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Development of the Storage Batteries
and Accumulators.

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June 7th. 1901.

THE DEVELOPMENT OF THE STORAGE
BATTERIES AND ACCUMULATORS.

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THE DEVELOPMENT AND APPLICATION OF
STORAGE BATTERIES AND ACCUMULATORS.

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According toHouston a storage battery, accumulator or secondary
battery consists of two inert plates of metal or metallic oxide
immersed in an electrolyte. On the passage of a current chemical
reactions take place such that the electro-positive or eletro-neg-
ative radicals are deposited on the plates;and after breaking the
charging currentxx an ordinary voltaic battery remains which is
capable of generating an electric current. The difference between
a primary and a secondary battery is,the primary battery is active
in itself;but after expending its energy cannot be renewedwhile a
secondary battery has to be acted upon by some external current
and then,after being run down,can be re-energized.
 The storage battery is as yet comparatively new so far as its
practical application is concerned; but it is rapidly becomin;an
important factor in the electrical field;particularly as an eco-
nomic factor in the generation of electric light and power.
 In regard to this particular branch of its use Mr.C.L.Edgars,
in a paper read before the American Institute of Electrical Engin-
eers,stated that the four uses of storage batteries for central
station work:were:
    1. To carry the peak of the load.
    2. To carry the entire load during minimum hours.
    3. To act as an equalizer or reservoir.
    4. For the equipment of an annex or substation.
 For ordinary central stationsthe peak of the load lasts for only
2 or 3 hours;and were it not for the storage batteries sufficient
power would have to be at hand to carry this maximum load.
 In many cases the battery can carry the entire loadx at minimum
hours. This is a great advantage in as much as it saves the run-
ning of large dynamoes at a small and uneconomical load.
 It has been said on good authority that where a storage battery
is used at least 15% in fuel is saved.
 Another field,in which the storage battery is making rapid xxxi-
development,is in the field of telegraphy and telephony,where the
constancy,cleanliness and flexibility of storage batteries is rap-
idly driving out the gravity cells. As an example in Washington
D.C.7300 gravity cells were replaced by 724 chloride accumulators
a few years ago.
 For traction work the storage battery is also becoming an impor-
tant factor;particularly in its application to automobiles where
it is by far the most satisfactory motive power.
 It is now about 20 years since storage batteries were brought to
such a state of perfection that they were of any commercial use;
but unfortunately the manufacturers claimed too much entirely for
their batteries in the way of capacity and durability and this
combined with its first cost soon brought the whole storage bat-
tery into disfavor.
 The later improvements in the storage batteries and greater con-
servatism in the claims of the manufacturers has now overcome this
effect so that in the last ten years many of the largest and best
generating plants have installed accumulator systems,and have de-
rived very satisfactory and unexpectedbenefitsfrom them.

The history of the storage battery begins in 1801. In 1800,the
year in which Volta discovered the voltaic cell,it was also found
that this voltaic cell would decompose water;and in 1801 Gautherot
found that if the electrodes were connected together,after having a
voltaic current passed through them,that a short secondary current
would flow. From time to time other investigators added to this
to this first knowledge,and in 1837 Sir Wm. Grove found that metal
plates,covered with a layer of oxide,were much better than plain
metal plates. Wheatstone and Siemen found that lead-peroxide was
the best for this purpose.

In 1860 M.Gaston Planté made his first famous battery,in which
he used coiled lead plates. From this time up to about 1880 great
progress was made in the development of storage batteries,particu-
larly by Planté. Among the important dis coveries was the fact
that the per-oxide of lead could be applied mechanically and so
the tedious forming process could be done away with.Metzger is ac-
credited with first doing this,but Camille Faure came to the front
in developing this form of the secondary battery.

Several classifications have been made of secondary batteries,
but probably thebest is that suggested by Reynier which is as fol-
lows:

1. The Lead-sulphuric-acid genus. This class includes all those
cells belonging to the Planté and tothe Faure groups and soincludes
nearly all batteries in use today.

2. The Lead-copper genus. This class has metal plates covered
with lead-oxide for the positive electrodes,and copper plate for
the negative electrodes. The electrolyte is a solution of copper
sulphate ($CuSO_4$). These batteries are of very little practical use.

3. The Lead-zinc genus. This group is similar to the preced-
ingexcept that it has zinc plates instead of copper and zinc sul-
phate ($ZnSO_4$)for the electrolyte instead of copper sulphate.

4. The Alkaline-zincate genus. Copper plates are used for the
positives and iron platesor gauze for the negatives,with sodium or
potassium zincate for the electrolyte.

5. Miscellaneous. Those cells which cannot be placed under
the other four classes.

One of the requirements for a good cell is that when it has been
charged and discharged the final conditions are so nearly like
those at the beginning ;that is,the actual chemical and physical
change is so small,that the cell can be charged and discharged a
great number of times before the total amount of change is suffi-
cient to make the cell useless. The change in most cells,using other
metals than lead,is so large that they deteriorate much more rapid-
ly than do the lead-sulphuric acid cells. The superiority of the
lead-sulphuric acid cells over others is due largely to the chemi-
cal and physical properties of lead and its compounds. Lead is the
only metal whose sulphate is not acted upon by water and dilute
sulphuric acid. Its per-oxide is also not acted upon by these chem-
ical agents,and yet is a good conductor electrically. When such a
cell is discharged,the lead sulphate ($PbSO_4$)which is formed is de-
posited on theplates and remains unaffectedby the fluid,to be re-
oxidized when the cell is charged. In many cells of other metals
the compounds formed are dissolved as rapidly as formed.

The first class of cells is divided into two groups,the Planté
and Faure groups of accumulators. Each of these groups are again
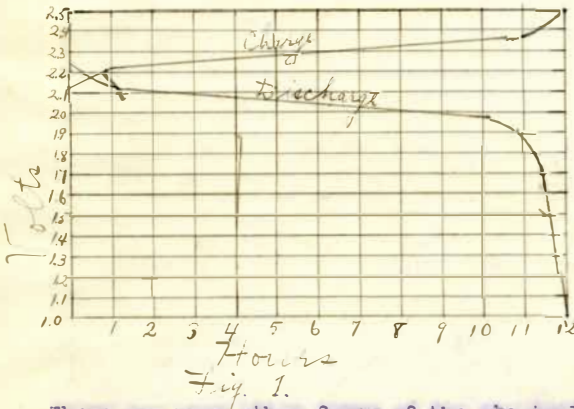divided according to their improvements and methods of formation.

M.Gaston Planté made the first practical secondary battery in
1860. It was made by winding two strips of lead ,insulated from
each other by pieces of felt,around a wooden cylinder. This was
immersed in dilute sulphuric acid. When a current was passed thro'
thisthe electrolyte was decomposed and hydrogen,passing to the neg-
ative plate, made a bright surface of metallic lead;while oxygen ,

passing to the positive plate, made a coating of lead-peroxide.
Planté found that by discharging the battery and then recharging
in the opposite direction several times, the capacity of the cell
was greatly increased. There was a great disadvatage in this how-
ever ,because of the waste of power and particularly, in the fact
that the plates became rotten after a few of these reversals.

Since 1860,many improvements have been made on the original
Planté cell. So many in fact,that it has lead to a subdivision of
the Planté cell;the cells being classed according to the method us-
ed in their formation. The method of formation by reversals how-
ever,has been done away with and all Planté cells are now formed
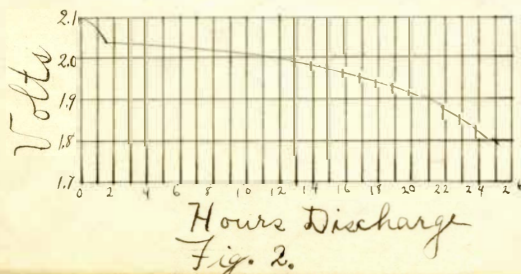in a few hours,by being placed in some pickling or forming bath.

The general method of making a Planté cell,is to give the plates
some treatment which reduces them to spongy lead,after which a
current is passed through,forming lead-peroxide on the positive
and metallic lead on the negative plate. Mostplates are grooved or
ribbed in some way,in order to give a larger effective area to
the electrolyte and also to give a better mechanical support to
the peroxide.

The first group of the Planté cell, which will be considered,is
the Chemical or Electro-chemicalgroup. The plates of this class
are formed by putting in some bath,which is generally a dilute sol-
ution of nitric and sulphuric acid. Some use a very strong oxidiz-
ing solution and thus have the peroxide formed on the plates while
in the bath. Under this head would come the Willard battery. For
this battery plates of pure rolled lead ,cut deeply on both sides,
are used. These plates are placed in the oxidizing solution and a
thick layer of peroxide is deposited on them,completely filling
the grooves. After remaining in the solution about four hours they
are washed thoroughly and given their charge. The plates are care-

Fig. 1.

fullyinsulated
from each other as
are the plates of
all batteries. In
this case corru-
gated hard rubber
separators being used,so per-
forated that the
electrolyte has
free circulation.

Fig.1. shows the
charge and dis-
charge curve of
this battery.

There are many other forms of the chemical cells,such as those we
manufactured by Planté,Elwell-Parker,Epstein,etc.

The Electro-chemical Storage Battery Co.manufactures plates as
follows: Plates of pure rolled lead are grooved by machine. They
are then placed in an oxidizing solution which attacks the plates,

Hours Discharge
Fig. 2.

after which a current is
passed through,filling
the grooves with pure
peroxide. The whole plate
is thus covered with per-
oxide which prevents any
local action between the
grid and electrolyte.

Fig.2.shows the dis-
charge curve of this
battery.

In order to have a large charging or discharging current, a large active surface is necessary. For this reason many investigators turned their attention in the direction of developing the largest possible active surface for a given weight. The improvements for this were naturally in a mechanical direction, such as making the lead plates porous.

Siemen used lead wires instead of a solid plate. He formed the lead wires by pouring molten lead through a cullender into water. The wires thus formed were rough and porous exposing a large surface.

The plates made by the Standard Battery Co.are made by mixing pumice-stone with the molten lead. This makes the plates very porous throughout their whole mass giving a very large active surface.

Another method to obtain a large surface is by using a series of thin laminea instead of a solid plate.
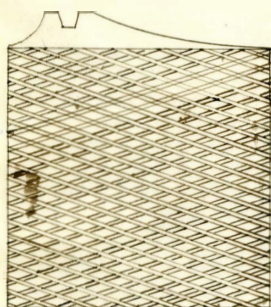
Fig. 3.

The New York Accumulator Co.makes plates in the form of a lattice as shown in fig. 3. These plates are made either by casting or sawing it out of a sheet of lead.

The Electrolytic method is another method of making the Planté plates. The plates made by electrolysis are divided into two classes. The first class are made by the electrolsis of lead salts. The second class by the eating away of lead salts. The method used for the first is to place lead sheets in a solution of lead in potassium and water or some similar bath and coating it with electrolytic lead by passing a current through it. For the second class, the general method is to use some salt of lead and reduce it by electrolysis.

Under this class comes the cell manufactured by the Chloride Accumulator Co. The method used by this company is as follows: Commercial lead is reduced to a fine powder, dissolved by nitric acid and precipitated by hydrochloric acid. The lead choride is then fused with zinc chloride and the molten mass poured into a mould forming pastelles about 5/16 inches thick. For the positive plates these pastelles are 3/4 inches in diameter, and for the negative plates they are 3/4 inches square. These pastelles are then placed in a mould and a lead-antimony grid is cast around them. Most of the chlorine is extracted by placing the plates between zinc plates and shortcircuiting them while in a solution of dilute zinc chloride. The remaining chlorine is removed by washing thoroughly in water. The plates are then pure spongy lead. The plates are formed by passing a current through them for two weeks. Lately this company has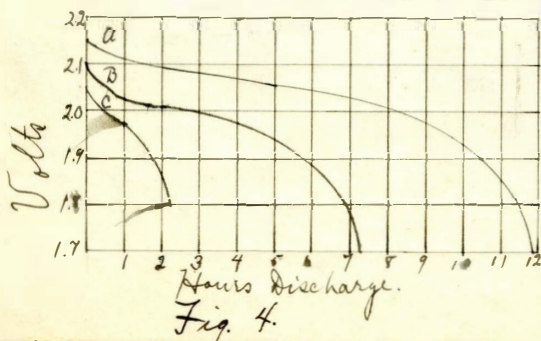 changed its positive plates by using a corrugated lead strip bent into a spiral and pushing them into the holes instead of using lead chloride pastelles.

Fig.4. shows the discharge curves of this battery. These are taken from a 70 ampere-hour cell charged with a constant current and discharged through a constant resistance. The curves A,B and C were

Hours Discharge.
Fig. 4.

taken when the cell was discharged in twelve,seven and two hours respectively.

The cells manufactured by the Chloride Accumulator Co.are probably the best and most widely used storage battery;particularly for large installations in central stations,where they are generally used as regulators.

At the time when the Planté cells were formed by a large number of reversals,which were very expensive both in time and energy, Metzgar and Faure claimed that,if the active material were applied mechanically,this expensive formation would be avoided. Accordingly they experimented along this line and the cells made by them have been so developed that the use of the two types of accumulators is about evenly divided;the pasted type being used mostly in Europe and the Planté type in America.

The Faure type has advantages in that the percent of active material is greater and so the cell takes a larger charge. The Planté type however on account of its greater mechanical strenth can stand a much more rapid and large current of discharge.

The paste used in the Faure type of cells is generally composed of some lead oxide and sulphuric acid;frequently some substance such as potassium silicate or powdered carbon being used to give it firmness and adhesiveness. In order to reduce the weight of the frames and give them firmer holding power,they are generally made in the form of a lattice or are deeply grooved. The frames are also frequently made of some alloy of lead. A practice which is coming into use among manufacturers,to make a very light cell, is to have the support of the active material made of some light nonconducting material. This support is generally porous, as unglazed earthenware.

A battery of this class is the Hatch battery,in which the earthware support has square holes on one side and straight grooves on the other side. The square holes are filled with paste,and the pasted sides of two plates are put together with a lead electrode between them. The grooved sides are placed together with the grooves at right angles to each other. Several of these are fastened together firmly to form one cell. This allows a good free circulation for the electrolyte. The discharge curve of a 100 A.H.cell discharged at a constant current of ten amperes is given in fig.5.
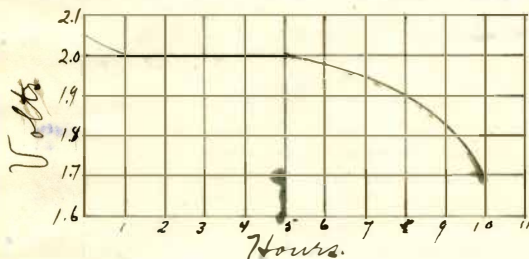
To avoid the falling out of the paste ,which was very troublesome in the Faure cells,the past-

Hours.

Fig. 5.

ed type,the plates were made in such a shape that it would hold the material as firmly as possible. A common form is that shown in fig.6. page 5.

Probably the form most commonly used is to have the plates perforated and so have the active material extend clear through the plates. It is better to have these perforations larger at the center than at the surface as shown in fig.8.or have them as in fig.9.
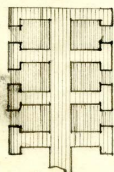

Fig. 6.

Fig. 8.

Fig. 9.

Cells have been made in which one or both electrodes are of some other metal than lead. Those in which copper is used have the advantage of being easily constructed. Their voltage however is low. The sals formed are also easily effected by other substances and so it is not nearly so reliable as the lead-cells. The electrolyte used for these cells is generally a solution of copper sulphate. These cells are of no practical value,being used merely in laboratory experiments.

Those batteries in which zinc is used in combination with lead are better. They are lighter than the regular lead cells and their voltage is considerably higher. The electrolyte used for these cells is zinc sulphate. Lately these cells have come into considerable commercial prominence.

A battery,which is very interesting theoretically,is the Marx Liquid Battery. Inthis battery the energy is stored in the electrolyte instead of the electrodes. The electrodes are generally carbon and the elecltrolyte has the following composition:

Perchloride of iron	-	-	-	-	- 450 grams.
Water -	-	-	-	-	-	- 900 grams.
Hydrochloric acid -	-	-	-	-	-500 grams.

When to large a current is passed through a cell,the current is not distributed evenly over the surface of the plate and unequal expansion of the active material takes place. This results in what is kown as buckling. When buckling occurs a short circuit soon follows in the cell. Buckling is due to the fact that when a cell is discharged,the paste expands,and when it is charged,the paste contracts. In order to prevent buckling, this expansion must be uniform over the surface of the plate. The chief advantage of the Planté cell over the pasted cell is its ability to allow the passage of a large current without buckling. There are several mechanical ways of avoiding this but no very sure way. A chemical method commonly used is to treat the lead oxide with sulphuric acid to cause it to expand and then dry it with heat.

THEORY OF THE STORAGE BATTERY.

Very little of a definite nature is known regarding the exact chemical reactions which take place in a storage battery. This is due to the great difficulties which are encountered in trying to determine the reactions. While the physical properties and qualities of a cell can be studied very accurately,the chemical properties cannot. The reason for this is that the materials are mixtures,and at the end they are also mixtures, and these mixtures are insoluble except in reagents which decompose them. Neither can they be volatilized or sent through a process of solution and crystallization to seperate orpurify the elements.

The general theory of the storage battery is quite similar to that of a primary battery. Infact a secondary batteryis a primary battery when it is charged,and differs simply in that the secondary battery can be brought back to its original condition after being run down by recharging with a current.

According to Duncan and Weigand the chief defects of the Lead-sulphuric acid battery of today are

    1. Loss of energy.

    2. Depreciation.

    3. Small storage capacity per unit of weight.

    4. Low rate of discharge necessitated by considerations of efficiency and durability.

The first two of these could undoubtedly be greatly lessened

were the theory of the storage battery better understood. As regards the third defect it may be said that during discharge, owing to the poor conductivity of lead sulphate, the action cannot proceed very deeply into the active material. This makes the actual weihgt of the plates very large compared with its capacity. The theoretical capacity per pound of peroxide and spongy lead is 50 ampere-hours, while plates of the highest capacity do not give more than 16 ampere-hours.

The last objection of the rate of discharge has been practically done away with in the last few years, particularly in the Planté type.

Crosby and Bell have divided the losses of a cell as follows:
1. The direct losses due to heating.
2. The losses due to local action between the supporting grid and the active material.
3. The losses due to local action in the active material.
4. The losses due to unreversed chemicalxx actions.

The chief cause of the first is due to the internal resistance of the cell.

The losses due to the third and fourth are by far the most serious. If the grids are thick and the plugs of active material are heavy and large, it has been found that the local action in the active material is large, because in a large mass, the same chemical action is not uniform and this'causes a difference of potential in the different parts of the same plug. The losses duetothe unreversed chemical actionsare caused by the formation of irreversable compounds and bythe electrolytic actions producing free hydrogen, oxygen, ozone and hydrogen peroxide. All these losses combined brings the efficiency of an ordinary cell down to about 70%.

The general theory of the storage battery is in brief as follows: During discharge both electrodes are converted into lead-sulphate with the extraction of suphions(SO_4)from the electrolyte, which reduces the density of the solution. The process on the positives takes place in two steps. First the peroxide(PbO_2) is reduced to the monoxide(PbO).

If the chemical actions during discharge were exactly the reverse of the actions during the charge the E.M.F.wouldbe the same for both charge and discharge. This however is not true. Proffessor Ayrton has found that the E.M.F.for about two thirds of the charge is nearly 0.14 volts higher than for the corresponding period of discharge. After this the difference increase continually. Taking into consideration the drop of potential due to the resistance of the cell,the E.M.F. for dischargex is


Fig.10.

still lower than the E.M.F. for charging.
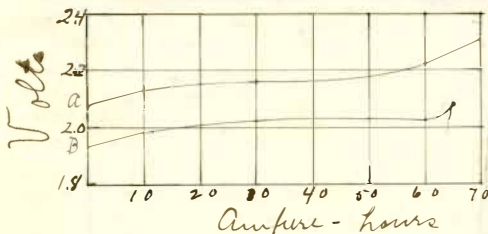
This xx is shown in fig.10. Curve A shows the E.M.F. for charging and curve B shows the E.M.F. for discharging. Curve B is expressed in ampere-hours remaining in the cell at any time, so that the point where the discharge is stopped corresponds to

emptiness or zero in the figure. This makes the curve of discharge backwards.

Messrs.Gladstone and Hilbert have proved that the E.M.F. of the cell depends on the strength of the acid used.

Fig.11. shows the results of their observations. In connection with this,Gladstone found that if the acid were very weak the chemical action was changed.
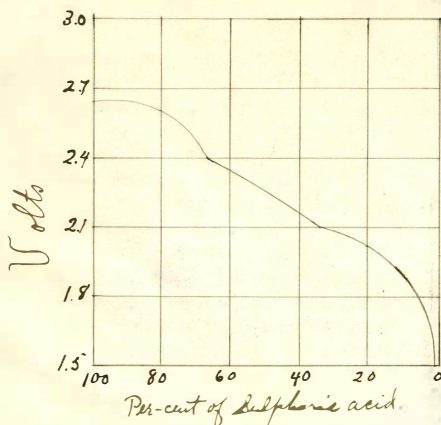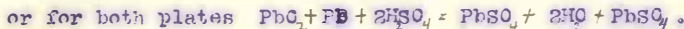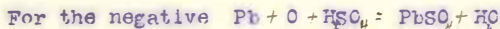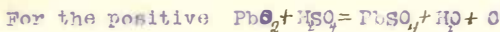
Per-cent of Sulphuric acid.

Fig. 11.

A mixture of yellow and puce-colored lead oxide being form-ed on the positvie plates and a white scaly substance being formed on the negative plates.

Mr. Griscom found that the E.M.F. of a cell depended partly on the degree of charge of the positive, partly on the negative, and partly on the electrolyte. For instance if the negative be taken from a fully charged cell and con-nected with the positive of a partially discharged cell the resulting E.M.F. will lie be-tween the E.M.F. of the two cells. Again if the plates from one cell be placed in a cell with an electrolyte of different density the E.M.F. in the new electrolyte will be higher or lower according as the density of the new electrolyte is higher or lower .

Investigators differ most radically as to what chemical ac-tion the energy of a cell is due. Dr. Streintz believes that the energy is due to the sulphating and neglects the secondary reactions, such as the evolution of free gases and the forma-, tion of hydrated lead peroxide. This is based on the fact that metallic oxides cannot exist in the presence of free acids. Dr. Darrieus however, believes that the sulphate on the positive af-ter discharge is a variable quantity and is due only to local action of the acid on the oxide and is not included in the principal reactions of discharge.

The generally accepted theory at present, is that the energy is due to the formation of lead sulphate at both electrodes as indicated by the following equations:

For the positive $PbO_2 + HSO_4 = PbSO_4 + H_2O + O$

For the negative $Pb + O + HSO_4 = PbSO_4 + H_2O$

or for both plates $PbO_2 + PB + 2HSO_4 = PbSO_4 + 2H_2O + PbSO_4$.

The final result then is the formation of lead sulphate and water by the extraction of sulphuric acid from the electrolyte.

Because of the poor conductivity of the coating of sulphate, only about 50% of the peroxide is acted upon. When about 31% of the peroxide is left, the sulphate prevents the action so much that the E.M.F. falls very rapidly. About this time also lead-peroxide begins to form on the negative plate and this also, causes a drop in E.M.F. If the circuit is broken this peroxide on the negative is reduced and this accounts for the increase in E.M.F. after the cell has rested for some time.

Sir David Salomons has divided the charging process into three stages as follows:

|	Positive		Negative
1st stage - - -	$PbSO_4$	$H_2SO_4 + H_2O$	$PbSO_4$
2nd. stage - - -	PbO	$H_2SO_4 + H_2O$	PbO
3rd. stage - - -	PbO_2	$H_2SO_4 + H_2O$	Pb

There are other secondary reations which come in with these
and probably the reations are much more complicated than indi-
cated. One action which takes place is the generation of gases
on the electrodes. Streinz and Neuman claimed that a large part
of the hydrogen and oxygen is occluded and that the occlusion
of these gases is the chief factor in the charge of a cell. Ac-
cording to this theory the E.M.F. would be due to the combin-
ation of the oxygen on the positive and the hydrogen on the neg-
ative. The E.M.F. developed however by the combination of hy-
drogen and oxygen is 1.5 volts,while the voltage of a lead-sul-
phuric acid cell is nearly two volts. There would therefore,have
to be more than the tension,produced by the occlusion of these
gases,to account for the electromotive force of a cell. Dr.
Frankland has also shown,that neither hydrogen or oxygen are
occluded during charging.

It is now generally assumed that the sulphuric acid breaks
up under the influence of a current into H_2 at the negative and
the sulphion (SO_4) at the positive electrode. According to the
present accepted theory of electrolysis,some of the sulphuric
acid will be already dissociated in the solution into its ions.
When a difference of potential is made between the plates,these
ions are attracted;the H_2 to the negative,and the SO_4 to the
positive electrode. As these ions are taken out,more sulphuric
acid is dissociated. Thus the water acts merely as a solvent
and is not,as claimed by some investigators,the chief factor in
the charge of an accumulator.

Some investigators discovered the presence of persulphuric
acid $H_2(SO_4)_2$ inthe cells after it had been charging for some
time. Its presence was explained as follows: The sulphion (SO_4)
cannot remain free and since under the circumstances it cannot
unite with the material at the positive plate it combines with
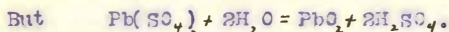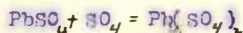the sulphuric acid thus:

$$H_2SO_4 + SO_4 = H_2(SO_4)_2$$
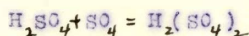
This may account for the high E.M.F. since $H_2(SO_4)_2$ is an
exothermic substance. This $H_2(SO_4)_2$ being very unstable reacts
with the water thus:

$$H_2(SO_4)_2 + 2H_2O = 2H_2SO_4 + H_2O_2 = 2H_2SO_4 + H_2O + O$$
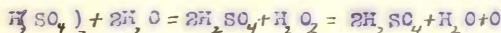
This also then accounts for the liberation of oxygen at the
positive electrode.

At the end of the discharge or the beginning of the charge,
there is a large quantity of $PbSO_4$ present and the free sulph-
ion combines with it to form lead persulphate $Pb(SO_4)_2$.

$$PbSO_4 + SO_4 = Pb(SO_4)_2$$

But $$Pb(SO_4)_2 + 2H_2O = PbO_2 + 2H_2SO_4.$$

Later in the charging process,part,and at the end,all the sulph-
ions combine with the sulphuric acid and this decomposing
liberates oxygen. On the negative electrode nascent hydrogen
is liberated and this acting strongly on the lead sulphate re-
duces it to metallic lead.

$$PbSO_4 + H_2 = Pb + H_2SO_4.$$
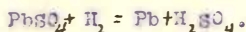
Towards the end of the charge,there being only a small amount

of sulphate, free hydrogen is given off.

Though other theories have been advanced and each has some point of strength, this last theory brought forth by Darrieus explains the actions of accumulators better than does any other and is the most generally accepted at the present time.

Time in hours from commencement of charge and discharge.

Fig. 12.

One thing which should help some in solving this problem is the change of temperature of the cell, during charge and discharge.

Fig.12.shows the change in temperature with respect to the time. Curve A shows the rise in temperature during charge and curve B the fall in temperature during discharge. If the reactions were entirely electrolytic the only heat generated would be that due to the resistance of the cell. Any other heat generated would be due to wasteful actions, such as the Joule effect, the currents set up by local actions in the plugs and the action between the active material and the support plates and the losses due to the electrolysis of the solution. It has been found that the average variations in capacity of a cell, whose temperature ranges from 0 to 22 centigrade, is about 1/2 of one percent for each degree change in temperature.

THE APPLICATION OF STORAGE BAT-

TERIES AND ACCUMULATORS.

A comparatively recent but very successful and economical use of the storage battery is its installation in central stations. Though as yet not very widely used for this purpose in this country, it is rapidly growing in favor among engineers, many of whom claim that it is the only solution of many problem and difficulties which are encountered in operating central stations. The use of storage batteries in Europe is quite common, over half the plants useing them.

The use of storage batteries for this purpose can be divided into four heads:

    1. To carry the peak of the load at maximum hours.

    2. To carry the entire load at minimum hours.

    3. To act as an equalizer or reservoir.

    4. For the equipment of an annex station.

1. To carry the peak of the load. In most all central stations a large part of the connected load is used only a small part of the twenty four hours. The period of maximum load lasts for only between 1.5 and 4 hours. In order to take care of this load some operators have set up cheap and inefficient machinery; but this is not very satisfactory.

In the case of the Boston station 90% of the output is produced by very efficient multipolar dynamoes. If a steam plant were installed to take care of 50% of the maximum load, which is only 10% percent of the total output, the station would be run-

ning at a very small load factor. This plant has however installed a large storage battery and so are able to run the dynamoes at a high load factor, for during light load the dynamoes are used to charge the batteries.

2. To carry the whole load during minimum hours. If the period of minimum load is long enough it is economical to shut down the machinery, draw the fires and let the batteries carry the whole load. Frequently one shift of men can be saved by this. This is done a good deal in Europe; but in America this period is to short to save a shift of men and so the batteries are generally charged during this period.

3. To act as an equalizer or reservoir. In central stations there is a continual change of E.M.F. due to the change in load. During light load the pressure is nearly constant but as the load increases additional dynamoes have to be started until the maximum load is reached. Ordinarily it is an hourly question whether to throw in or shut down a dynamoe to suit the varying load. If a storage battery is installed this number of changes is greatly reduced. In case of a sudden storm when the load would increase very rapidly, or in case of a breakdown the storage battery would take care of the load , which otherwise could not be handled properly, until more units could be started. In case of an extremely variable load such as an elevator or street car load there used to be a great deal of trouble at the central station; particularly a great wear and tear on the dynamoes due to the sudden changes in load.
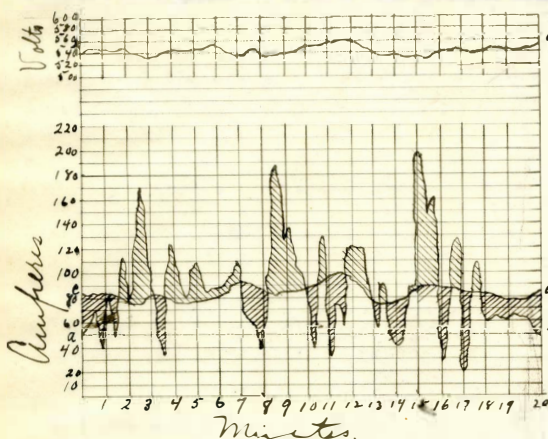

Fig 13.

If a storage battery is used in connection with the dynamoes it will take up the fluctuations and leave a nearly constant load on the dynamoes. Fig.13. shows how a storage battery evens out the load of a generator. In this figure ab represents the battery load curve, cd represents the generator load curve and ef represents the voltage curve. Were it not for the storage battery the generator load would be about like the storage battery load. While such chages do not hurt a battery they are very harmful to a generator.

Formerly an elevator load was considered a very undesirable load because of its fluctuating character; but now since the installation of a battery takes these fluctuations away from a dynamo it is considered a very desirable load because it is about the same throughout the day. Many large houses have installed batteries for the purpose of running elevators and in some cases "recuperation" is practised; that is, the car, in descending by gravity, restores a large part of the energy used in raising it.

4. For the equipment of annex stations. In cases where heavy currents were required at a long distance from the central station, it was customary to install a new plant or run very heavy lead wires to the point of consumption. In the later case there

was a very large loss due to the large currnet which pased;and
the wires had to be very large in order to accommmdate the max-
imum current which passed. This made the wire expense excess-
ively large. By placing a storage battery near this point of
consumption the losses due to heating and the large lead wires
can both be greatly reduced because in that case only an aver-
age current has to be passed,and this can be sent at a high
voltage by charging the cells in series and discharging in par-
allel.

One of the largest fields for the storage battery is the
field of telegraphy and telephony. As hinted at previously the
storage battery is rapidly replacing the primary cells in the
large offices. The advantages of the secondary over the primary
batteries are numerous. A storage battery requires only about
1/8 as much floor space and the corrosion creeping salts which
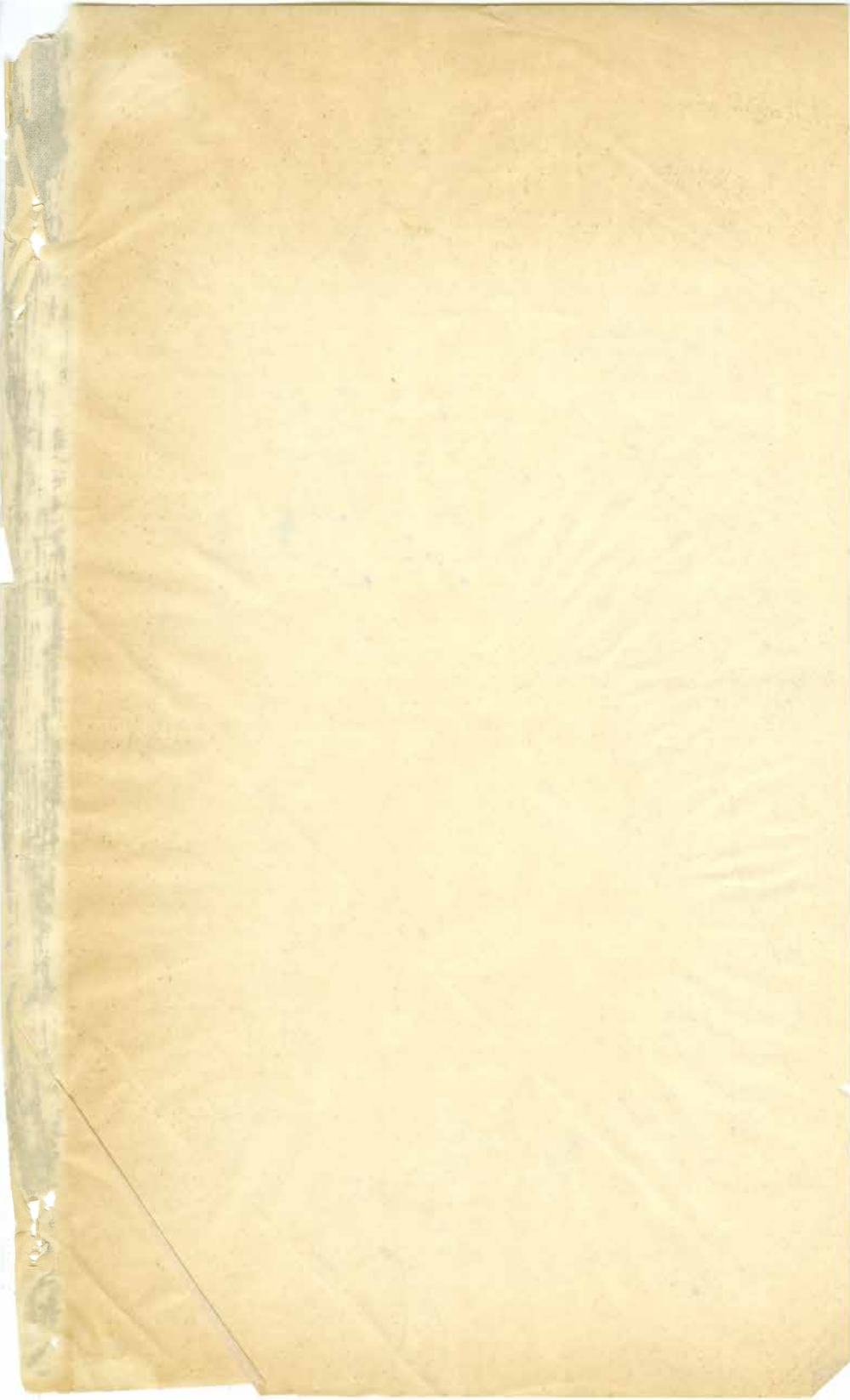attend the use of gravity cells is avoided.   cell

It has been estimated that the cost of maintaining a gravity
is $1.50 per year,while the cost of an equivalent amount of cur-
rent from a storage battery is only $0.14. The great flexibility
of an accumulator places it far ahead of an expensive series of
engines and dynamoes,in a telegraph office. In the office of the
Western Union Telegragh Co.700 chloride cells are now doing the
work of 3000 gravity cells. There are many similar installations
throughout this country.

Although a good many attempts have been made to run cars with
storage batteries they have not been successful in this country
with the possible exception of the Chicago - Englewood line.
Several lines are operated with,some success ,in Europe. The
chief disadvantage of storage battery traction is the weight of
the cells which in a car of about 10 tons weighs between 2 and
3 tons. One great advantage of this system however is that if
one car breaks down it does not effect the others. In a trolley
system,if one car breaks down it frequently happens that all
the other cars on that line are stopped. Then to by using the
storage battery system the dangerous and unsightly trolley and
the expensive conduit system are done away with.

It is claimed that where accumulators are used that for the
same amount of heat energy of the coal,20% more power is ap-
plied to the axle then in the trolley system. In spite however
of these and minor advantages the trolley system is cheaper
than the accumulator system.

Mr. Manville says,in regard to traction on English lines,that
the cost per car mile with accumulators is 18 cents and the
cost per car mile with the trolley system is 9 cents. Similar
results have been found in this country. Storage battery tracti-
tion will not probably be successful until a cell can be made
which,while it retains a large capacity,is lighter than those
of today.

On the other hand ,the application of accumulators to vehi-
cles is very successful;it having been found that this mode of
traction is very cheap in cities,in fact ,it is cheaper than
that by horses or anything else,and because of their conven-
ience and satisfactory results this field for storage batteries
is developing very rapidly.