

The Million Cell Plant of the Edison Storage Battery Company at Orange, N. J.

Extended as a single-story building these concrete factories would cover an area one and one-fifth miles long by sixty-two feet wide. They contain nine acres of floor space and have a manufacturing capacity of 3,000 cells (150-ampere-hour equivalents) per day.

A Trip Through the Factory

PERHAPS the easiest way to describe the manufacture of the Edison Storage Battery is to take the reader in imagination, through the factory at Orange.

Let us, therefore, enter the "Million Cell Plant" of the Edison Storage Battery Company, to observe the ingenious machines and processes that Mr. Edison found it necessary to invent, and to perfect, before the nickel-iron-alkaline storage battery could be made in commercial quantities.

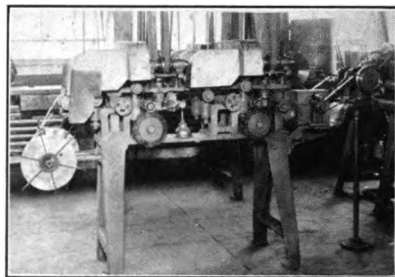
One of the first Edison Batteries to be put on the market was the 150 ampere hour size suitable for operating delivery wagons, passenger electrics and similar types of small cars. This was known as the Type A4 and since then the output of the factory has been estimated in "A4 equivalents." The buildings and their present equipment have a capacity of over 3,000 "A4 equivalents" per 10-hour day — a million "A4 equivalents" per year. Mr. Edison, however, looks upon this as only a nucleus of the business awaiting development and ample room has been left in the concrete structures with their nine acres of floor space for extension in every department.



Perforating carbon steel ribbon, 560 holes to the square inch.

In being shown the construction of the cell the first things to take up are, naturally, the "plates" that hold the active materials—nickel hydrate in perforated steel tubes for the positive, and iron oxide in perforated steel pockets for the negative.

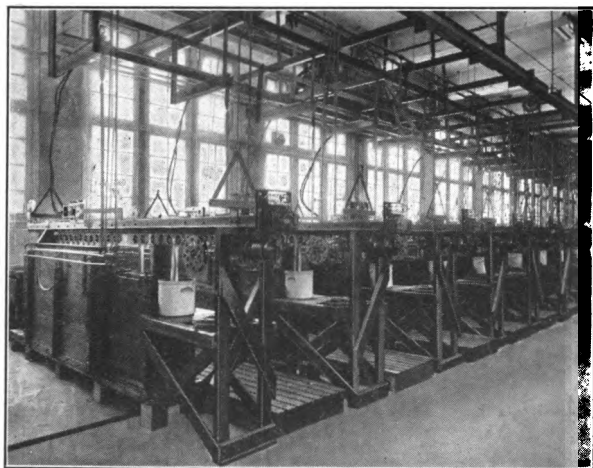
These perforated steel pockets and perforated steel tubes are made from cold rolled carbon steel ribbon which passes between two rollers. One roller has small projections on its surface; the other roller corresponding depressions. The ribbon comes out filled with regular rows of rectangular perforations, so small that 560 are included in one square inch. This perforating is necessary so that the potash solution may come in contact with the iron oxide and the nickel hydrate, and the necessary chemical action take place.



The perforated steel ribbon "zig-zagging" between the cleaning brushes.

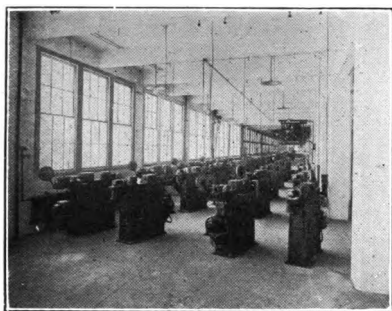
To remove any little burrs that might remain after the perforating process, the ribbon is ground by emery wheels that smooth the rough side. But, emery dust gets into the little perforations, and to clean them the ribbon is fed through a machine with six revolving wire brushes. As it zig-zags up and down, on its way through the machine, two brushes rub one side, two the other side, and two brush cross-wise—the ribbon emerges with every perforation perfectly clean.

The ribbon is then nickel-plated. It is drawn from a reel and travels in and out through a series of tanks containing respectively, a potash solution; hot water; a double solution of nickel ammonium sulphate; hot water; cold water; and ammonium hydroxide. Pulley wheels located above and in the bottoms of the tanks guide it, the lower wheel being



Traveling in and out through a series of baths, the perforated steel ribbon is subjected to a continuous nickel-plating process.

made of non-conducting material. The potash solution removes all oil and grease; the hot water removes the potash; the double solution of nickel ammonium sulphate is the nickel-plating bath; the hot water again washes it and dissolves any salts that may have lodged in the perforations; the cold water removes what the hot water does not; and the ammonium hydroxide removes all



From ribbon to completed tube in one operation. Each machine makes 20,000 tubes a day.

trace of acid that may remain from the nickel-plating bath.

It takes eight minutes for a given point on the ribbon to pass through the entire process.

After being nickel-plated the ribbon is dried. This prevents any rust forming during the brief interval before it goes to the annealing furnaces.

From the drying oven it is placed in a crucible. The crucible is hermetically sealed and as much air exhausted as possible. The crucible is

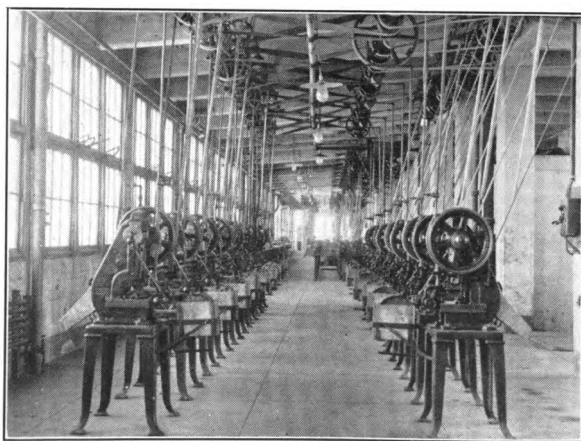
put in an oil-burning furnace. To prevent oxidation or discoloring of the nickel-plated material, while under the action of the extreme heat of the furnace, a stream of hydrogen gas is constantly passed through the crucible, keeping the ribbon in an "inert" atmosphere.

All steel parts used in the Edison Cell are annealed in this manner. In the annealing process the nickel-plating is fused or welded to the steel itself. Thus it becomes an integral part of the steel and removes the possibility of the nickel coating peeling off or being chipped off.

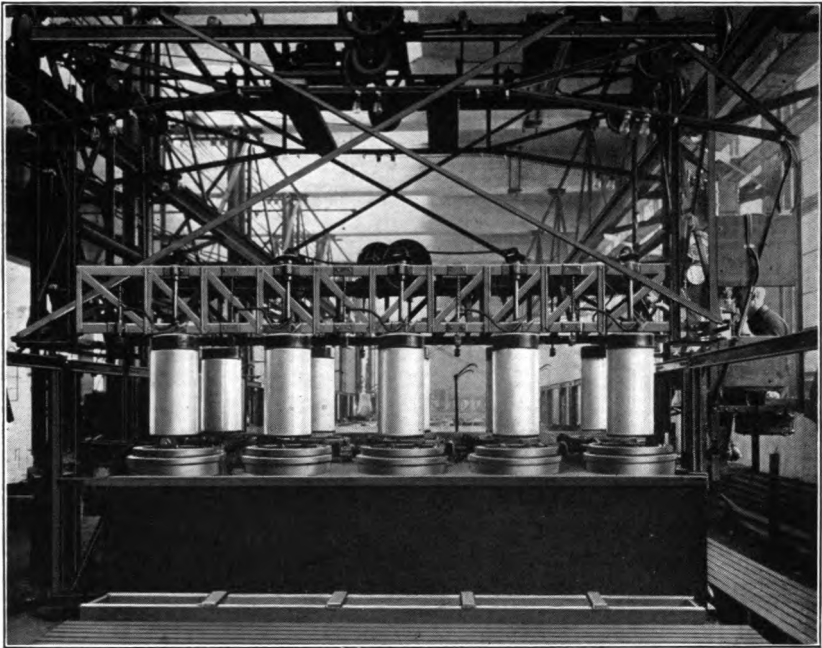
Before being nickel-plated and after being annealed the ribbon is weighed and micrometer readings taken to make certain that the nickel is properly deposited.

The ribbon is prepared in two widths, the narrower being used for the negative or iron oxide pocket. The negative pockets are formed in halves not unlike the well-known paper scarf-pin box in which the box proper and cover are approximately equal, one fitting over the other. Groups of punches cut the ribbon to required length and stamp the halves into form. The halves are then slid together, forming the pockets. One end is left open for filling with iron oxide.

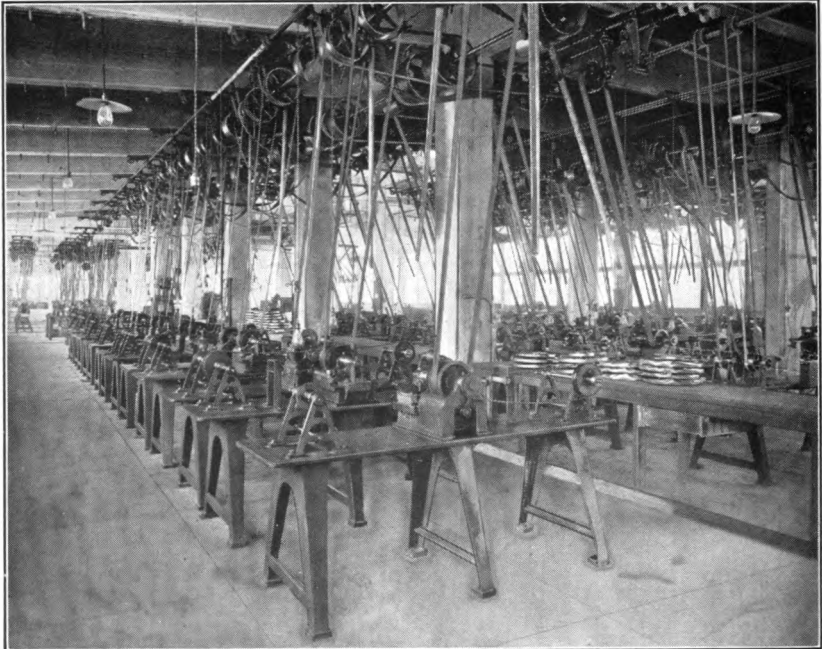
The ribbon for the positive tube is fed automatically into a machine through a shaping die that not only forms it spirally into a tube $\frac{1}{4}$ inch in diameter, but laps the edges of the ribbon over each other, forming a perfect joint. This lapped-over seam is pressed flat or swaged, and



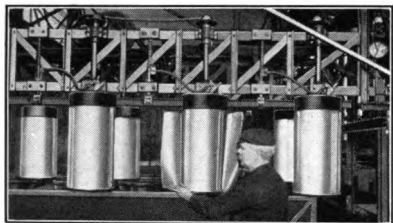
The negative pocket "halves" are formed from the ribbon by one blow in these perfected die-stamping presses.



The first process in making nickel "Snow Flake." Plating 250 alternate layers of extremely thin nickel and copper on revolving cylinders.



Perforating machinery. The active material is held in tubes and pockets made of perforated steel ribbon. The cutting and finishing of these perforations is one of the most interesting processes in the manufacture of the Edison Cell.



Stripping copper-nickel sheet from cylinder. The sheet is .0075 inch thick.

chine before he can make it produce a normal output of 20,000 tubes a day.

The positive tube is ready to be filled. Ordinarily to fill it with nickel hydrate would be neither difficult nor interesting, but there are certain electrical characteristics wanted that gave Mr. Edison many sleepless nights before they were obtained.

The electricity in flowing through the solution from the positive element (nickel hydrate) to the negative element (iron oxide) causes the oxygen in the iron oxide to come over to the nickel hydrate. This oxidizes the hydrate and forms nickel oxide or peroxide. This nickel oxide has comparatively high electrical resistance, so it is advisable to divide it up into very thin layers and to conduct the electricity to these layers by intervening layers of metal.

Pure nickel is not difficult to obtain, but to get it in the form required for loading the positive tube, is an original and interesting process.

After a multitude of experiments to obtain a layer of thin conducting metal that would prove satisfactory electrically and yet have as long a life as the rest of the battery, the plan was conceived of using "flakes" of nickel which could be loaded into the tubes the same as the nickel hydrate but which, when tamped down, would give the desired conducting element. The processes for manufacturing this nickel flake are perhaps the most interesting in the factory.

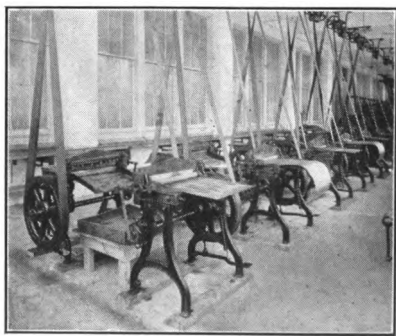
A traveling crane carrying 10 revolving copper cylinders is shown on the opposite page. The cylinders are lowered into two parallel rows of 5 copper baths each corresponding to the 10 cylinders, where a very thin film of copper is deposited on them. Then they are lifted out and travel past multiple water jets that spray them thoroughly before they are lowered into a row of nickel baths where a film of nickel, approximately $\frac{4}{100000}$ inch thick, is deposited over the copper.

Then they travel back to the copper baths pausing at the water jets for another thorough spraying. This operation is repeated until there are 125 films of copper and 125 films of nickel.

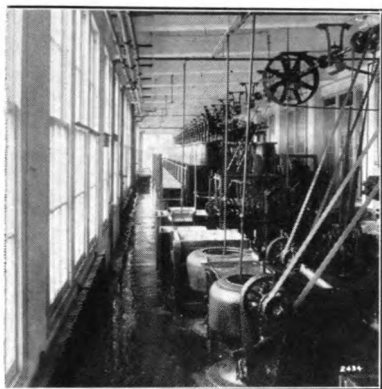
The time the cylinders should remain in the nickel bath is accurately regulated by a circuit breaker and amperes hour meter combined to automatically permit only sufficient cur-

as a last operation, the tube is cut to correct length ($4\frac{1}{2}$ inches). In some of these machines the tubes are wound to the right, in others they are wound to the left. The purpose of making these tubes in "rights" and "lefts" will be explained later.

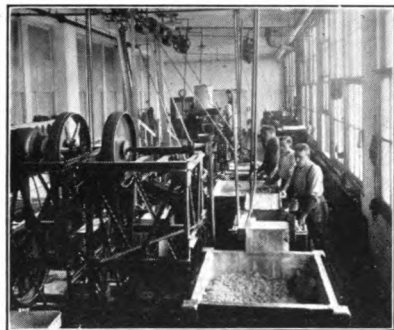
It is customary for a workman to have had six months' experience in setting the forming dies of this machine



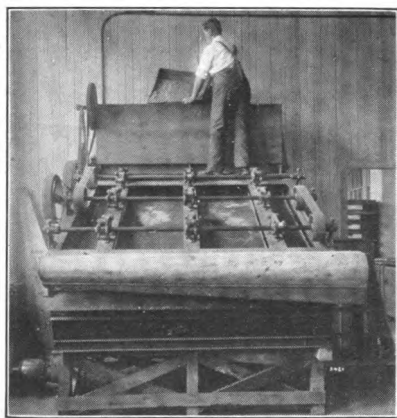
Cutting copper-nickel sheets into 1-16 inch squares. Each square makes 125 nickel "flakes" when the copper is chemically removed.



Dissolving copper from small copper-nickel squares.



Washing the flake. Centrifugal dryers shown in the background.



After drying over steam coils the flake is carefully screened

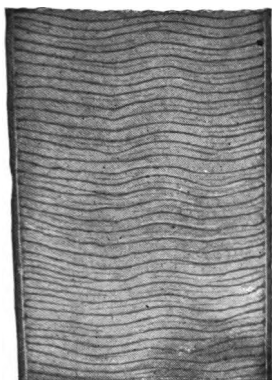
rent to pass to deposit a nickel film of the correct thickness. The length of time required to give the copper coating is not so important. It takes about five hours to make one 250-layer sheet .0075 inch thick.

The sheet is removed from the cylinder; cut into pieces 1/16 inch square and the pieces put into a solution where the copper is dissolved leaving thin films of pure metallic nickel. After thorough washing and the forcing out of the water by centrifugal machines similar to sugar driers, the nickel is dried over steam coils, screened and sent to the tube-loading machines—the thinnest, lightest, pure metal product ever used in a manufacturing process, nickel “snow-flake.”

It would take 85 flakes, placed one on top of the other, to equal the thickness of the paper used in this book, and a bushel weighs only 4½ pounds.

Filling the positive tubes is the next operation. Again it was found to be necessary to provide machinery of special design. The tubes are taken eight at a time and a little metal cap is inserted in the bottom of each. They are then placed in a mould and the mould placed in the machine directly under a row of fixed tubes through which metal rods pass. The tube-loading machines are also equipped with two hoppers; one hopper dumps a specific quantity of nickel hydrate, the other dumps a specific quantity of nickel flake. Then, with a force of 2,000 pounds per square inch, the metal rods ram the layers down. This process is automatically repeated until there are over 300 alternate layers (about 630 layers in all) in a tube only 4½ inches in length. As each tube becomes fully loaded, the machine automatically stops the plunger for that particular tube.

To make certain that the tube-filling machines are alternating accurately, one tube is taken from every lot filled, sawed longitudinally, and



Magnified section of a $\frac{1}{4}$ inch tube. Light layers show nickel hydrate. Dark horizontal lines show nickel flake.

put under the microscope. (A magnified section is shown on this page.) Should the filling be improperly done, the error is detected promptly and that lot of tubes rejected.

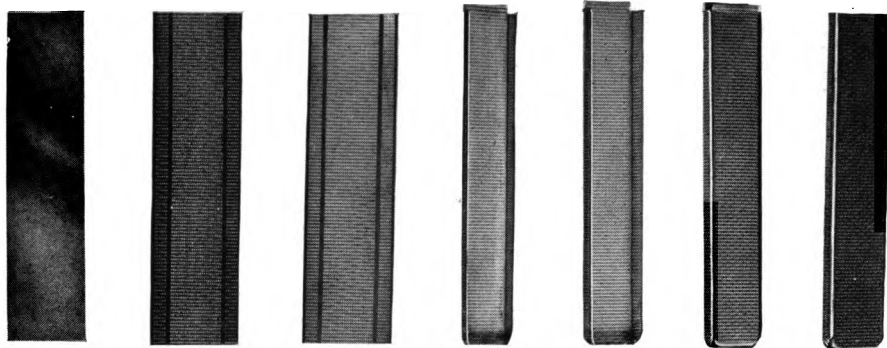
Early experiment showed that the oxidizing of the hydrate had a tendency to cause the tubes to swell. To overcome this absolutely, each tube is reinforced with eight seamless steel rings, equidistantly spaced.

These little rings are punched, ten at a time, from a ribbon of highest grade finished cold rolled steel. This steel is made especially for the Edison Storage Battery Company for this particular job; if made too soft or too hard it will not do. The ribbon travels from a reel through the press to another reel on which, after the rings are punched out, it is wound as "scrap."

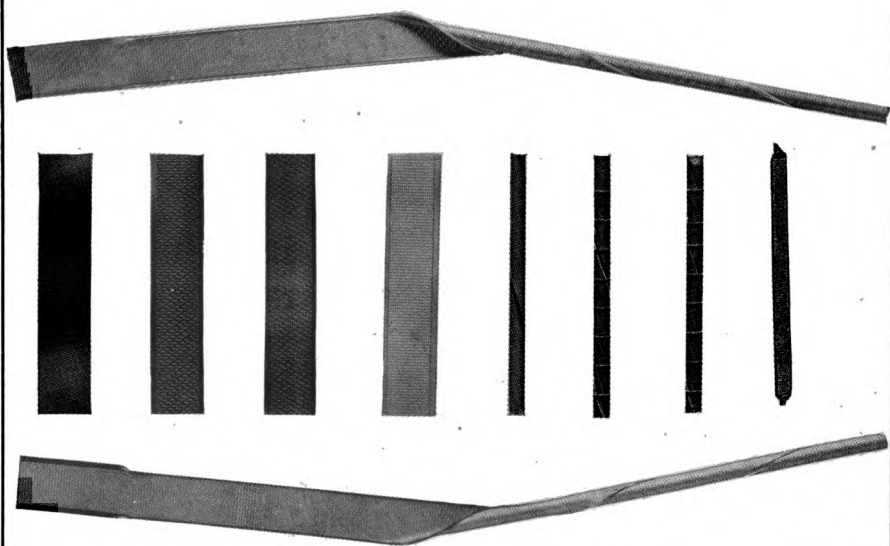
On its way through the punch the ribbon pauses as dies descend and punch out ten holes. Then it advances and when the dies descend again to punch out another ten holes the first ten have arrived at another row of dies which force down the inside edges of the holes making rims, or flanges, equal in depth to that of the desired rings. The dies that force down the edges are encircled with a hard steel shell that reaches the ribbon $\frac{1}{16}$ " behind the dies and cuts off the rim.



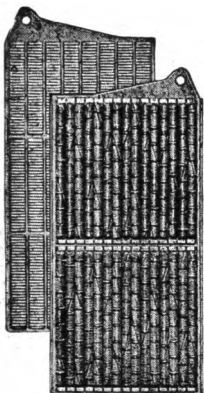
Loading 630 layers, alternately nickel hydrate and nickel flake, into a tube $4\frac{1}{2}$ inches long. See magnified section of tube above.



Evolution of the Negative Pocket from carbon steel ribbon to the loaded pocket. Perforated, nickel-plated, pressed into halves, the halves put together with one end open for loading. The loaded pocket.



Evolution of the Positive Tube from carbon steel ribbon to the closed and trimmed finished tube. Perforated, nickel-plated, drawn into tubes, loaded, ringed. The last figure shows a tube cut longitudinally for inspection. The pieces at the top and bottom of the picture have been lifted from a tube winding machine to show operations. Note right and left hand twist.



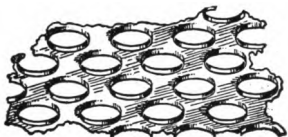
Type A — Positive plate in front, Negative behind.

It is interesting to note that the sheet steel from which the rings are made is thinner than the width of the bands. These rings, before being used, are nickel-plated and fed into a machine that automatically discards any that are imperfect.

The filled tubes and the seamless rings are put into another automatic machine. The rings gravitate into 8 equidistant grooves in such a position that the tube can be forced through them by a plunger working from the side.

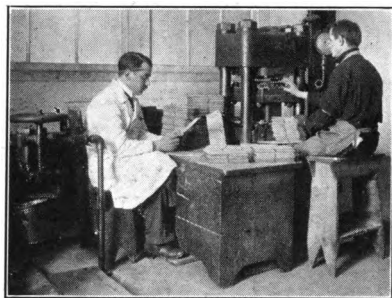
After being closed, trimmed and inspected, 30 of these positive tubes are mounted on a nickel-plated steel grid and pressed into permanent position by hydraulic pressure of 40 tons. You will remember these tubes were made in "rights" and "lefts." They are mounted alternately in the grid so that

any tendency to twist on the part of one tube will be counteracted by the next one which is oppositely wound.



Making rings with rims of greater width than the sheet from which they are punched.

The negative pockets, which hold the black iron oxide, are filled and tamped by a method much like that used in filling the positive tubes.



Hydraulic pressure of 40 tons secures the positive tubes in a steel grid, the last operation in the construction of a strong, durable positive plate.



Loading the Negative Pocket with Iron Oxide.

Twenty-four finished negative pockets are placed in the openings of the negative grid. Hydraulic pressure of 120 tons is used to clamp them firmly to the grid. It also corrugates the sides of the pockets, imparting sufficient elasticity to cause them always to adhere tightly to the iron oxide mass within and strengthens each individual pocket.