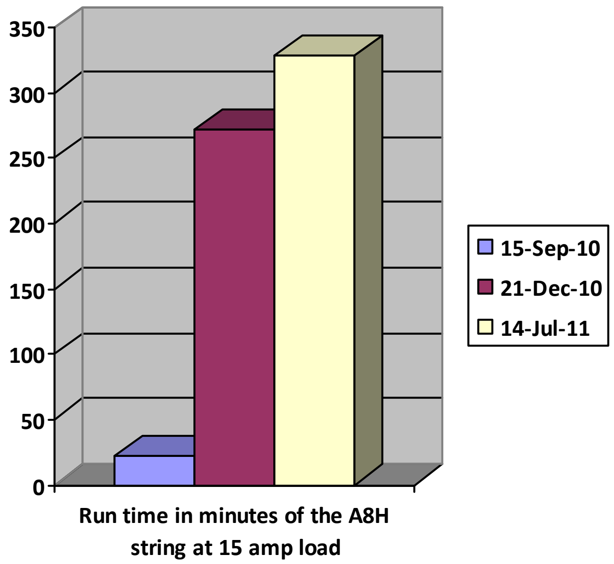


Chart 3. This chart shows the increase in run time with this battery with a 15 amp load.

VIII. Conclusion

This find of these old Thomas Edison Nickel-Iron cells has been quite an education for us at Battery Research and Testing, as our work for the past 29 years has been primarily with lead acid and some Nickel-Cadmium, but with nothing of the age of these cells. In fact the oldest lead acid cells that we have load tested and that were still functional were old Exide Manchex strings that were 42 years old, and it appears that the only existing lead acid cells that might be able to be functional at 40 years of age are the Bell developed round cells for Telecom applications.

What we have learned has opened up our minds to explore possibilities for this design long life design cell. It would sure seem that any site that has a requirement for a long life battery that will tolerate abusive conditions would consider the total life costs of these type cells and see which works out to be the most cost effective.

I have approached the IEEE Battery Working Group to have Nickel-Iron included in the IEEE 1106 and IEEE 1115 documents during the recent re-affirmation process, but it was decided to not include Nickel-Iron in those documents at this time. It would seem that since the IEEE 450 and IEEE 485 documents cover all of the different Vented Lead Acid designs such as Lead Antimony, Lead Selenium, Plante, or Lead Calcium which all use sulfuric Acid, that the IEEE 1106 and IEEE 1115 which covers Nickel-Cadmium cells which also uses Potassium Hydroxide as the electrolyte could easily have been expanded to include the Nickel-Iron cells.

That these 80+ year old cells are still functional proves without any doubt that Nickel-Iron is a long lived design, now it will just take another 15 years to see if they will still be functioning at 100 years of age as Thomas Edison is supposed to have declared.

IX. Acknowledgements

I would like to extend a special thank you to Weston Mitchell of the Fayetteville Hunting Club for providing us a chance to learn about Nickel-Iron cells and these specific pieces of the Thomas Edison history. If it had not been for his environmental consciousness, we would not have our eyes opened to this very durable battery technology that is all but forgotten here in the US. Also thanks need to go to Bob Howland and Jim Miner of Battery Research for their assistance and technicians time to perform the various assembly of the strings and testing. And last but not least, 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 support.

X. References

1. General Information and Instructions for the Operation and Care of the Edison Alkaline Storage Battery. Edison Publication Bulletin 850X.
2. The Edison Alkaline Storage Battery. By the technical staff of the Edison Storage Battery Company. For the National Education Association Joint-Committee Series Monograph III. Document 804. Copyright 1916. From the University of Michigan Libraries. Digitized by Google.
3. Saft Installation and operating instructions for single cell Ni-Cd, models SCL, SCM, and SCH plastic case cells.
4. IEEE Std. 1106. IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Nickel-Cadmium Batteries for Stationary Applications.
5. ChangHong Battery Performance Data Manual. ChangHong Battery Operation and Maintenance Manual.