Version: 18 May 2021

Battery Replacement Project

Haakon MacCallum
member of Detroit Committee
Vancouver Electric Vehicle Association

Introduction

The lead acid batteries in the Vancouver Electric Vehicle Association's (VEVA's) 1913 model 38 Detroit Electric by the Anderson Car Company were at end of life. The capacity of the 16 T-105 batteries measured at only 10% of their original capacity. Instead of replacing the batteries with another set of lead acid batteries, VEVA decided to re-install the original nickel iron (NiFe) technology in the vehicle. This would make the vehicle look original, and even though more expensive should easily pay for itself because of the longevity of the NiFe batteries.

This document explains the various tasks required to convert VEVA's Detroit back to the NiFe batteries.

Vehicle Battery History

VEVA's Detroit was originally shipped with NiFe batteries. The pictures shown are the only ones that VEVA has that show the original batteries. These photos were taken the same day that VEVA took possession of the car from the BC Transportation Museum on 16 March 1993. Immediately after VEVA took possession of the car, the original batteries were replaced with a set of lead acid batteries. This change was made at that time because the original nickel-plated steel cases of the Edison batteries had many leaks from corrosion. It was reported, however, that the original batteries still worked well as batteries – they just leaked.

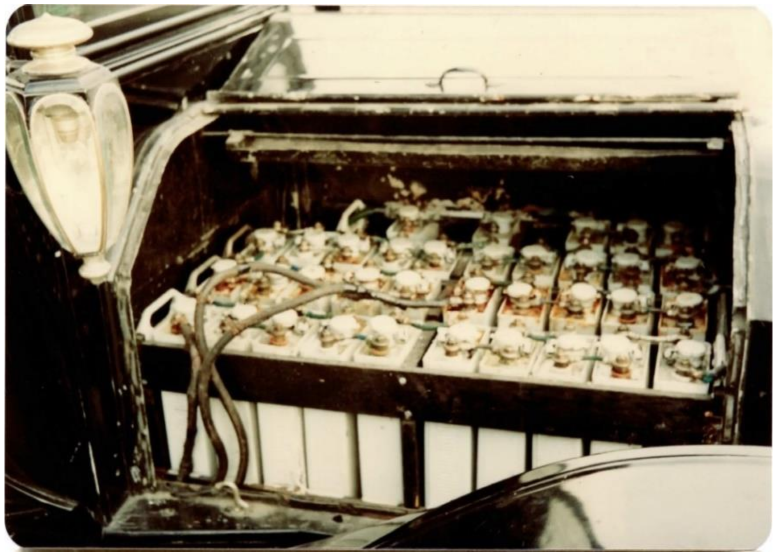

Figure 1: Original Front Battery Pack, 1993

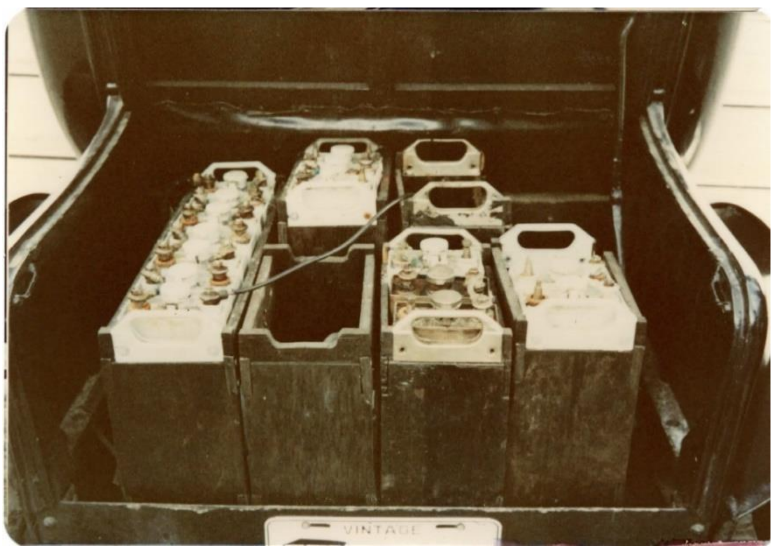

Figure 2: Original Rear Battery Pack, 1993

Determining the Original Battery Configuration

According to VEVA's records, the Anderson records specified the original batteries as "Edison 64-94."

At the beginning it was not known what either of these numbers referred to, and therefore, the number and size of the cells were also unknown. The arrangement of the battery packs in the original photos does not match any of those shown in the wiring diagrams, for example.

An inspection of drawing 3148 "Diagram Showing Edison Battery Arrangement Types U – V – W", shows only 60 cells (VEVA's Detroit is a Type W). However, it is known from anecdotal evidence that there were batteries located under the seat of the car (the springs in the seat cushion were reported to have been short circuiting the battery terminals) – and drawing 3148 does not show these batteries.

According to the “Wiring Diagram Index” page 2 (unnumbered drawing), the possible combinations for VEVA’s Detroit are shown in the table. All drawings and historical documents are from the electricvehiclemuseum.org and VEVA thanks both the electricvehiclemuseum.org and Galen Handy for making these invaluable documents available.

Table 1: Possible Battery Combinations for VEVA's Detroit

Battery Type	**Number of Batteries**	**Battery Size**	**Corresponding Wiring Diagram**	**Has batteries under the seat?**
Edison	60	A4	4203	No
Lead	38	?	4204	No
Lead	40	?	42255	No
Edison	62	A4	52254	No
Edison	64	A4	42257	Yes
Edison	66	A4	42258	Yes

From the table, the only combinations that match what was known about the original battery arrangement is the 64 and 66 cell combinations.

From drawing 3175 “Bottom Detail of Part 4196”, the domed portion only shows two divots towards the front. These divots line up to clear the batteries and containing tray of only the forward 2 cell containing tray. The 2 cell containing tray is shown in drawing 3154. Therefore, the only combination that fits our car is the 64 cell combination – and matches the “64” in the battery specification is the number of cells. Therefore, drawing 42257 also applies to our vehicle, and shows the arrangement of the cells, and their respective containing trays.

Since this project was completed, VEVA has learned that its records were incorrect, and that the Anderson sales ledger specifies 64 A4 Edison cells. Many thanks to Galen Handy for this information.

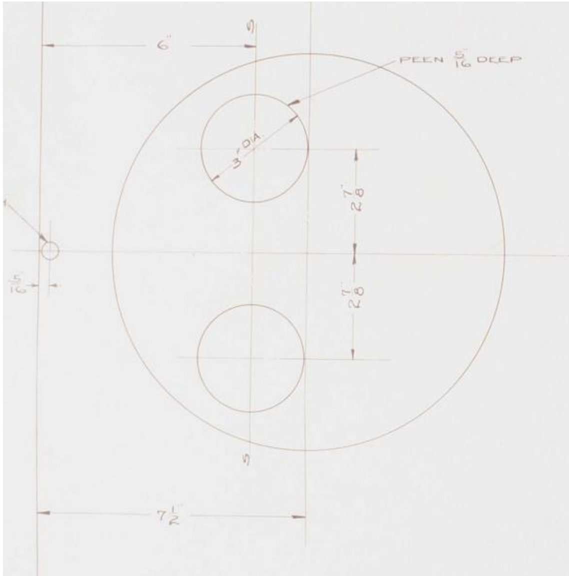

Figure 3: Drawing 3175 "Bottom Detail of Part 4196," Front of Car is to the Left

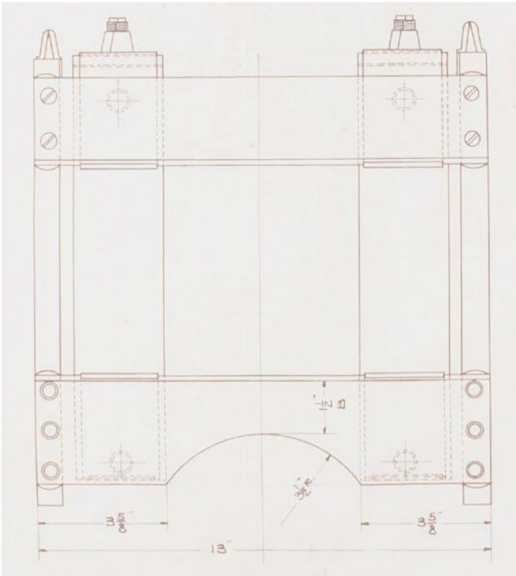

Figure 4: Drawing 3154, a 2 Cell Containing Tray

Purchasing of NiFe Cells

The best solution would have been purchasing a set of original A4 Edison cells. Because these old cells usually still function as batteries, had an original set been found any holes in the cases could have been patched or new cases manufactured. However, locating these batteries in the correct size has continued to be remarkably unsuccessful.

Therefore, VEVA decided to purchase new cells. These were found on Alibaba, and Ciyi Battery was chosen as the vendor. The closest match in size to the A4 battery was the 60Ah size – less than half the capacity of the 100-year-old batteries. Thankfully, VEVA has no need for a range of more than a few hundred yards – enough for the car to drive on and off a trailer and to its display location.

Figure 5: Ciyi Battery 60 Ah NiFe Cells

Addition of Suspension Bosses to Battery Cases

The original Edison batteries have four small bosses on the cell casings to suspend the cells in the containing trays. These bosses slip into slightly larger adapter parts that increase the approximately 16 mm diameter metal bosses to 13/16".

Figure 6: Suspension Bosses on an Edison Battery

The adapters are likely made from phenolic. They measure 1.135" OD on the flange and 0.878" on the stem. The total height is ½", the flange is 0.2" high and stem is 0.2" long. On the end opposite to the stem, the OD tapers from 1.135" to 0.87" over the remaining height and is then flat. The ID is 0.645” at the mouth, and 0.605” at its deepest, 0.35” measured from the aforementioned flat.

Figure 7: Suspension Boss Adapter

For the new batteries, a ¾” boss is attached – ¾” allowed for error in the manufacturing of the containing trays and placement of the bosses. These bosses are attached by friction (also called spin) welding them to the case. ¾” polypropylene rod is spun with an electric drill against the polypropylene case until the plastic melts slightly, and then stopped. The melted plastic then quickly re-solidifies to make the weld. The ¾” rod is held in place by a jig over the batteries during the spinning.

Figure 8: Spin Welding 3/4" Rod to the Battery Cases

After the rods were welded to the cases, they could be cut off to a length of approximately 5/16” with a jig saw. A piece of wood clamped to the foot of the jig saw kept the length consistent

Figure 9: Trimming the Bosses to Length

Containing Trays

The containing trays are manufactured from maple as specified in the original drawings 3149 to 3154. The only deviation is to use the battery suspension bosses as is done in newer Edison trays. The original trays used two metal pieces for each cell – one at the top, and then one at the bottom that held the weight of the cell. This deviation to the newer design made the trays easier to construct, while still remaining true to original Edison construction.

A quick examination of the vehicle photos shows that these containing trays must have been remade at some point over the years. However, the cells were still original: the metal suspension pieces and the cells are white. On later cells there is either no coating or Asphaltum – which is black.

Number 10, brass, slotted wood screws were used for the assembly. It is unknown if the originals were nickel plated.

Containing Tray Handles

To finish the containing trays, handles had to be made. They were made from 20-gauge, mild steel.

To form the shape, a sheet steel blank is hammer-formed over a form. The form is manufactured from ½” steel. In VEVA’s case the form blank was cut with a water-jet cutter – giving great accuracy. After cutting, the shape of the form is then filed by hand, using paper cut-outs to determine when the shape was correct.

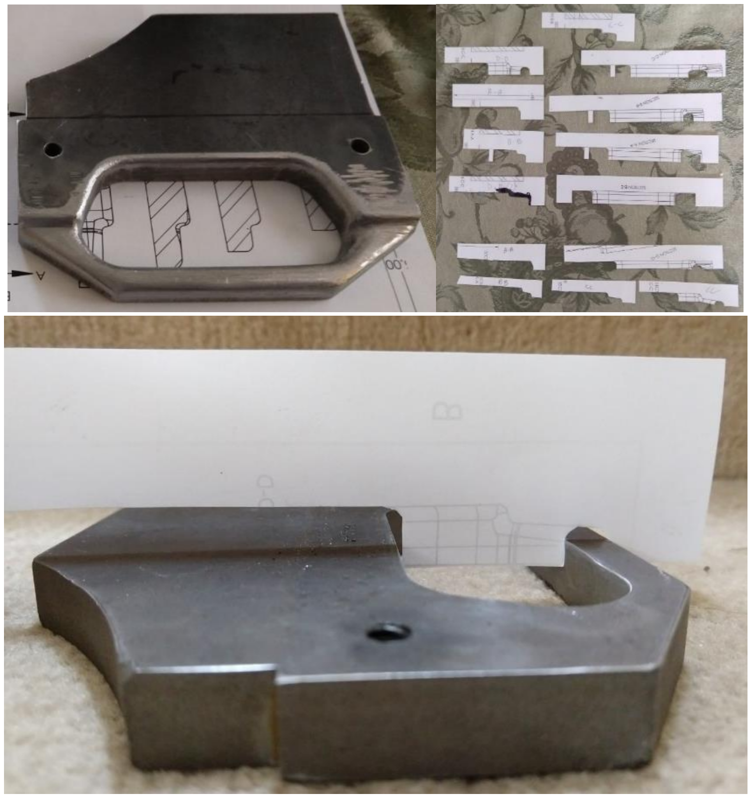

Figure 10: Handle Form and the Paper Cut-Out's Used to Create It

The sheet steel handle blank is cut with a combination of shears and an air nibbler. The air nibbler is a quick and easy tool for cutting out a section from a sheet without deforming the edges. Hand snips would have made too big a mess of the job. An aluminum form is used to make the cut with the nibbler fast and accurate. The same form also locates the drill holes in the handles – which are drilled before the hammer-forming.

Figure 11: Cutting the Handle Blank

The blanks are then clamped in the hammer-forming form and beaten to the shape of a half-handle. After hammer forming, a quick touch up on a belt sander smooths the edges, and the holes are countersunk.

Figure 12: Hammer Forming the Handles

Two half-handles are welded together with a MIG process, and ground smooth, with a final coat of white paint finishing the handles.

Figure 13: A Containing Tray Handle

Battery Interconnects

Battery interconnects are made from 3/16" solid copper rod with crimped terminals – as the originals. To save money, the original, cast ring terminals are not reproduced, and off-the-shelf ring terminals are used. Ring terminals with the correct ring dimensions are intended for wire that is larger in diameter than the 3/16" rod, so copper plumbing pipe is cut to make adapter sleeves. A hammer crimper did the best crimping job. The battery interconnects are finally electroplated with nickel and coated with a petroleum grease to prevent corrosion and match the originals.

Figure 14: Battery Interconnects

Assembled Containing Tray

Figure 15: Assembled 4-Cell Battery Containing Tray

Battery Commissioning

The NiFe cells are shipped from China dry, with the required potassium and lithium hydroxide coming as a powder. The electrolyte was mixed at approximately 1:3 by weight potassium hydroxide and distilled water to a target specific gravity of 1.20 gm/ml. Lithium hydroxide is then added at 20 gm per litre to make the final solution.

After filling the cells, they sit overnight as per the instructions.

Also, according to the instructions for the NiFe batteries, when first commissioned the cells require cycling to achieve full capacity. Therefore, the capacity is measured over a number of discharge cycles to confirm that cells are operating properly.

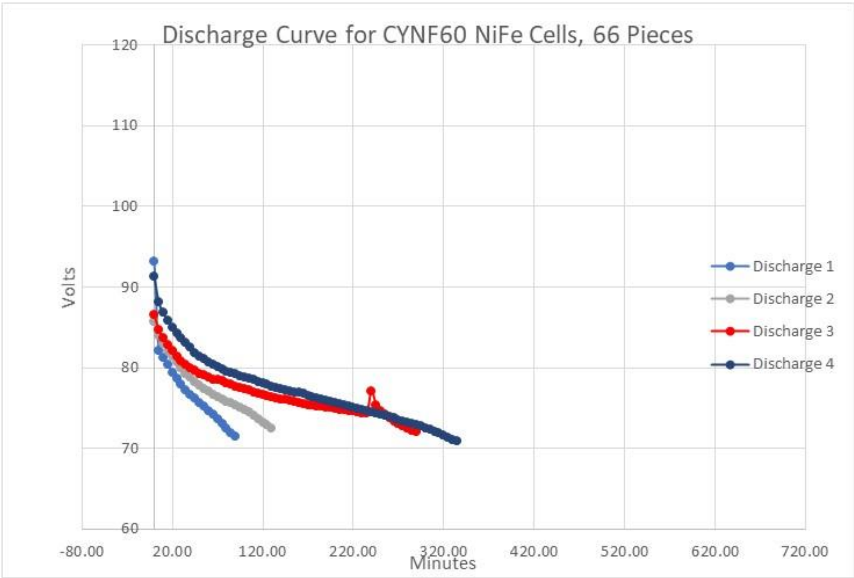

Figure 16: Discharge Test Data

As the graph shows, the first cycle showed only a startling 20% of rated capacity, but after four cycles the cells had reached their 60 Ah rating.

Some observations for the NiFe cells are as follows.

- Cells gas continuously and only stop when they are fully discharged – but the gassing tapers after sitting for several weeks.
- They can be safely stored at any state of charge, though electrolyte loss appears to be least when fully discharged.
- Their capacity increases further after the batteries are installed and tested in the car – because of the high discharge current during vehicle operation.
- The resulting range has not been tested, though measurements indicate that the resulting range with the 60 Ah cells will only be 10 or so km. Plenty for VEVA but insufficient for others.
- The modern NiFe cells are not nearly as space and weight efficient – being approximately 160% larger and 140% heavier than the original 100-year-old Edison cells for the same 150 Ah rating.
- Since no off-the-shelf battery chargers are available today that meet the exact requirements for this custom battery pack, a 96V Delta-Q QuiQ charger is modified to give a constant output voltage and then used with a timer to give 2, 4, 8, or 12 hours of charging – depending on required charging.

- NiFe cells are forgiving of over charge and over-discharge and therefore precise charging is not required. The same charge algorithm recommended when the vehicle was new is still as good as anything else today.

Installation in the Vehicle

Removal of the failing lead-acid batteries (16 pieces of T105 or T125 golf type battery) that were in the car at the beginning of this project went smoothly. Similarly, for the cleaning and repainting of the chassis before the installation began. Installation was made easier by the removal of the (imitation) radiator and hood in the front, and a trim piece in the rear (the piece that a licence plate hangs from).

Once the cells were assembled in the containing trays, installation in the vehicle was relatively straightforward. Drawing 42257 shows the arrangement of the containing trays and polarity of the connections.

At the same time, the existing (original) wiring in the vehicle was checked for shorts between circuits and to chassis with a high voltage Fluke insulation tester – an insulation tester works much like an ohmmeter but tests at a high voltage. Several areas of concern were found and repaired – the bell (see the article entitled “Repair of the Signalling Bell in VEVA’s Detroit”) and the ampere-hour meter – both with partial shorts to chassis due to the failure or contamination of the old insulation in them. Nearly every light on the vehicle was found to have a short to chassis, and therefore the lighting was disconnected until it could be repaired.

To maintain as much originality as possible fabric electrical tape was used, though modern wire insulation materials and crimps were used for any replacement wires. These modern materials were disguised beneath the cloth tape.

Additional features added that were not in the original car were inline battery disconnects and fuses. The inline disconnects were Anderson SB175 connectors. The inline disconnects were bypassed with diodes to allow charging when the disconnects are open. The fuses are cartridge type, bolt-on fuses though the exact part numbers are unknown.

Note that the 4 cells under the seat were not installed to keep any potential detrimental effects of corrosion out of the cabin. Instead, these 4 cells were replaced by an extra 2 cell tray in the rear battery pack (the same layout as the 66 cell cars) – giving a total of 62 cells instead of the original 64.

According to the drawings 4195 and 4196, the batteries should be installed in an inclosure [sic] both in the front and rear. In the rear, this inclosure has a dome shape to clear the differential should the suspension compress to the bump-stops, but for now a flat piece of plywood serves as a stand-in until the inclosures can be made.

Figure 17: New Front Battery Pack

Figure 18: New Rear Battery Pack