the formation of lead peroxide on one of the plates, causing a difference of potential.

He also observed that by a series of charges and discharges of this nature, and by reversing the direction of the charge each time, the quantity of lead peroxide on one plate was greatly increased, while a spongy surface of pure lead was formed on the other; as this increased the capacity of his battery, he was able to construct a cell that was of some practical value. His method was to roll together two sheets of roughened lead, which were kept from touching by sticks of paraffined wood, and to immerse the whole in dilute sulphuric acid. The cell was then charged, discharged, and charged again in the opposite direction, until the plates were "formed," i.e., a coating of lead peroxide was formed on one plate and of spongy lead on the other. This process occupied a month or two, but after several experiments Plante succeeded in reducing this time considerably by soaking the plates in a bath of nitric acid, previous to the formation process.

Plante carried on his research work until 1879, but he does not appear to have succeeded in sufficiently shortening the formation period of his battery, although he is said to have made some experiments with mechanically applied active material.

FAURE SYSTEM.

As the long and tedious process of formation of the Plante element added much to the expense, it greatly checked the commercial growth of the storage battery.

In 1879, however, R. L. Metzger partially overcame this by mechanically applying to a lead plate active material in the form of a paste of lead oxide. This important improvement was not generally known, until Camille Faure obtained patents on a similar process, which is now known as the Faure system. Faure's first experiment was to cover an ordinary Plante plate with lead oxide but he subsequently improved this by using an antimonious lead grid, with a paste of red lead, and sulphuric acid for the positive and litharge and sulphuric acid for the negative. The advantage of the antimonious lead grid over pure lead will be dealt with later.

COMPARISON OF PLANTE AND FAURE SYSTEMS.

We now have two methods of making a storage battery, both of which have striking advantages, and both, unfortunately, striking disadvantages. In the Plante system the time of formation is long and a large amount of electric power is consumed; the proportion of active material to the weight is small, as the lack of mechanical strength of the lead makes it necessary to have a thick plate to withstand any strain; the lead plate is continually undergoing a formation process from the repetition of charge and discharge, which reduces its strength. On the other hand, the conductivity of the Plante plate is excellent as the active material being formed directly on the surface is always in good contact with its supporting lead plate. The active material is not likely to be jarred off or forced off by the evolution of gases; rapid discharges of heavy currents may be maintained with little or no injury to the plates.

In the Faure system the advantages and disadvantages are almost diametrically opposed to those of the Plante. The formation is quick and may be accomplished in one continuous charge. The proportion of active material to the weight is large, therefore the capacity is increased. The antimonious lead grid has greater strength, and is more rigid than the lead plate. The antimonious lead grid is only very slightly subjected to the "forming" process, and therefore retains its strength.

Here it may not be amiss to explain the term antimonious lead grid. I have used it in a general way to represent those alloys of lead, antimony, arsenic and tin, which have been made with a view to obtaining increased strength and immunity from the electrolytic effects of the current on charge and discharge. Some of these are quite successful, but the manufacturers keep the exact composition secret.

On the other hand, the conductivity is lower than in the Plante, as it is difficult to maintain good contact between the active material and the grid. The expansion and contraction on charge and discharge is apt to loosen the active material and render it liable to fall out. Very heavy discharges are likely to force off the active material by forming gases inside of it.

Since this time the manufacturer has been endeavoring to produce a battery which will combine the advantages of both with none of the disadvantages. Needless to say, this battery has not yet been made, but nevertheless the improvements now existing are such that the storage battery holds an important place in modern engineering practice, and it is safe to say that few, if any, of the larger direct current plants could be considered up-to-date without such an auxiliary.

To enumerate the varieties of batteries which have been patented and manufactured would occupy the remainder of the evening, but it may not be out of place to mention those which present radical improvements or entire departure from standard practice.

METHODS OF MANUFACTURE.

In order to increase the capacity per pound, many methods of increasing the active surface of the lead plate have been devised.

1. Lead plates are scored all over with a sharp tool, which raises fine leaves on the surface and increases the area, in some cases, to 17 times the superficial area.
2. Grooves are cut in a thick plate generally by sawing,
3. Plates are built up of alternate laminae of flat and corrugated lead, which are burned together at the ends.

In these three systems solid ribs are usually left at intervals in the plates, to increase the rigidity, which, however, never equals that obtained by the antimonious lead grid of the same weight.

The advantages of these systems in increasing the active surface are manifest, the drawbacks, however, are rather serious. In all three cases the chief support is pure lead, which, as was mentioned before, is subject continually to a formation process. Thus the thin leaves, ribs or laminae produced by these methods are apt to become formed right through and so break away. Too many ribs or laminae will not allow sufficient room for the formation of the lead peroxide, and buckling or forcing off some of the active material is sure to result.

Plates of this type expand and contract laterally across the surface and consequently are sure to buckle sooner or later, as it is manifestly impossible to keep this expansion and contraction the same for both sides of the plate.

The long formation process of Plante has been overcome to a great extent by the addition of lead dissolving acids or salts. The formation of peroxide or sponge lead is so hastened that the time taken is not much longer than that required for the Faure system. In some cases it has been reduced to fifty hours. Care must be taken, however, to free the plates thoroughly from such chemicals before putting them into use, as otherwise the formation process will continue until all the lead is worn away.

In these ways the Plante plate has been so improved that from a standpoint of capacity and fairly quick formation little is left to be desired, but it must be remembered that the former is only obtained by a sacrifice of mechanical strength.

These methods refer more particularly to positive plates. Negative plates for batteries of these types have been made in a similar manner, although there is not so great a necessity for strength, and consequently the number of ribs is usually less.

The Faure system has resulted in more varieties than the Plante. The chief improvements have been the shaping of the grids so as to retain more firmly the active material and the discovery of pastes which set more firmly than those originally used by Faure. Various attempts have been made to increase the porosity of the active material by the addition of powdered pumice, asbestos, etc. The exact composition of the pastes used in the leading batteries of this type are kept secret.

With all these improvements the initial disadvantages still existed, although to a less degree. The next step was to cast the grid about active material formed into pellets. In the original chloride accumulator, buttons of fused lead