# Advanced Nickel Cadmium Batteries for Telecom Applications

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## ABSTRACT

With the widespread use of digital subscriber carrier systems in outdoor cabinets, most telecom operators have experienced a variety of problems with Valve Regulated Lead Acid (VRLA) batteries. Ranging from unexpected short battery life to unpredictable and catastrophic failures, these problems have, over the last few years, become the subject of ongoing discussions at industry meetings such as Intelec and other conferences. It has become obvious that the environment inside these cabinets, particularly the high temperatures and lack of adequate ventilation, often exceeds Bellcore's specifications for a normal battery environment and therefore exceeds the design criteria of most VRLA batteries.

On request from major operators, Bellcore has tested alternative energy storage systems to find a replacement for VRLA batteries in outdoor cabinets. An advanced nickel cadmium battery, the product of extensive research to optimize batteries for aviation and electric vehicle application, has received a positive recommendation from Bellcore for continued testing in outdoor cabinets. Furthermore, Bellcore has suggested that the operators begin field trials to validate the laboratory findings. Field tests are currently in progress, and they have confirmed this type of nickel cadmium battery may indeed solve of the many problems common with VRLA batteries.

This paper will briefly describe the technology behind the advanced nickel cadmium battery system; point out differences and improvements achieved compared with traditional nickel cadmium batteries; and elaborate on how the specific features of this newer technology can be applied to provide a more reliable and durable energy storage system for outdoor telecom cabinet plants. Finally, we will discuss the installation, operation, and maintenance of the advanced nickel cadmium battery.

## PROBLEM STATEMENT

As mentioned in the abstract, the extensive use of compact outdoor cabinets to house telephone equipment and battery back-up systems has made it common practice to install Valve Regulated Lead Acid (VRLA) batteries in an environment that is often too extreme for this product. This problem has been augmented by a lack of cooling and ventilation in the design of the cabinet. It can be argued that this results from battery manufacturers failing to inform the cabinet manufacturers of the battery's needs and limitations. Conversely, the accommodation provided for the battery by the cabinet manufacturers, in most cases, clearly did not meet the requirements for temperature control and ventilation as specified by Bellcore and the National Electrical Safety Code.

When VRLA batteries were first introduced to the telecom market they were advertised as sealed, maintenance free products with a 20-year life in float charging applications. This would appear to make these batteries ideal for compact, low maintenance, telecom installations. Experience later proved these statements to be both exaggerated and misunderstood. The VRLA batteries are not sealed, they need considerable ventilation to dilute the hydrogen they produce under the abnormal and extreme conditions that occasionally occur. Nor are VRLA batteries maintenance free; IEEE 1188 bears testimony to that. Finally, Dr. David Feder exposed the myth of 20-year batteries with his famous paper, "Performance Measurement and Reliability of VRLA Batteries", presented at Intelec95.

The result of the elevated expectations and the hostile environment in outdoor cabinets is now recorded history in the telecom industry: short life and unexpected, premature failures have been common complaints. Even catastrophic failures such as battery melt downs, thermal runaway, and battery explosions have occurred regularly, particularly in the warmer regions of the country. These failures have often caused extensive damage to telecom equipment from acid corrosion and excessive heat. There have been only a few reports of violent cabinet explosions from hydrogen accumulation, which is fortunate, as such incidents have the potential of causing serious personnel injuries and even death.

## THE SEARCH FOR SOLUTIONS

For the last few years, all major telecom operators have been searching for ways to eliminate their battery problems. Improvements have been made to the outdoor cabinets to provide better ventilation and cooling. Batteries have been installed in separate environmentally controlled cabinets. Electronic controls have been added to the battery circuits to avoid overcharge and thermal runaway.

The telecom community has also investigated alternative energy storage systems such as flywheels, super conductors, mini generators, and new battery systems. Some telecom companies are simply waiting for possible improvements to the VRLA batteries while others are considering flooded lead acid batteries or other existing battery systems. One of the existing battery systems that is being investigated is the advanced nickel cadmium battery which will be discussed in this paper.

## BELL COMPANIES INVESTIGATE NICD BATTERIES

During 1996, on request from a number of Bell Operating Companies (BOC), Bellcore tested several energy storage systems. By the end of the year, Bellcore reported on an advanced nickel cadmium (ANC) battery system that was already on the market and classified this battery as a candidate for high temperature applications and recommended the BOCs proceed with field tests.

The first test battery was installed in Orlando in June 1997, in parallel with two VRLA battery strings. This installation would examine the possibility of replacing a VRLA battery with an ANC battery without any modifications to the charging system or cabinet configuration. This trial installation has been followed by similar trial installations in other locations. To date, the test installations are running well; more details are provided below.

## DEVELOPMENT OF ANC BATTERIES

Due to proven durability under extreme operating conditions, nickel cadmium batteries received a major share of R&D funds in the 1970s and 1980s when the interest for electric vehicles gained momentum. New plate manufacturing technologies were developed to improve operating life and efficiency while implementing aggressive cost reduction measures.

One result of these investments is a highly automated production facility in France fully dedicated to the production of electric vehicle batteries. Another result is several new ranges of ANC batteries for more traditional applications such as rail transit cars, jet aircraft, engine starting, UPS systems, and other stand-by applications. The battery tested by Bellcore came from a range designed for UPS applications.

## GENERAL NICKEL CADMIUM BATTERY PROPERTIES

Nickel cadmium batteries are known for being durable and reliable even under severe operating conditions. Their main properties can be listed as follows:

- Long operating life, even at high temperatures
- Reliable and predictable performance
- Resistant to abuse, electrical and mechanical
- Superior performance at low temperatures
- Indefinite shelf life
- Low maintenance costs

Considering all these valuable features for telecom applications, why were nickel cadmium batteries not considered earlier for telecom applications? There are several reasons:

- Lead acid has a long tradition in the telecom industry
- The purchase price is higher for nickel cadmium batteries than for lead acid batteries
- The minimum and maximum voltage limits specified for telecom equipment made it difficult to obtain full capacity from a traditional nickel cadmium battery
- Generally, previous flooded nickel cadmium battery designs needed more space than VRLA batteries

However, nickel cadmium batteries are occasionally used in telecom applications. Several SLC-40 systems operate today with nickel cadmium batteries. Many of these have been in operation for over 15 years without a change of batteries.

## ANC BATTERY PROPERTIES

In addition to the traditional nickel cadmium battery properties, new and improved properties can now be added to the list:

- Improved constant voltage charge acceptance (Fig 1)
- Higher discharge voltage
- Compact design
- Excellent cycle life
- Much less maintenance

Armed with these new and improved properties, the ANC battery has become much more attractive as an alternative battery for telecom applications.

ANC batteries can be charged close to 100% capacity at voltages as low as 1.42 volts per cell. See Fig 1. Bellcore has recommended a charging voltage of 1.43 volts per cell and 38 cells for a 48 volt battery. This means a total charging voltage of 54.34 V that concurs with existing practices in the industry. As can be seen from the curves displayed in Fig 1, the charging result is similar for any voltage between 1.42-1.45 volts per cell (54-55 V for 38 cells). This means that a 38 cell ANC battery can be charged at the same voltage as a 24 cell VRLA battery.

Nickel cadmium batteries are, from a charging point of view, less sensitive to temperature variations than VRLA batteries. For operation in the southern regions, where the battery temperature rarely goes much below freezing, no temperature compensation of the charging voltage would be necessary. However, an ANC battery would also work very well with temperature compensation circuits as used for VRLA batteries.

Normally, nickel cadmium batteries are rated for a nominal capacity to an end voltage of 1.00 volts per cell. ANC telecom batteries will be rated to 1.10 volts per cell. This equates to 42 volts for a 38 cell battery and corresponds to an end voltage of 1.75 volts per cell for VRLA batteries. Nominal capacity for VRLA is generally specified to 1.75 volts per cell.

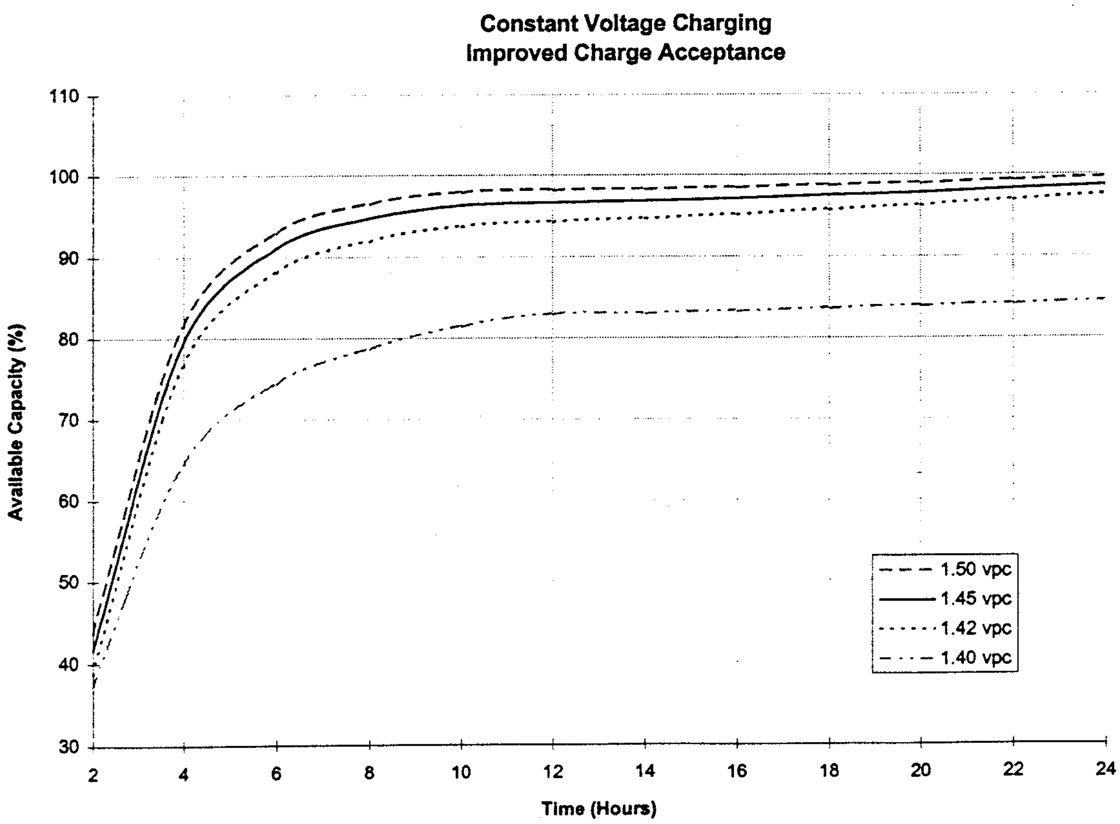


FIGURE 1

Most telecom plants require a slightly higher end voltage; in some cases 43.75 volts is specified (Bellcore TA-NWT-000406). This corresponds to 1.82 volts per cell for a lead acid battery and 1.15 volts per cell for a nickel cadmium battery. In both cases, it means that a little less than full capacity can be utilized. In other words, the discharge performance of the ANC telecom battery should be expected to be very similar to that of a VRLA battery.

In conclusion, from a charging and discharging point of view, an ANC battery can replace a VRLA battery of similar capacity without any adjustments to the charging system or load requirements.

The ANC batteries, which are of a similar construction to those made for electric vehicles, are relatively compact. In the 80-125 Ah range, they are of a similar volume compared to VRLA batteries of the same capacity. Actual measurements of the most common outdoor cabinets, such as the Lucent 80 series, Mesa, and Litespan cabinets, have shown that it is quite possible to fit the same amount of Ah capacity of ANC batteries as for VRLA. In most cases, no modification of the available battery space is required when changing from VRLA to ANC batteries.

As the ANC batteries were originally developed for electric vehicle applications, their cycling capabilities are quite amazing. Tests have been made with more than 2000 deep discharge cycles at elevated temperatures with very little loss of capacity. See Fig 2. Several hundred thousand cycles can be sustained at very shallow discharges.

With the use of separators that include a special membrane, the flow of oxygen is controlled. On float charge, when the current and oxygen production are very low, virtually all the generated oxygen is able to migrate and recombine, reducing water consumption to an absolute minimum. Abnormal conditions such as increased charging voltage or very high temperatures will cause sharp increases of charging current and oxygen production. The membrane will not allow the larger flow of oxygen to pass and will thereby restrict oxygen recombination during these conditions. This will prevent excessive heat generation and thermal runaway.

The high degree of oxygen recombination on float charge has severely reduced the need for frequent top-up. Figure 3 shows the expected top-up interval at various operating temperatures. The data displayed in Fig 3 is based on lab tests of cells with normal vent caps. Field tests with batteries equipped with central filling systems (see next page) seem to use much less water; probably due to the high humidity in the tubing system. Lab tests are currently being conducted on batteries equipped with a central filling system.

Further, if temperature compensation regulation is employed, which in effect will keep the float current almost constant, the water consumption should be expected to remain close to the room temperature level irrespective of operating temperature.

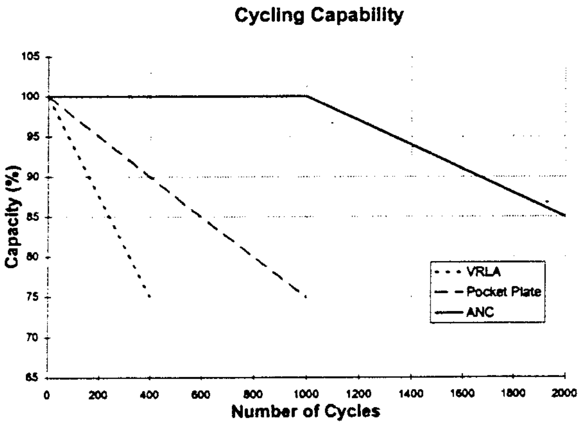


FIGURE 2

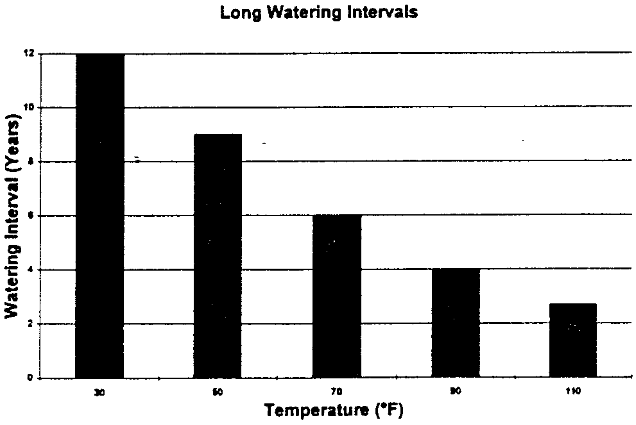


FIGURE 3

## CENTRAL FILLING SYSTEM

For those rare occasions when a top-up is required, the ANC batteries will be fitted with a central filling system. This means that the whole battery can be topped up through a single plastic tube. Special vent caps (no moving parts) will ensure that all cells are filled to the correct level. The batteries will not have to be disconnected or moved during the filling process which will only take a few minutes. Snap in tube connectors will be used.

An added benefit of using a central filling system is that it also provides a way of transferring battery gasses out of the cabinet or to a location where they can be expelled into free air. This will eliminate the possibility of accumulating high densities of hydrogen inside poorly ventilated cabinets. Such accumulations from VRLA batteries have resulted in explosions in the past and represent a serious safety hazard.

In the design of a telecom ANC battery, the goal is to provide sufficient electrolyte reserve to enable top-ups to be performed at intervals longer than the actual life of a VRLA battery.

## FIELD TRIAL RESULTS

A trial battery has been in operation in a poorly ventilated, in-service, telecom cabinet in Orlando for 10 months. This battery was installed by removing one (of three) VRLA battery strings and replacing it with a string of 38 ANC cells of the same capacity. This was achieved without any adjustments or modifications to the existing equipment. The trial battery is connected directly to the DC bus in parallel with two VRLA batteries and is equipped with a central filling system. The three batteries and their environment are monitored continuously by a data logger installed and controlled by Bellcore.

During the operating period there have been no unusual occurrences. The ANC battery draws less charging current than the VRLA batteries. Temperature sensors are placed inside and outside the cabinet and between battery blocks to record battery temperature. During the summer, the battery temperature oscillated between 45 and 47°C on a daily basis with internal cabinet temperatures changing between 40 and 50°C. In the winter, the temperatures have been running about 10°C lower.

Discharge tests have been carried out twice. Typically, the VRLA batteries carry most of the load during the early part of the discharge, while the ANC battery took most of the load during the second half. See Fig 4. This was to be expected when considering the voltage profile of the discharge curves for these two battery systems. See Fig 5.

Level markers were placed on several cells to monitor electrolyte levels. To date, no water usage has been detected. The system is operating with a temperature compensated charging system set to VRLA requirements.

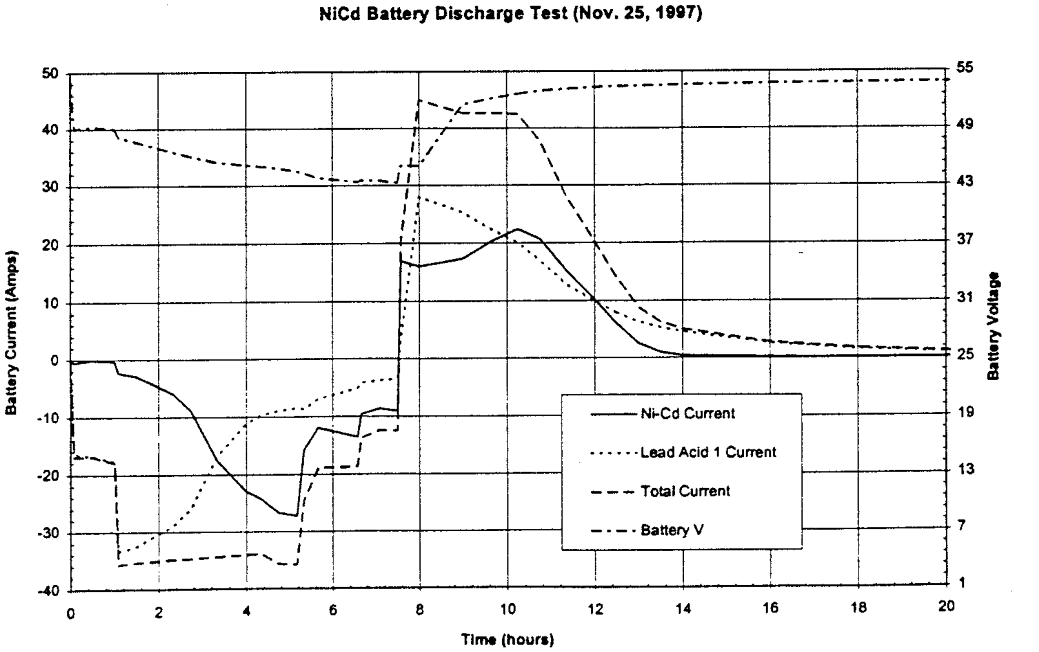


FIGURE 4

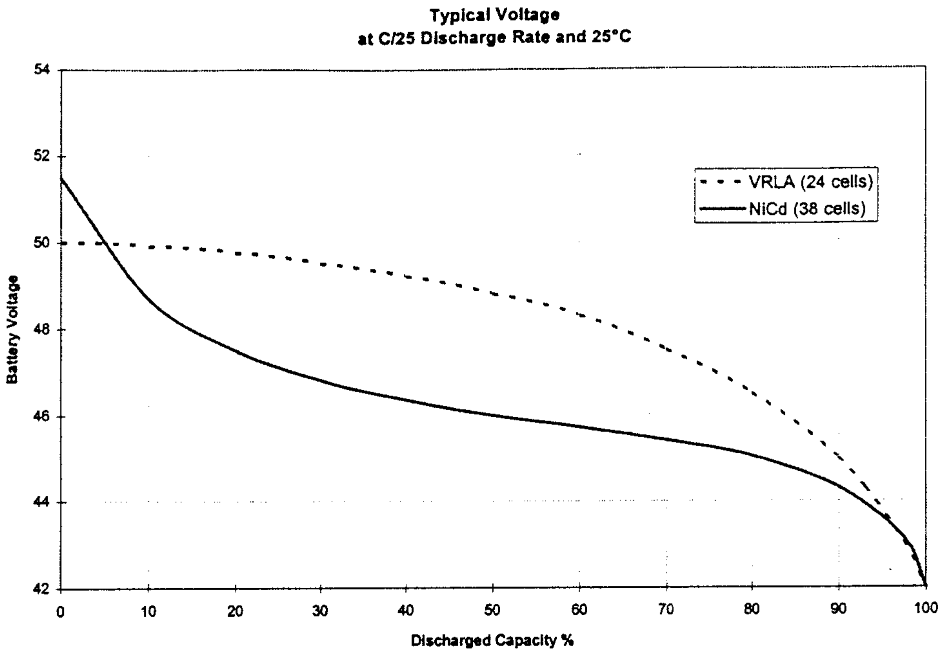


FIGURE 5

## LIFE CYCLE COST

The purchase price of ANC batteries will be 2-2.5 times higher than for VRLA batteries. Based on the VRLA life study made by Dr. Feder and his associates and presented at Intelec95, the average life of VRLA cells in reality seems to be closer to 5 years than to 10 years, even at room temperature. The life of ANC batteries is at least 3-4 times longer, which significantly compensates for the higher price. At an elevated temperature, the life cycle cost benefit is much more attractive, as the life of a VRLA deteriorates much faster with increased temperatures than the life of an ANC battery. See Fig 6 and 7.

There are additional saving on maintenance. While a VRLA battery will require frequent replacement, the ANC battery just needs a top-up at about the same interval. It must be quite obvious that the work and cost involved with a battery replacement is far more extensive than for a 10-minute top-up.

There is also an added cost for the VRLA battery from the occasional failures that will lead to other equipment damages and possible injuries,. This is a real cost which is evident from the additional protective equipment and circuits that the telecom companies have invested in to protect the VRLA batteries from over charging and thermal runaway.

When everything is added up, the life cycle cost of an ANC battery is very attractive and will provide cost savings to the BOC.

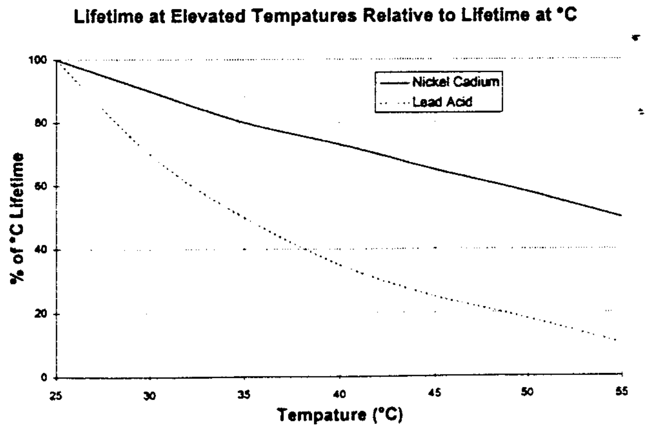


FIGURE 6

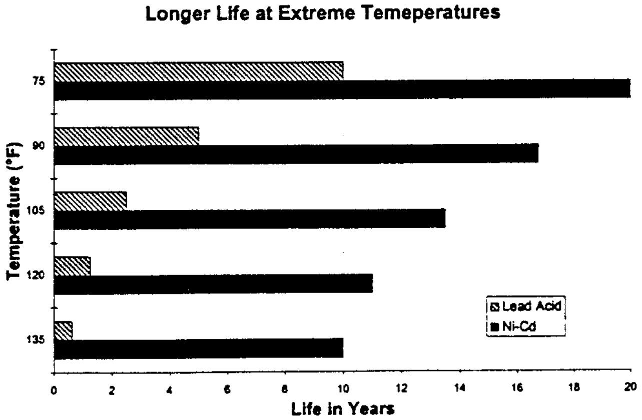


FIGURE 7

## CONCLUSION

It is obvious that the ANC battery represents a convenient and realistic alternative to VRLA batteries for outside telecom cabinet applications. This solution should be particularly economical and attractive in high temperature locations.

ANC batteries are available today and have already been qualified and used for many years in extremely demanding applications such as railroad, rail transit and onboard passenger jets as well as military aircraft where life, valuable property, and major liabilities are at stake. The ANC battery for telecom applications is an evolutionary design, time tested and field proven. It should therefore be safe to conclude that the ANC battery could be utilized with a large degree of confidence in the telecommunications industry as well.

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