'3 D

MODERN
PRIMARY BATTERIES

THEIR CONSTRUCTION,
USE AND MAINTENANCE.

Including Batteries for Telephones, Telegraphs,
Motors, Electric Lights, Induction Coils,
and for all Experimental Work.

BY

ugh

NORMAN H. SCHNEIDER.

Author of "Electrical Instruments and Testing," "Electric Bells, Annunciators and Alarms," "Care of Electric Plants," "Electrical Circuits and Diagrams," Etc., Etc.,

EIGHT THOUSAND.

NEW YORK
SPON & CHAMBERLAIN, 120 LIBERTY STREET.

LONDON
E. & F. N. SPON, LIMITED, 57 HAYMARKET, S.W.

1917

UNIVERSITY OF
ILLINOIS LIBRARY
AT URBANA-CHAMPAIGN

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

621.353
Sch5m

o. 5. Price, 25 cts.

.353
5m

MODERN
RIMARY BATTERIES.

THEIR CONSTRUCTION,
USE AND MAINTENANCE.

luding Batteries for Telephones, Telegraphs, Motors, Electric
Lights, Induction Coils, and for all
Experimental Work.

BY

NORMAN H. SCHNEIDER.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Entered according to Act of Congress,
By SPON & CHAMBERLAIN. 1905,
with the Librarian of Congress. Washington. D.C.

Entered at Stationers' Hall, London

CAMELOT PRESS, 226-228 WILLIAM ST., NEW YORK, U. S. A.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

621.353
Sch5m

PREFACE.

The following pages are intended for descriptions of battery cells and their use rather than for a study of electro-chemical theory. For those who do not understand the rudiments of electricity, No. 1 of this series has been written and contains a digest of all the elementary laws.

It has not been considered wise to give actual dimensions in many cases as such must be often governed by the facilities at hand. The reader who wishes to construct any of the cells described should be able to do so after reading the descriptions of them.

Descriptions of cells using "secret" formulas are omitted, it is above all desired to make the book of practical value.

It must be urged upon the battery constructor that the only way to obtain good results is to use care and pure material.

The reader is warned against expecting too much from batteries.

The cells invented for heavy work to replace dynamos have been innumerable and all failures.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

So complete is the knowledge regarding chemical means of current production that no wonderful invention can be expected in this connection.

The foremost inventors of the past and present have tried every known chemical combination and turned to other fields of activity.

The battery has many applications peculiar to itself, furnishing power for commercial purposes is not one of them.

Much valuable information on copper oxide cells has been kindly furnished by Mr. J. W. Gladstone. Illustrations and notes of interest have been received from the following: Mr. F. M. Dusenberry, of the Western Electric Company; Messrs. C. E. Lee and W. F. Abely, of the Electric Gas Lighting Company; The Gordon Battery Company; J. H. Bunnell and Company, and others.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

CONTENTS.

INTRODUCTION.

CHAPTER I.

CELLS FOR INTERMITTENT USE.

CHAPTER II.

ACID CELLS.

CHAPTER III.

COPPER SULPHATE CELLS.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

CHAPTER IV.

MISCELLANEOUS CELLS.

CHAPTER V.

SELECTION AND CARE OF BATTERY.

CHAPTER VI.

PRACTICAL NOTES.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

LIST OF ILLUSTRATIONS.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

INTRODUCTION.

NOTE: These introductory remarks need not be read by those possessed of No. 1 of this series.

It will be necessary before discussing practical details, to briefly mention the main points concerning galvanic batteries.

A current of electricity is manifested when two pieces of metal or one of metal and one of carbon are partly immersed in a fluid. The following conditions must, however, be fulfilled.

The metal pieces or plates must be of dissimilar metal, or one may be of metal and the other of carbon.

The fluid must be alkaline or acid and capable of attacking at least one of the plates.

The plates must not touch in the fluid and must be connected by a conductor of electricity outside the fluid.

Exceptions to the above are not of practical interest here.

Such a combination of two plates or " elements " is a cell; two or more cells, a battery.

In the majority of cells, zinc is used for the ele-

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

ment to be attacked, carbon for the one to remain unaffected.

The fluid of a one fluid cell is known as the electrolyte, this word being most used in storage battery work.

The zinc is termed the positive element but the negative pole. The other element, perhaps carbon, is the negative element but the positive pole.

The terminals of a cell are the binding screws to which are attached the outside wires. The terminals take the name of the pole to which they are attached. The zinc pole is thus the negative terminal, the carbon pole, the positive terminal. The algebraic sign + denotes the positive, the − sign the negative.

Current is assumed to flow from the positive element through the fluid to the negative element, thence through the outside conductor or circuit from the positive terminal to the negative terminal.

Opposition to the flow of electricity in a conductor is resistance and is measured in ohms. Conductors of *extreme* resistance are classified as insulators.

The rate of current flow is measured in amperes, the force with which it is caused to flow, in volts.

The term ampere-hour is used in denoting the output of a cell. One ampere-hour is a current of one ampere flowing for one hour, one-half ampere for two hours, two amperes for one-half hour would each equal one ampere-hour and so on.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Resistance offered by the outside circuit is external resistance, that offered by the fluid of the cell, internal resistance.

The term electromotive force or e.m.f. is used instead of voltage, " current " taking the place of amperage or rate of current flow.

Battery cells which are replenished by the addition of fresh chemicals and metals are primary cells.

Those which are reconverted by the application of electric current are storage or secondary cells. The latter are also known as accumulators.

A cell which is to be used only for a short period at a time is an " open circuit " cell. One that is so made that it will work the greater part of its life continuously is a closed circuit cell.

There is no absolute line of distinction possible as many cells are suitable for both purposes.

Where a battery is made up of cells connected, the negative of one to the positive of the other, the cells are in series.

If all the negatives are connected together and all the positives together, it is a multiple arrangement.

The series connection gives an e.m.f. equal to that of all the cells added together. The current will be that of one cell.

The multiple connection gives the e.m.f. equal to one cell, but the current of all the cells is added.

In the following descriptions of cells, many details of construction and proportions of chem-

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

icals are omitted. Such will be found in the chapters on construction and on the preparation of electrolytes.

It has been considered best to adopt this plan in order to avoid repetition. Much of the detail of one type of cell applies to other types.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

CHAPTER I.

CELLS FOR INTERMITTENT USE.

Carbon Cells. For work requiring intermittent current various combinations of carbon and zinc are used.

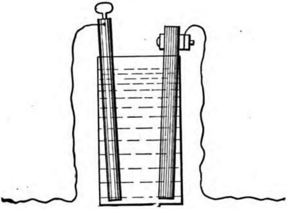

FIG. 1.

A plate of carbon and a rod of zinc (Fig. 1), immersed in a jar of salt and water will give current. The salt should be in the proportion of 6 parts salt to 16 parts water.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Sal ammoniac may be substituted for the salt with better results.

After a few minutes the cell ceases to work. Hydrogen gas has been liberated and forms a film over the carbon. It arrests the current by reason of the high resistance of hydrogen and also because the latter acts on the carbon to produce an e.m.f. in the opposite direction to that of the cell.

This opposing e.m.f. or counter e.m.f. is about one volt. The weakening effect is termed polarization.

The remedying of the polarization is depolarization.

Depolarization being the removal or destruction of the liberated hydrogen may be done in several ways.

First, it will take place if the cell is left on open circuit for a while.

Second, the carbon plate may be shaken in the solution or the latter may be stirred up.

Third, the carbon surface may be increased so as to lower the internal resistance of the cell and also lengthen the time before the plate will be covered with hydrogen.

Fourth, a chemical may be used to combine with the hydrogen. The latter is the best and most generally employed. Chemical depolarization will be treated of in descriptions of cells using it.

Commercial carbon cells have a large carbon

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

surface. This is obtained by making the carbon hollow and in the form of a cylinder or several cylinders each one inside the other.

The zinc rod may stand in the centre of the carbon, being kept from contact with it. Or it may surround the carbon being then in the form of a cylinder of thin sheet zinc.

Carbon Cylinder Cell. A typical carbon cell using sal ammoniac (Fig. 2) has a large cylindrical carbon with a slot cut in it for passage of the solution. This carbon is shown separately in Fig. 3. The zinc passes through a hole in the top of the carbon and is insulated by a porcelain bushing. The form of zinc has lugs on the sides near the top to prevent its falling too far down into the

FIG. 2.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

cell. The internal resistance of such a cell is .7 of one ohm, and owing to the large carbon surface, depolarization is rapid.

Fig. 3.

Earth Cell. A sheet of zinc and a sheet of copper several square feet in area may be buried in the earth and current obtained.

The earth at the location selected must be damp and the plates should not be more than six inches apart.

Connecting wires should be well soldered and at least of No. 12 B. & S. gauge. They should also be insulated between top of the plates and surface of the earth.

As it is best to sink the plates vertically, the tops may protrude about the surface.

In that case wires will not be in contact with the earth. The reason for avoiding this is that a short circuit would be formed between the plates.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

The e.m.f. will be slightly less than 1 volt, the current dependent upon size of plates and distance apart.

No more than one cell can be constructed for series connection as the effect of the moist earth is that of an electrolyte. And two cells placed in the same jar of electrolyte could not be connected to operate in series. The electrolyte would connect all the plates together in both cells.

Multiple arrangements can, however, be obtained.

Such a battery has been used successfuly to operate electric clocks.

A bag of carbon dust or coke may be substituted for the copper at a slight gain in e.m.f. but loss of current.

A sea water cell has been in successful operation at the end of an ocean pier.

A plate of zinc and a plate of copper (or carbon) were fastened in a frame, wires attached, and the frame lowered in the sea.

As the movement of the water washed off the hydrogen, such a cell gave fairly good results.

But in practice, a regularly constructed cell with containing jar and electrolyte would have done as well.

The absurd claim has been made for earth and sea cells by inventors or promoters that they collect electricity from the earth. If this were the case the plates would not be consumed, and certainly better results might be expected than are

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

actually obtained. The electric and magnetic influence of the earth alone is so weak as measured by the compass needle that it may be confidently assumed to be useless for purposes of electrical energy.

Leclanche Cell. The polarization defect of the simple carbon cell is remedied in the Leclanche cell, by chemical means.

Peroxide of manganese is used as a depolarizer in connection with the carbon element.

The name of this cell is the name of its inventor. The word should, correctly speaking, have an accent on the final *e*. But it is most generally omitted to simplify matters of printing or speaking.

The Leclanche cell (Fig. 4) was introduced in 1868, and since that time has not been replaced by a more efficient substitute.

It is made in several forms, the porous pot type being the most popular.

A carbon plate surrounded by a mixture of carbon dust and peroxide of manganese forms the negative element.

A zinc rod or sheet is the positive element.

A solution of sal ammoniac 4 parts, water 16 parts, forms the electrolyte.

The carbon and zinc element are kept apart in three ways. Carbon and manganese is moulded into blocks and two of these blocks fastened to each side of a central carbon.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

This style of construction is similar to that known in England as the agglomerate.

In another type, the Samson, the carbon is a hollow cylinder. The carbon-manganese mixture is filled into it, and the carbon element sealed.

FIG. 4.

When exhausted, the carbon may be emptied and filled with fresh mixture.

In another method of construction the carbon cup is fitted with a screw plug also of carbon, which can be removed when desirable to refill the carbon.

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

The porous cup type has the carbon and manganese compound contained in a pot of porous or unglazed earthenware.

The porous pot must be of such strength that it will hold the carbon and depolarizer, but be porous.

Other use it has none, in fact it only interposes resistance in the cell. In double fluid cells described elsewhere the porous pot separates the solutions. The Leclanche being a one fluid cell needs no separator.

For these reasons the porous pot may be replaced by a canvas bag or the carbon-manganese may be compressed into a block

FIG. 5.

Where intended for long service but small current output, the zinc is a rod (Fig. 5). But for large current the zinc takes the form of a cylinder or sheet bent around the porous part but not quite touching it.

The best results from a Leclanche cell are obtained when all the sal ammoniac is in solution.

Undissolved sal ammoniac will form crystals in the cell and weaken it.

Milky or opaque solution shows a need of more sal ammoniac.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

A cell working well gives off but little odor, when worked too hard ammonia gas is liberated quite perceptibly.

The salammoniac has a tendency to creep up the sides of the cell. To prevent this the top of the jar and the top of the porous pot are dipped in melted paraffin wax. Vaseline may also be used around the jar top for the same purposes. Care must be taken that none gets in the brass terminals or poor contact will result.

To prevent evaporation, some cells are furnished with covers.

Leclanche cells should be kept at an even temperature, not below 50 degrees Fahrenheit, or over 65. Water to make up for evaporation is added from time to time.

The action in a Leclanche cell is as follows: The chlorine from the sal ammoniac (ammonium chloride) attacks the zinc and forms zinc chloride.

The free ammonia passes into the peroxide of manganese, where the hydrogen liberated by the ammonia is converted by the manganese into water.

Depolarization is thus effected by the manganese.

The e.m.f. is about 1.5 volts, but the effective e.m.f. is only 1 volt in actual work.

When worked, the e.m.f. falls rapidly but will recover after a rest.

Cells temporarily exhausted will recover if allowed to rest on open circuit for a few days.

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Zincs must be kept clean, they should be removed and scraped bright at intervals.

As there is very little gas given off, cells may be sealed, leaving a small vent hole.

A short piece of $\frac{1}{8}$ inch glass tube passed through the seal or cover is sufficient.

Leclanche cells properly constructed of pure materials and set up with care, last a long time. On ordinary door bell work, they should last for at least one year; in many instances ten years has been the life of a cell.

During this period, however, new zincs were used and the solution was several times renewed.

In an emergency the porous pots may be made to work a while even when apparently exhausted.

They are soaked in hot water, and set to drain in a moderate temperature, being well exposed to air currents. This seems to renew the cell by action of the oxygen in the atmosphere on the manganese.

At any rate, porous pots should be scraped and washed clear of crystals when the latter accumulate.

In special types of Leclanche cells, provision is made for renewal of the depolarizer, the Samson cell is probably the best example of this.

The Samson Cell. This is one of the best commercial cells made on the Leclanche principle.

It differs from the older types of Leclanche cells in the construction of the carbon, the shape

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

of the zinc and minor details of binding posts and adjustment.

The carbon, Fig. 6, is shown upside down. It consists of a fluted hollow cylinder of French carbon provided with a removable seal at the lower end.

The depolarizing mixture of carbon and manganese is filled into the cylinder and the end sealed when furnished by the makers.

FIG. 6.

When the carbon element becomes exhausted, the lower end is heated over a Bunsen burner and the seal removed.

The exhausted mixture is poured out and fresh added, after which a cork stopper is inserted to close the hole. This operation can be performed

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

by anyone who cares to do so, the mixture being supplied ready for use.

The shape of the carbon gives a large surface, its grade is such that the hydrogen is readily liberated. The terminal is a bolt passing through a hole in the lug on top of the carbon.

The top of the carbon is of a denser material than the lower, resulting in a lessened liability of creeping salts.

FIG. 7.

FIG. 8.

A complete element of the No. 1 cell is shown in Fig. 7, a circular zinc being used and provided with insulating projections inside to prevent contact with the carbon.

The cell set up is in Fig. 8, which shows the correct level of the sal ammoniac solution.

The No. 2 cell is larger and the shape of the

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

zinc is modified so that it is held by the cover without needing insulating studs.

The No. 3 is the largest cell. The carbon element is here enclosed in a canvas bag which does not offer any undue resistance as is so objectionable in the porous pot types of cell.

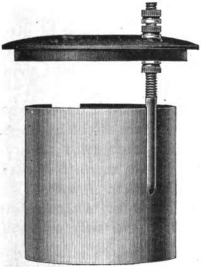

FIG. 9.

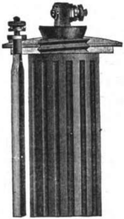

FIG. 10.

The zinc, Fig. 9, has a threaded bolt and nuts by which it is suspended from the cover.

The form of construction enables the zinc to be raised as it becomes eaten away, this action taking place more strongly near the solution level as in most cells using alkaline solutions.

Where a less current is required a flat rod zinc is furnished, as in Fig. 10.

This element fits the No. 2 cell before described.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

CHAPTER II

ACID CELLS.

Smee Cell. The elements are a plate of platinized lead or silver between two plates of zinc.

The electrolyte is water to which is added about thirty per cent. sulphuric acid.

In action the deposit of platinum on the lead or silver plate prevents adherence of the hydrogen to a great extent. At the same time the cell gradually polarizes and is not of more than passing interest. Its e.m.f. is less than .7 volt.

It was formerly much used for electroplating work, as it is easy to handle, has only one fluid and does not require attention.

More particulars of this cell will be found in the latter part of this book.

Grove Cell. This is a cell much used in the early days of electrical work on account of its great energy.

It consists of a platinum plate in a porous pot and a zinc plate in the outside jar.

The porous pot contains strong nitric acid, the outer jar, water 16 parts, sulphuric acid 5 parts.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Its e.m.f. is nearly 2 volts and current is very great.

Fumes are given off, and the cell is not recommended for use in a dwelling house. In most forms the zinc plate is bent around the porous pot and is about one-quarter inch thick.

Bunsen Cell. This is a modification of the Grove cell and is the forerunner of many forms of acid cells. Instead of platinum, a carbon rod *R* or plate, Fig. 11, is used in the porous pot *P*. The solutions are the same as in the Grove cell.

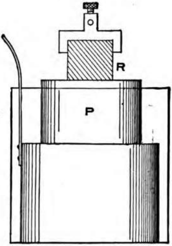

Fig. 11.

It gives off fumes which are very unhealthy.

In operation the nitric acid turns to a reddish tint and then green. Lastly, it becomes clear, at which stage it is exhausted and must be replaced.

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

The e.m.f. is about 1.9 volts and current large owing to low internal resistance and high e.m.f.

In both the Grove and Bunsen cells, the cylindrical form of zinc corrodes most inside; it must therefore be well amalgamated inside

Bichromate or Grenet Cell. The carbon-zinc combination in an acid solution of potassium bichromate is one of the most favored for experimental work. It is known as the Grenet cell.

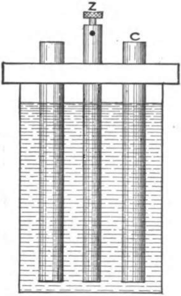

FIG. 12.

Fig. 12 shows a simple form of this cell. Two carbon rods *C C* such as are used for arc lighting have a copper wire soldered on one end of each.

If a coppered carbon is used, the copper must be entirely removed from the part which is immersed in the solution. At the dry end, the copper coating is left on which to solder the wire for connection.

A zinc rod *Z* amalgamated with mercury forms the positive element.

A Leclanche zinc rod may be used but one of greater diameter is desirable.

The electrolyte is composed of bichromate of potash dissolved in water, to which has been added strong sulphuric acid.

Where acid solutions are used, zincs must not be left in them when the cell is not in use. No amalgamation is sufficient to prevent the zinc being attacked.

A good way to hold the rods in this cell is to pass them through wood blocks, Fig. 13.

The block *W* is made large enough to reach across the jar and about one-half inch thick. Holes are bored in it through which the rods can be forced.

Before doing the latter, the block should be kept immersed in hot molten paraffin wax until it has soaked up as much wax as it will.

The time depends upon the density of the wood, generally a half hour is sufficient.

The block having been removed from the wax drained dry and become cold, the rods may be inserted.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Screws can be driven through the block to secure the rods if desired.

To obtain a large carbon surface and thus a greater current, a multiple element may be constructed.

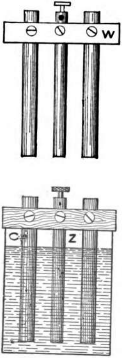

FIG. 13.

A wooden ring or cover is bored with a number of holes arranged in a ring around a central hole, Fig. 14.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

The holes in the ring are to hold carbon rods, the central one the zinc rod.

The wooden ring is to be soaked in paraffin wax or painted with asphaltum varnish.

All the carbons are to be connected together, thus giving a very large carbon surface. The carbon rods may have lead caps cast on them or be plated on the dry ends for attachment of wires. Details of both schemes will be given in a later chapter.

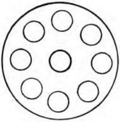

FIG. 14.

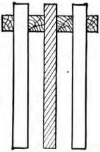

FIG. 15.

A more serviceable cell is made with plates of carbon and zinc as in Fig. 15. Here one zinc plate is held between two carbon plates.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

The current of the cell will depend upon the size of the plates and their nearness to each other. But at least one-quarter of an inch clear space must be left between the zinc and its attendant carbons to permit the gas to pass off.

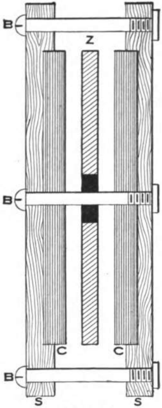

FIG. 16.

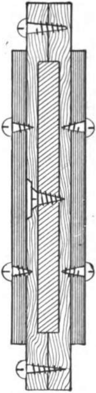

FIG. 17.

There are various ways by which the plates may be held. Fig. 16 shows a method of bolting the plates together with wooden separators.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Three brass bolts *B* are inserted through holes drilled in the wooden separators and plates. Wooden separators between zinc and carbons are not shown in the illustration.

The zinc plate *Z* has the hole much larger than that necessary for the bolt. A hard rubber bushing is fitted in this hole so that the bolt cannot make contact with the zinc plate.

The outside wood strips *S* are cut out so as to hold the carbon plates *C* and yet permit of a shorter bolt being used.

The wood must be thoroughly saturated with paraffin wax or insulating paint.

Another method shown at Fig. 17 is to use only two wood pieces and wood screws. The wood strips are here cut out to hold the zinc plate, a screw inserted through the wood and the zinc holds the latter in place. A screw at each end clamps the two pieces of wood together.

The carbon plates are drilled and simply screwed on to the outside of the wood strips.

Care must be taken that the screws do not penetrate the wood far enough to make connection between carbons and zinc. The strip should be long enough to reach across the jar used and support the elements by resting on the jar edges.

Connections to the zinc plates may be by means of a wire soldered on, or if the zinc be long enough, enough may project above the wood to admit of a bolt and nut being used.

The carbon plates may be also furnished with

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

bolts and nuts. Or strips of sheet copper can be laid between wood and carbon so as to be clamped tightly.

Bottle Grenet Cell. This is a very convenient form for coil work and is shown in Fig. 18.

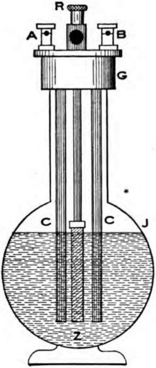

FIG. 18.

A bottle shaped glass jar *J* fitted with a cap of insulating material *G* contains the solution.

Two carbon plates *C C* are attached rigidly to

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

the cap and are connected together and to one binding post *A*.

The zinc plate *Z* is held at the end of a brass rod *R* which slides up and down, raising or lowering the zinc plate.

The brass rod is electrically connected to the second binding post *B*.

The solution fills the lower or globular part of the jar only. When it is desired to use the cell, the zinc is lowered into the solution by means of the rod.

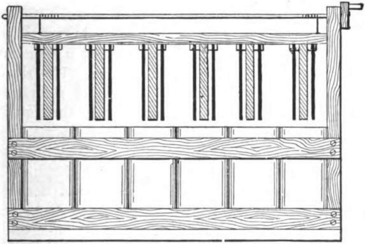

FIG. 19.

When the cell is not needed, the rod is pulled up, raising the zinc clear of the solution, and a set screw clamps it and prevents it slipping down.

A handy frame to permit of the removal of the elements is shown in Fig. 19. The jars are held

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

on a base board by strips of wood fastened at each end to uprights. The elements of each cell are made up separately as before described, and fastened to a strip of wood running lengthwise of the cells. This strip is provided with small metal chains which are secured to a spindle rod turning in the uprights. By means of a handle on this spindle rod, the entire element frame may be raised or lowered, thus raising or lowering the elements.

Another mode of construction is in providing each battery element with a hook but not fastening the element to the rising frame. The rising frame is below the wood strips to which the plates are attached, the latter passing freely through it. Raising the frame also raises the elements, but if desired to cut out a cell or two, the hooks on the cut out elements are caught over the spindle rod. The elements thus hooked do not descend with the frame and are disconnected from the battery.

Fuller Cell. The Fuller form of bichromate cell is shown in Fig. 20.

The carbon is generally in the form of a plate three inches or so wide by about nine inches long. But some Fuller cells are made up with four carbon plates suspended from a wooden cover. In this case all the carbons are connected together and give a large surface, thus decreasing the internal resistance and increasing the current.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

The zinc takes the peculiar form of a cone as shown in the figure. A copper wire is cast in the zinc so the connection may be good.

As zincs are attacked in greater degree at the portion near the top of the solution, this zinc is more uniformly used up.

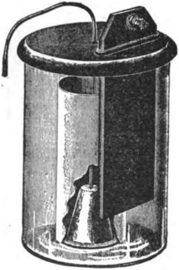

FIG. 20.

An ounce of mercury is poured into the porous pot to keep up the amalgamation. As the zinc is short, the mercury creeps up all over it and its amalgamation is good.

In the outer jar with the carbon, various solutions are used. Those suitable for bichromate cells are all suitable for the Fuller cell.

The most generally used is composed of 8 parts

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

of water, 1 part bichromate of potash, and 3 parts of sulphuric acid.

The porous pot containing the zinc is filled with water 7 parts, common salt 2 parts.

Although the Fuller cell is capable of giving a large current for many hours and over long periods, the fluids gradually mix.

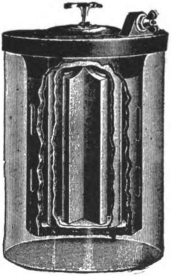

FIG. 21.

The Fuller cell was much used by the Bell Telephone Companies in connection with long distance work. The low resistance, high e.m.f. and consequent great energy fitted it for such services.

Low internal resistance is to be desired in cells for telephone work, especially where the conditions necessitate a considerable current output.

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

A Fuller cell with a large carbon surface is shown in Fig. 21.

Granule Fuller Cell. This is a special arrangement of the Fuller cell. The space around the porous pot is packed with crushed carbon which thus makes connection electrically with the carbon plate.

The effect is to greatly increase the carbon surface and to reduce the internal resistance of the cell.

The porous cup containing the zinc is nearly filled with water to which is added two ounces of sal ammoniac and one ounce muriatic (hydrochloric) acid.

The outside jar contains one of the bichromate solutions given elsewhere.

This cell gives an e.m.f. of about 1.9 volts and a large current.

It is suitable for induction coil and motor work, also for lighting small lamps.

Practically no fumes are given off while in operation.

Sulphuric acid can be substituted for the muriatic acid to reduce the fumes, but they are not objectionably strong. Sulphuric acid is not as good for results as muriatic acid.

The zinc may be the Fuller cone shape, a rod, a plate, or for heavy work a cylinder of thick zinc exposing a large surface.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Chromate of Lime Cell. This cell has a jar and a porous pot and two fluids.

In the porous pot is placed a carbon rod or plate. Broken or crushed carbon is packed around the rod or plate, and if desired, melted sealing wax or pitch may be run over the top for sealing. If the porous pot is sealed, a hole must be left for introduction of liquid.

A cylindrical zinc is placed in the outside jar surrounding the porous pot.

The fluid for the porous pot is made as follows: 2 parts chromate of lime is dissolved in 5 parts of water, and 5 parts sulphuric acid added.

In the outside jar water 16 parts, sulphuric acid 3 parts.

The current is large and the cell is suitable for the same uses as the Fuller.

But the porous pot must be emptied when not in use, although the same solution may be used frequently.

Practically no fumes are given off by this cell.

Iron-Carbon Cell. In many cells iron may be used instead of zinc, the e.m.f., however, will be less. In an iron-carbon cell the following gives fair results.

A porous cup holds a piece of thick iron plate in a solution of nitrate of soda, sulphuric acid and water.

The outer vessel containing the carbon is supplied with water only.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

The two liquids gradually filter through the porous pot and lower the internal resistance of the cell.

The e.m.f. is a trifle less than 1.5 volts.

Iron-zinc Cell. A zinc plate is placed in a porous pot containing water 16 parts, sulphuric acid 3 parts.

The porous pot stands in an outside jar containing a circular sheet of iron bent around the porous pot.

Strong nitric acid is used in the outside jar, acting on the iron plate.

In another form the iron plate is replaced by an iron vessel in which the porous pot stands. Connection is made to this iron vessel as in the case of the plate.

This cell does not fume until the acid becomes weak.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

CHAPTER III.

COPPER SULPHATE CELLS.

The Daniell Cell is one of the most constant cells for practical use, but its e.m.f. and current are both low.

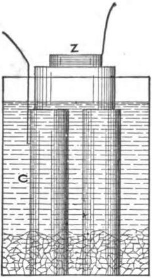

FIG. 22.

It consists, Fig. 22, first of a zinc cylinder *Z* in a porous cup nearly filled with water. A few

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

drops of sulphuric acid or a teaspoonful of zinc sulphate is often added to hasten action.

A copper sheet *C* is contained in the outer jar and surrounds the porous pot. The copper sheet is as thin as can be conveniently made to stand without curling up. A form of zinc much used in Fig. 23.

FIG. 23.

In some forms the copper plate is placed inside the porous pot and the zinc outside it, the solutions of course being also reversed.

This arrangement is not good for the reason that the larger the copper surface the better the depolarization.

If the cell is to give a small current for a long period of time, copper sulphate crystals should be packed between the copper sheet and the porous

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

pot. Copper sulphate is also packed in between the copper and the outside jar walls.

This, although increasing the life of the cell, also increases its internal resistance.

If a larger current for a shorter period is required, a saturated solution of copper sulphate is used in the outside jar.

If zinc sulphate is added to the solution in the porous pot, the resistance is somewhat increased and the current diminished.

But the cell remains at a steady output for a longer period than when sulphuric acid is used.

Daniell cells are intended for use on closed circuits of high resistance such as telegraph lines and burglar alarms. They are not of much use in telephone work or the operation of small motors.

But a number of cells may be used to charge small storage batteries, the number being calculated taking 1.07 as the e.m.f. of the Daniell cell.

As the resistance of a storage battery is low, at least four cells of Daniell will be needed to one storage cell.

The easiest way to find out the exact number required is to put an ammeter in series with the charging circuit and adjust the number accordingly.

Working of a Daniell Cell. The action that takes place in the Daniell cell is as follows:

The copper sulphate is decomposed into sulphuric acid and copper. The copper is deposited

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

on the copper plate, the latter therefore becoming thicker as the cell is worked.

The sulphuric acid attacks the zinc and forms sulphate of zinc which is mostly dissolved and held in solution in the porous pot.

After a time this zinc sulphate solution becomes very strong and increases the resistance of the cell.

A quantity of it is to be dipped out and replaced by water.

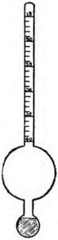

FIG. 24.

A hydrometer, Fig. 24, is used to determine when the solution is too dense.

This is a weighted glass tube with a bulb at the lower end. The stem is marked to show how much denser a liquid is than water.

As the solution gets dense, the hydrometer rises

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

just as a body which would sink in water would float in oil.

The principal objection to the Daniell cell is that the porous pot becomes clogged with copper and often cracks open.

Gravity Daniell Cell. The principal commercial form of Daniell cell is the one in which the porous pot is dispensed with.

The solutions are kept apart by gravity.

Fig. 25 is a Gravity Daniell or gravity cell, as it is most generally called. *C* is the copper, *Z* the zinc.

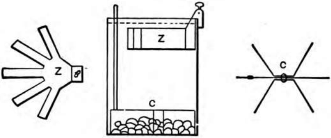

FIG. 25.

The copper is made of a number of thin leaves of copper riveted together in the centre and having an insulated wire attached.

The leaves are opened out into a star form as shown on the left of the figure and stood on edge at the bottom of the cell.

The corners of the copper are bent over in a

Digitized by Google

Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

similar manner to that is known as dog-earing the leaves of a book.

A pound or so of copper sulphate is poured over the copper, the bending of the copper corners serving to anchor the copper in among the crystals.

The quantity of sulphate varies with the size of the cell. In a large jar four pounds is used, the idea is to cover the copper leaves at least one inch above their edges.

The zinc is made in several shapes, the form shown being the "crowfoot." It has a lug projecting from the top provided with a hole and screw for connection of the wire. This lug hooks over the edge of the jar as shown in the figure.

Water is poured into the jar until the zinc is covered for an inch or a little less.

If the cell is to work at once, a few drops of sulphuric acid or a teaspoonful of zinc sulphate is added.

If not for immediate use, the zinc and copper of each cell are connected together, that is, short-circuited. They are left on short circuit for some hours, often over night.

The chemical action is the same as in the porous pot type. The peculiarity of this cell, however, lies in the fact that as the copper sulphate solution is heavier, it remains near the bottom of the jar.

When the cell is working at its best, the top solution will be colorless and the bottom solution deep blue. The division of the two solutions

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

should be clearly visible and at least an inch below the zinc.

If the cell is not worked enough, the blue solution will rise and copper will deposit on the zinc in a dark muddy paste.

The gravity cell should always be left working through a few ohms resistance.

The e.m.f. of the gravity cell is the same as that of the porous pot type, that is, 1.07 volts.

Its current is very small, rarely exceeding one-half to one ampere.

Gravity cells must never be allowed to freeze. In fact, they give a greater current if kept warm.

A very large current has been obtained from gravity cells by keeping them standing in a hot water bath.

Gravity cells are variously termed "Crowfoot," "Gravity," or Callaud cells.

Wasteless Zinc. This form of zinc was invented by M. George D'Infreville.

It is called the "wasteless," because it is possible to use up the stubs by forcing them into the hole left in the under side of each zinc, Fig. 26.

This form of zinc is used by nearly all the telegraph companies and is the only noticeable improvement in gravity batteries made in recent years.

Crowfoot Zinc. The Crowfoot zinc, Fig. 27, is much used in fire alarm and telegraph work, but

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

has been replaced in many places by the wasteless zinc. The lug shown in the figure hooks over the edge of the jar.

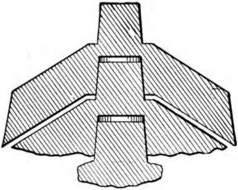

FIG. 26.

Thomson Gravity Cell. This embodies a method of construction whereby the internal resistance is much lowered.

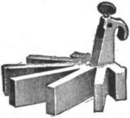

FIG. 27.

Fig. 28 shows a section of one cell in which *P* is a porcelain or glass dish such as is used for photographic developers. *C* is a thin copper

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

plate with a wire attached, laid on the bottom of *P* and covered with crystals of copper sulphate.

Small porcelain insulators are placed at each corner, and if a large plate is used, in the centre also.

Upon these insulators is laid a zinc plate *Z*, which has been wrapped in one fold of canvas, parchment paper, or (wool) flannel.

Water is poured into the tray covering the elements and the cell is put on short circuit for an hour or so.

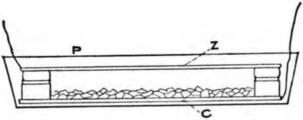

FIG. 28.

The distance between the top of the crystals and underside of the zinc may be about one inch.

A number of tray-cells may be made and mounted one on top of the other.

The foregoing general directions can be modified to suit circumstances; a battery made up on this plan is excellent for charging small storage cells.

Instead of using a porcelain tray and copper sheet, lead trays will answer admirably. They are made out of thin sheet lead and the copper sulphate is poured over the bottom. The lead

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

forms a ready connection and soon becomes copper plated.

If a number of trays are made, a long strip of lead may be bent up from the lead tray and fastened to the zinc of the next cell. Or a lead lug may project from the bottom of one tray to make connection with the zinc below it.

At the same time, when the cells make series connection by their own weight it becomes difficult to clean them. They have to be lifted apart one by one.

The e.m.f. is the same as that of a gravity crowfoot cell, but the current may be from 5 amperes upward.

The current depends on the size of the plates and their nearness to each other.

Semi-dry Daniell Cells. The gravity cell is most inconvenient to carry about when charged, in fact, it is impracticable to do so as it is usually made.

To render it portable some means must be provided to soak up the solutions.

In the Minotto cell, before adding water, the bluestone is covered with a piece of cloth or blotting paper. Over this is placed a layer of sand or sawdust two or more inches in thickness.

A second piece of cloth or blotting paper is then put on top of the sand or sawdust and the zinc block laid on top of it.

Water, being now added the cell is left on short circuit for several hours. Or zinc sulphate may

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

be added to the water as in the case of the gravity cell.

The internal resistance is thus very high and the current very small rarely exceeding one-twentieth of one ampere.

A simple form of portable cell or rather battery may be made by using flat plates of thin zinc and thin copper.

Pieces of blotting paper are cut the same size as the plates. One piece is soaked in copper sulphate solution and laid on a copper plate.

A second piece is soaked in zinc sulphate solution and laid on top of this, and a zinc plate is placed so as to cover the zinc sulphate moistened blotting paper.

A number of simple cells may be made in a similar manner and laid on top of each other in series.

The bottom of a copper plate will then lie on top of a zinc plate and make contact with it. Of course no blotting paper must separate the zinc of one cell from the copper of the next.

When the cell becomes dry it may be dipped in water and drained. Or new soaked blotting paper may be used.

A battery made on this plan will have quite a low resistance if the plates are large.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

CHAPTER IV.

MISCELLANEOUS CELLS.

Lalande and Chaperon Cell. The copper oxide cell introduced many years ago by Lalande and Chaperon is a most excellent cell for work requiring constancy of current.

Cells of this type require practically no attention, give off no fumes, and as the internal resistance is low, furnish a large current.

The e.m.f. is low, being about .68 volt on actual work.

The cell consists of a positive element of zinc and a negative element of black oxide of copper. The electrolyte is caustic soda dissolved in water.

When working the zinc is attacked by the caustic soda forming zincate of sodium. The oxide is liberated from the copper salt which gradually becomes entirely pure copper. The oxide plate thus becomes more conducting and the internal resistance of the cell is bettered.

As the atmosphere would act on the caustic soda and form carbonate of soda, a layer of heavy paraffin oil is poured over the top of the solution.

In the early days of this cell, an iron vessel,

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Fig. 29, was used to hold the solution. Copper oxide in powder was poured in to cover the bottom. Connection being made on the iron gave connection also to the copper oxide which was in contact with it.

The zinc in the form of a hollow cylinder was supported in the centre of the cell but insulated from the iron.

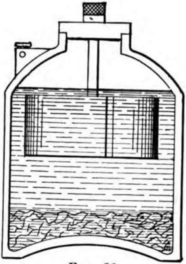

FIG. 29.

A cell of this type may be readily made by using a sheet iron can such as is used to hold canned articles of food. It is to be absolutely tight at the sides and bottom and to be well cleansed.

A copper wire is riveted or soldered to the can to form a connection.

The bottom is covered with black oxide of copper to a depth of two or three inches.

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

A zinc block such as used in the gravity cell is suspended from a wooden support so as to hang within an inch of the oxide layer. The small "wasteless" zinc is excellent for this purpose.

The part of the zinc passing through the surface of the solution is to be painted with asphaltum varnish.

The cell is to be filled with caustic soda 1 part and water 4 parts.

A layer of heavy oil is then poured over the liquid surface.

The solution must not cover the zinc entirely, enough of the latter must protrude from the solution to admit of wire connection.

Another way is to put the copper oxide in an open iron box *B* fitted with a copper wire for connection. The iron box rests on the bottom of a glass jar, Fig. 30, in which hangs the zinc block *Z*.

The nearer the zinc is to the oxide, the more current will be obtained as the resistance of the soda solution is lessened.

Caustic potash may also be used instead of the soda.

When the oxide is all reduced to copper, the cell ceases to work. The copper may then be removed, washed and dried.

It can be roasted on an iron shovel over a gas stove and reoxidized by action of the atmosphere.

The cell may also be reconverted by connection

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

to a direct current circuit as is done in the case of a storage battery.

The positive terminal of the cell which is the copper oxide element, is connected to the positive terminal of the charging circuit.

Sufficient resistance is interposed to keep the charging current at its proper value.

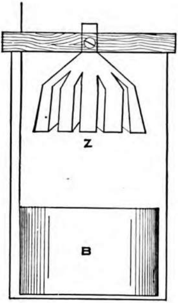

FIG. 30.

Full directions for charging storage cells will be found in works devoted to the subject.

Reconversion of the copper oxide cell by the above means is not recommended as it leaves the zinc in a very spongy condition.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Gladstone Lalande Cell. A more practical form of the Lalande Chaperon cell is the Gladstone Lalande Fig. 31.

The copper oxide is made into plates which are held in the cell by a framework of copper. This framework is fastened to the cell cover and is so constructed as to admit of the plates being changed when necessary with but little trouble.

In the older form of the Lalande cell, the copper oxide plates are held in the frame by screw clamps and nuts. In this type a spring clamp is used to facilitate quick changes of plates. Details of this frame and clamp will be understood upon reference to Fig. 32 and Fig. 33. The frame is formed of copper rod bent to shape and has a flat copper spring clamp riveted across it. The oxide plate is laid on this and the detachable clamp locked across the frame by a few simple movements.

FIG. 31.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

The surfaces being large make good contact and require practically no cleaning.

Fig. 32.

Two zinc plates connected together are placed, one on each side of the oxide plate. A lug on each zinc plate passes through a hole in the cover and is bolted to a shoulder on the cover top.

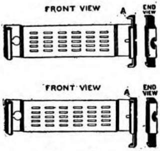

Fig. 33.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

This form of zinc is shown separately in Fig. 34. Another mode of construction employs a **U**-shaped hanger which carries the zinc plates and is in turn suspended from a bolt provided with lock nuts and a terminal for wire connections.

The cell shown before in Fig. 31 has the zincs thus suspended, the illustration is of the G 30 or 150 ampere-hour cell with enameled steel jar.

FIG. 34.

In the larger sizes, two oxide plates are used. Fig. 35 shows the elements and Fig. 36 the complete 300 ampere-hour cell known as G 60.

The copper oxide plates of the Gladstone Lalande cell may be partly regenerated by being removed, washed and exposed for a few hours to free currents of air. A reabsorption of oxygen takes place and the plates recover about 20 per cent. useful life. This operation will often be of service in a case where it is not possible to obtain new plates immediately.

The electrolyte is caustic soda 1 part, water 4 parts. Formerly caustic potash was used in stick form, but the powdered soda is far more readily dissolved.

FIG. 35.

It has been found from repeated tests that caustic soda gives better results and does not freeze at temperatures when the potash would be useless.

A layer of heavy paraffin oil poured on top of the solution prevents formation of sodium carbonate by the atmosphere.

In order to lower the resistance of the oxide plates and hasten the full effect of the cell, the

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

plates have a thin coating of reduced copper on their surfaces.

The caustic soda will attack the zinc more at the point where the latter enters the solution. For this reason the zinc is thicker at the top than lower down.

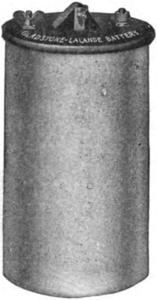

FIG. 36.

The oxide plates must always be below the level of the electrolyte. A one inch layer of oil and electrolyte is sufficient between the top of the oxide plate and the surface of fluid.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Gordon Cell. The Gordon cell, Fig. 37, is one of the Lalande group but uses the oxide in powder. The latter is contained in the perforated iron box suspended from the cover. A large circular zinc surrounds the oxide element and owing to its large surface and position lowers the internal resistance of the cell. The zinc is supported as shown on porcelain insulators fixed to the oxide can.

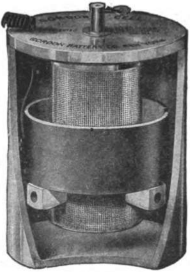

FIG. 37.

Nungesser Cell. The general type of this form of Lalande cell is shown in Fig. 38. The copper oxide is contained in the cylindrical copper can shown suspended in the centre of the zinc.

The zinc is a hollow cylinder hanging from thread-

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

ed bolts by means of which new zincs are attached when necessary.

The elements of copper oxide and zinc are so proportioned that both are exhausted and require renewal at the same time. To renew the copper

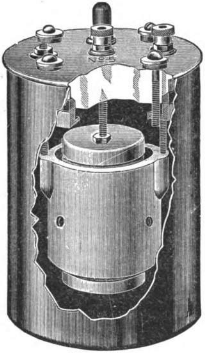

FIG. 38.

oxide, the copper can bottom is removed by unscrewing a nut and the old powder poured out. It will be found in a metallic state when entirely exhausted. New oxide powder is poured into the can, the bottom replaced and the zinc attached to its supports.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

The solution is renewed at the same time, care being taken not to get any of it on the hands or clothing. An animal or vegetable oil applied instantly to the spot will destroy the corrosive action; mineral oil will not answer, as it will not combine with caustic potash or soda.

Bennett Cell. The Bennett or tin pot cell is somewhat similar to the Lalande only that iron shavings are used instead of copper oxide.

The elements are zinc and a perforated sheet iron vessel holding the shavings.

The electrolyte is caustic soda or caustic potash 1 part, water 4 parts.

The e.m.f. is slightly under one volt.

An efficient cell may be made as in Fig. 39, where *B* is a sheet iron (tin) can of convenient size, perhaps 4 inches high by 1½ inches in diameter. Holes are drilled or punched in it so as to make it resemble a sieve.

If a number of these cans are to be prepared it is a good plan to fit a cylinder of wood to enter the can freely. The punch or pointed tool will then make the holes without bending the can out of shape.

An element made up of iron gauze is preferable but not so easy to construct.

The can has two or more heavy copper wires fastened to it at the top by rivets. These wires come through holes in the wood cover *C*, and

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

are for connection as well as to hold the can suspended.

The latter is filled with coarse iron filings, clippings or shavings. If greasy they must be washed in hot soda and water.

The zinc *Z* is preferably a circular one as the current will be greater. At the same time a rod zinc will answer only it gives less current.

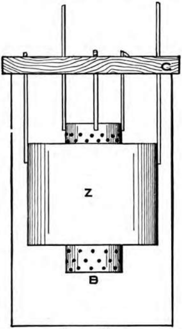

FIG. 39.

Another method of construction is to use a shallow iron can about two inches or so high in which to place the filings. This lies on the jar bottom and has a copper wire attached. The zinc in this case may be a "wasteless" zinc and hang from the top of the jar. The can must be lap-jointed, not soldered.

A third form employs a porous pot but gives less current.

The porous pot is packed around with filings into which is an iron or copper plate for connection. The zinc stands in this porous pot.

The caustic soda is poured into both jar and porous pot.

Harrison Cell. This is practically a lead-zinc storage cell and can be either recharged from a source of current or replenished mechanically.

The negative element consists of a lead rod around which is compressed a block of peroxide of lead (litharge).

In the large sizes this block is perforated with holes to expose a greater surface to the solution.

The zinc is made in two forms. In Fig. 40 the zinc is cast on the end of a copper rod. A deep groove surrounding this rod holds a quantity of mercury.

This mercury keeps up the amalgamation of the zinc, which is necessary as the electrolyte is dilute sulphuric acid.

The zinc is also used in small pieces lying on a copper dish or over a copper flat spiral at the bottom of the jar.

A quantity of mercury is poured over the zinc

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

pieces which are taken up by the mercury forming a paste or amalgam.

The copper wire or dish forms the connection to the zinc element.

The e.m.f. of this cell on open circuit is nearly 2.7 volts, its effective e.m.f. on a circuit of high resistance about 2.3 volts. From this it drops rapidly until exhausted.

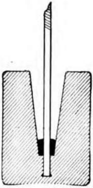

FIG. 40.

For work requiring large current and where a steady e.m.f. is not necessary, it is an excellent cell.

It may be reconverted by attaching it to a direct current circuit as in charging a storage cell. The practical directions for this are out of place here.

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Red Lead Cell. A powerful cell may be constructed by mixing equal parts litharge (dry red lead) and permanganate of potash.

This is then worked with a stick or non-metallic rod into a paste with hydrochloric (muriatic) acid.

The paste is filled into a porous pot which contains a central carbon plate provided with a terminal. When set the porous pot is placed in a jar containing sulphuric acid 1 part, water 4 parts. and a lead plate for the other element.

Such a cell can be reconverted by direct current as in storage cell charging.

Hussey Bisulphate Cell. This is an improvement on the cell which was used in medical apparatus and operated with bisulphate of mercury.

It consists of a cylindrical carbon standing in a glass or rubber jar. The carbon is hollow and holds loosely a porous cup.

A zinc is suspended in this porous cup. Bisulphate of mercury is poured between the carbon and porous pot. The entire cell is then filled with water.

Aluminum connections are used as they are less liable to corrode.

The e.m.f. is 1.5 volts and current large. It is a constant cell and of use for closed circuit work.

Nesselrode Cell. The carbon in a porous pot is packed with carbon dust one part and permanganate of potash two parts.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Over this is poured a solution consisting of water 16 parts, chlorate of potash 6 parts, formaldehyde 6 parts.

The e.m.f. is 1.4 volts, the internal resistance low. It stands well on open circuit.

Permanganate of potash is somewhat insoluble and although tried in cells of the Fuller type, was rejected for that reason. It makes but a poor substitute for bichromate or chromic acid.

Chloride of Silver Cell. This cell was much used for testing and medical batteries but has been largely replaced by small dry cells. The e.m.f. is 1.19 volts.

A cell can be made using glass cells, or the zinc may constitute the containing vessel, as in a dry cell.

A glass tube about three inches high by one inch in diameter, closed at the lower end, is provided with a good cork, Fig. 41.

A sheet of thin zinc three inches by two inches is rolled up to fit the inside of the bottle. A connecting wire being soldered to the zinc, the latter is inserted in the bottle and expanded to fit the inner wall.

A layer of melted paraffin wax is poured in so as to cover the bottom for one-half of an inch and hold the zinc from shifting.

A piece of silver foil similar to that used in the Smee cell, but not platinized, is cut three inches long and two inches wide. A piece of thin

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

blotting paper the same dimensions is coated for about one-sixteenth of an inch with the following paste:

Chloride of silver is mixed with sufficient water to form a paste and unslaked lime added in the proportion of 1 part lime to 24 parts silver chloride.

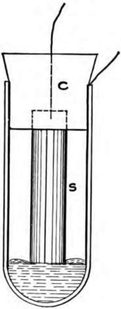

FIG. 41.

The silver foil to which a wire has been soldered is laid on the blotting paper paste side and the sandwich rolled up with the silver in the inside.

A strip of cambric or India muslin is wrapped around the roll for two turns and tied with cotton thread. This roll *S* is inserted in a hole cut in the cork *C* so that the lower end just reaches the

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

cell bottom. The wire comes through the cork, the roll may be held securely by pouring a little melted paraffin wax over the cork end.

The silver-cork combination is inserted in the tube with which has been poured enough water 16 parts and sal ammoniac 1 part to fill it without running over.

The cork also should hold the zinc cylinder in position, the latter coming up to the top of the tube and being wedged in place by the cork. A seal of paraffin wax completes the cell.

Standard Cells. Standard cells are designed to give a uniform e.m.f. of fixed value. They are used for comparisons of e.m.f. and for calibrating measuring instruments.

It is not intended that a Standard cell shall be allowed to give at any time much more than one one-thousandth of an ampere. The internal resistance is often as high as 600 ohms.

The two best known forms of these cells are the Clark and the Weston.

The Clark Cell. The Clark cell is much used in England and is made under specifications of the British Board of Trade.

It consists of a rod of chemically pure zinc as one element, mercury as the other. A platinum wire immersed in the mercury makes the electrical connection to the latter.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

The electrolyte is a saturated solution of zinc sulphate and mercurous sulphate in water.

The e.m.f. is 1.434 volts.

The directions for making this cell as laid down by the British Board of Trade are most minute.

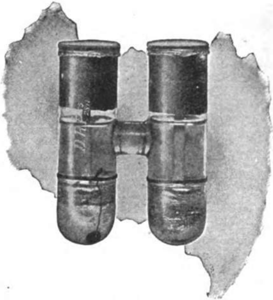

Fig. 42.

Almost every detail is specified. A full account may be found in Kempe's Handbook of Electrical Testing.

The Weston Standard Cell. In the United States the Weston cell is more generally used, in fact, it bids fair to be universally adopted.

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

It is the invention of Dr. E. Weston of electrical instrument fame.

The general outline of the Weston cell is shown in Fig. 42, the form of *H* tube of glass being used.

At the bottom of each leg, Fig. 43, is a small quantity of mercury into which is inserted a platinum wire sealed into the glass.

Lying on top of the mercury in one leg *A* are crystals of cadmium sulphate. The mercury in this leg contains cadmium. In the other leg *B* is mercury and mercurous sulphate.

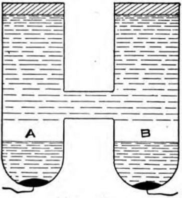

FIG. 43.

The cell is filled with a solution of cadmium sulphate in water.

Its e.m.f. is 1.019 volts.

Standard cells are generally equipped with a thermometer, the Weston cell, however, changes but little through ordinary variations of temperature.

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

CHAPTER V.

BATTERY SELECTION AND OPERATION.

Selection of a Battery. The selection of a battery suitable for the particular circumstances under which it must work is vitally important.

A battery made for intermittent work is useless on a closed circuit.

Cells of the carbon-zinc type with alkaline solutions are mostly for operating door bells, annunciators and light work with long periods of rest.

The copper-zinc combinations with copper sulphate solution can be used for bells but they are most efficient when a small current is being taken from them constantly.

For light closed circuits such as burglar alarms and telegraphs the latter are most suitable.

Lalande cells or all using copper oxide and caustic potash (or soda) are excellent on bell work and for closed circuits as well.

In fact, if large enough they are suitable for the heaviest closed circuit work that any battery can perform, such as running motors, lamps or induction coils.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

For heavy service where large currents are needed but where the elements can be dismantled or otherwise left free of the solution, the Grenet type are indicated.

The open circuit and closed circuit services do not strictly include all.

The terms really apply to the conditions under which the battery is left when not actually in use.

For example, although a Grenet cell is meant for heavy work it would not be left on a closed circuit as is the gravity Daniell cell.

Neither would the Lalande cell because it does not need to have current flowing to maintain the elements and solutions in good condition.

Convenience is another point to be considered.

It is certainly inconvenient to set up a Grenet or Fuller cell for a few experiments and then take it apart, clean it and lay it away for future use.

At the same time, experimenters who are willing to do this can secure a large current output at a comparatively small cost.

Where a heavy current becomes necessary at a moment's notice but at long intervals, the Lalande cell stands at the head of the list.

It is always ready and does not deteriorate if left without attention for weeks at a time.

And it will equally well furnish a small current as for bell work; in fact, it is here to be preferred provided the first cost is not prohibitive.

Very large cells made up on the order of the Leclanche need no attention to speak of and are

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

available for heavy currents for short periods For the experimenter they possess some advantages, but it must always be remembered that they soon weaken no matter how large they are made, and require a rest to recuperate. For electric gas lighting and heavy bell work the class with sheet zincs of cylindrical form are preferable.

Grenet type cells using iron instead of zinc have a lower e.m.f., the only advantage is a lesser expense.

Chromic acid is preferable to bichromate of potash but is not always so readily obtained.

Bichromate of soda from its greater solubility is preferable to the same salt of potash, and it does not form crystals of chrome alum.

Salt in the porous cup of a Fuller cell gives a lower efficiency than dilute sulphuric acid, but a slightly longer life.

Batteries for Gas Ignition. The ignition of gas or vapor in the internal combustion engines used in launches, automobiles, and work of the same class is generally accomplished by an electric spark.

The spark is either made in the engine cylinder by breaking contact between two metal pieces or a high tension spark jumps an air gap.

In either case a battery and induction coil of some sort is needed.

The work is severe, the number of contacts per minute being governed by the number of explosions

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

needed. The dry cell has met with great favor in this connection, as it is not disturbed by jolts and is convenient. But it does not last for any great length of time on heavy work. Cells of the Lalande type are excellent and can be sealed. They are put up by various makers in enameled steel jars with waterproof caps. Their greatest advantage is that they maintain a steady force up to the time when they give out entirely. The point when the latter occurs can be observed upon inspection of the cell as the zinc or oxide plates will show how much has been consumed.

The Bennett battery can be sealed and is of use for this class of work, but the Fuller or Grenet cells are not.

Leclanche cells of large size with large zincs give good results if looked after. A dry cell is only a Leclanche with a large zinc surface, low internal resistance and an absorbent to hold the fluid.

For stationary engines, the fluid cells have no disadvantages of spilling or leaking.

There are no valid reasons other than those mentioned against using large Leclanche cells of low resistance in place of dry cells.

Output of a Battery. Current strength depends upon the e.m.f. of the cell and its internal resistance. This is also true of a battery made up of a number of cells and arrangement of cells into

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

batteries must always be done with consideration of the work to be performed.

The ideal condition is when the internal resistance of the battery equals the external resistance of the circuits.

At any rate the external resistance must be higher than the internal resistance of the cell.

Take the case of a cell the internal resistance of which is one ohm and its e.m.f. two volts. It might be supposed from Ohms law that the current on short circuit would be two amperes and the output four watts. On a short circuit although the current might for an instant be two amperes, the e.m.f. would drop so low that the two amperes would not be effective to do any useful work.

Just as soon as the cell is put on work the e.m.f. drops in proportion to the external resistance.

In speaking of the e.m.f. of a cell, that on *open circuit* is meant, but this is not the effective e.m.f.

E.m.f. is used up in a cell causing current to flow through its internal resistance. This e.m.f. is not available in the outside circuit and therefore is to be deducted.

In all calculations of battery circuit resistance the internal resistance of the cell must be added to the external resistance of the circuit.

It will be seen why a cell with a low internal resistance gives greater energy. First, because but little e.m.f. is needed in the cell itself, its e.m.f. therefore drops but little. Second, the internal

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

TABLE I.

Internal resistance and e.m.f. of standard types of cells.

Cell.	Open circuit e.m.f. Volts.	Internal resistance Ohms.
Carbon cylinder, alkaline	1.25	.7
Leclanche, porous pot form	1.45	1.2
Samson No. 1	1.45	.15
,, No. 2	1.45	.10
Gravity Daniell, wasteless zinc	1.07	.7
,, ,, crowfoot zinc	1.07	2.00
Gladstone-Lalande, G10 and G80	.95	.09
,, ,, G20, G30, G36	.95	.07
,, ,, G50, G90	.95	.043
,, ,, G56, G60	.95	.025
,, ,, G70	.95	.020

The current output in amperes is not figured in this table. By Ohms law it should equal the e.m.f. divided by the resistance. In practical work a cell is not used on short circuit but with an external resistance added. And the e.m.f. of certain cells drops on working the cell on account of chemical changes.

The drop of e.m.f. which occurs in proportion to the current output is discussed elsewhere.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

resistance being low there is but little to add to the external resistance.

That this is important will be seen if the battery is, for example, two ohms and the outside circuit one ohm. Here the total is three ohms and the cell uses up two-thirds of the total e.m.f.

On the other hand, let the cell be two ohms and the external circuit 198 ohms.

Total resistance will be 200 ohms.

The cell resistance is only one-hundredth part of the total and only requires a like proportion of the total e.m.f. to force the current through it.

Ninety-nine-hundredths of the total e.m.f. are therefore available for useful work in the outside circuit.

This may easily be studied by connecting a high resistance voltmeter across the cell terminals and varying a resistance in series with the cell. As the resistance changes so will the indicated e.m.f. change.

The cell resistance is of course constant, but its proportion to the rest of the circuit must vary. And the e.m.f. of a part of a circuit must be dependent upon the proportion which that part bears to the whole.*

It is impossible to give more than approximate details of the current output of any cell. The e.m.f. is generally of a fixed value but the internal

---

*See Chapter II "Study of Electricity for Beginners" No. 1 of this series.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

resistance varies. A little more acid, a larger plate or closer arrangement of the plates and the internal resistance is lowered.

It is more than probable that in a battery each cell will give a different current output.

It would be possible to calculate beforehand the results to be expected, but the mass of figures and research necessary would be discouraging.

Cells of different construction must not be connected together except under almost prohibitive conditions.

If in series the resistance of each would have to be the same. If one were of a higher resistance than another the current would be decreased.

In multiple connection, the e.m.f. of all must be equal or the higher cells would suffer.

Care of the Battery. Cells should be covered to keep out dust and other foreign matter and lessen evaporation. This applies very strongly to Leclanche cells and those not giving off fumes.

Gravity cells have the surface of the solution often covered with a layer of heavy oil as in the Lalande type. It prevents evaporation and creeping of crystals up the sides of the jar.

Glass jars are preferable to earthenware except those made especially to withstand the action of acids. Cracks in the glaze of earthenware will soon ruin the cell.

Hard rubber or ebonite is good for jars and is much used for portable cells.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Jars for the Leclanche and gravity types must be paraffined for a couple of inches from the top. The mouths of the jars are dipped into melted paraffin wax and drained of superfluous wax. Sometimes when inconvenient to re-wax jars, vaseline may be smeared around the top sides of the jar inside.

Connections must be clean and tight.

There is no more important rule tending to efficient battery service than this one. Total failure of a battery can often be traced to a corroded wire or terminal. And a screw not set home, leaving a loose wire may cause a break in a circuit most difficult to trace.

Wires used for connecting up cells must be large enough. The e.m.f. being generally low, the output of the battery will be much impaired by the use of a small wire. For bell work, a No. 14 B. & S. is not too large.

For experimental work with Lalande or Grenet cells a No. 12 B. & S. is suitable. If only a few cells are used and situated at a distance from the apparatus operated nothing smaller than No. 12 is permissible. There is no reason in choking down the power before it gets to the point where it is to be used, by too small wires.

Solutions. In dissolving the salts used in the various cells described, warm water may be used to advantage. But the solution must always be cold before being used in a battery cell.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Bichromate of potash dissolves very slowly and water will not take up much of it. It should be powdered before being dissolved.

Chromic acid dissolves readily, as do sal ammoniac, common salt, sulphate of zinc, sulphate of copper, when crushed, and bichromate of soda.

Solutions must on no account be mixed in metallic vessels, glazed earthenware is preferable. If glass be used it may crack when mixing acid solutions.

Solutions must not be stirred with metal spoons, glass rods are best. If wooden sticks be used the same stick must not be put into solutions of different salts. Wood is apt to char, particularly in acids. An electric light carbon uncoppered makes a good stirring rod.

Sulphuric acid is *always* to be added to the water in a thin stream. Never pour water into sulphuric acid. Intense heat suddenly evolved would probably cause an explosion. Stir the water while the acid is being poured in; the solution will get quite warm.

Sulphuric acid for the acid cells should be of 1800 degrees specific gravity. This is actually 1.8, but it is customary to omit the decimal point and express the figures as above. Sulphuric acid used in storage battery work is generally 1200 and contains 30 parts acid to 70 parts water. Weak acid in a primary cell means less energy; in some cases it may be preferred as the zinc will last longer. The output of course is de-

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

creased. For handling battery solutions and acids a syringe, Fig. 44, of hard rubber is useful.

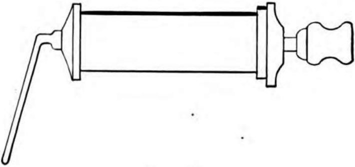

Fig. 44.

The long bent nozzle admits of removing fluid from the bottom of the cell.

SOLUTIONS FOR GRENET AND FULLER TYPE CELLS.

Trouve's Solution consists of bichromate of potash 3 parts dissolved in 16 parts of water to which is then added 8 parts of sulphuric acid.

Bottone's Solution. Chromic acid 6 parts, chlorate of potash one-third part, sulphuric acid three and one-half parts.

Swan Solution. Chromic acid 3 parts, nitric acid 1 part. This gives off but little fumes.

Chromic Acid Solution. Chromic acid 10 parts, water 10 parts, sulphuric acid 4 parts. This is a

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

very strong solution and is suitable for work where an intense current is needed.

Grenet or Electropoion Solution. Bichromate of potash 3 parts, water 16 parts, dissolved with heat, then 2 parts sulphuric acid is added.

Hydrochloric Acid Solution. Hydrochloric acid 10 parts, water 16 parts, bichromate of potash 5 parts.

Bichromate of Soda Solution. Bichromate of soda 4 parts, water 18 parts, should be very hot. Add when cool, 3 parts sulphuric acid.

Red Sand. Sulphate of soda 14 parts, bichromate of potash 30 parts, sulphuric acid 70 parts.

The soda is to be dissolved in the acid which should be quite hot. The potash (powdered) should be then stirred in slowly. The mixture when cool will crystalize. When cold break it up as needed. To use, dissolve 1 part of the red sand in 5 parts water.

All of the foregoing solutions are for the jar containing the carbon in the Fuller and Grenet cells.

When the carbon and zinc are in the same vessel the solutions may be diluted with water about 10 per cent. of water being added.

Bunsen Solution. The solutions were given for this cell in the section describing it. But a solu-

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

tion which fumes but little if any is made as follows: Nitric acid 1 part, chromic acid 3 parts, sulphuric acid 6 parts, water 5 parts. It is actually a Grenet solution and may be used in Grenet cells.

Chromate of Lime Solution. For outside jar. Water 16 parts, sulphuric acid 3 parts. For porous pot: Chromate of lime 2 parts dissolved in warm water, sulphuric acid 5 parts.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

CHAPTER VI.

PRACTICAL NOTES ON CELLS.

Amalgamation of Zinc. Zinc plates must be amalgamated, that is, have a coating of mercury on their active surfaces. This is to prevent as much as possible destruction of the zinc owing to impurities in it.

Zinc is manufactured combined with mercury, but it is not always available.

To prepare a zinc element, first clean it thoroughly with a rag dipped in dilute sulphuric acid. Then pour a teaspoonful of dilute acid over an ounce or so of mercury contained in a saucer or non-metallic vessel. Stand one end of the zinc in the mercury and with the rag mop up the mercury over the zinc surface. It will spread rapidly and leave a bright and shining face to the zinc.

The mercury can also be spread on by dropping it in globules on the cleaned zinc surface.

Muriatic acid is excellent for cleaning zincs before amalgamation. If very dirty or greasy they should be washed in hot soda and water.

After amalgamating, wash off all acid with water.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

The process by which zinc elements are produced with the mercury incorporated in them is as follows.

The zinc is melted, and while in a molten state about one per cent of powdered resin is added.

FIG. 45.

The mercury is then poured in slowly in the proportion of one part mercury to 16 parts zinc and the alloy is stirred.

FIG. 46.

The mercury becomes mixed with the zinc and the alloy may be poured into iron moulds.

It should be removed from the moulds before

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

cooling, just as soon as it sets, which will be seen to have taken place when the surface dulls.

Care must be taken not to drop or strike zincs thus alloyed, as they are very brittle.

If more convenient the proportion of mercury may be reduced to one-half of the above, but the alloy is not so effective in strong acid solutions.

Working Zinc. Thin sheet zinc can be cut with a pair of shears and may be easily bent when heated in boiling water.

Thick cast or rolled zinc is best cut by scoring a groove where the parting is desired and filling the groove with mercury. In a few minutes the metal will become brittle enough to break at the groove. All bending of zinc must be done before amalgamation, otherwise its brittleness will cause it to snap.

If thick zinc is to be drilled or tapped use turpentine to lubricate the drill or tap. It will not clog as much as if oil is used.

Forms of Zincs. Fig. 45 is a zinc for use in gravity cells and is known as the Boston fire alarm zinc. Fig. 46 is the Baltimore pattern of gravity zinc. In both cases they are adapted to hang from the edge of the jar.

Carbons. For small cells, round plain carbons may be used, the cored carbons are not suitable. Coppered carbons must be scraped clean of copper wherever they enter solution.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

For larger cells carbon plates can be procured from all dealers in electrical supplies. The large carbon manufacturing companies keep in stock a large variety of sizes and shapes.

Circular carbons present a large surface and are also made in stock sizes furnished with lugs for attachment of connectors.

The upper portion of all carbons used in battery cells must be impregnated with a moisture repellent such as paraffin wax. Otherwise the solution would rise and attack the metal terminals.

Although wax is a highly non-conducting substance, its use in this way does not seem to increase the cell resistance to any appreciable extent.

The grade of carbon has much to do with the results obtained.

In order to prevent as far as possible adherence of hydrogen gas and consequent polarization, carbons should present a large surface and be rough.

A smooth polished carbon surface would soon be covered with hydrogen gas, a roughened surface enables it to disperse freely.

Binding posts or connectors are applied to carbons in various ways.

In some cases the carbon is drilled and bolts with nuts and washers employed, Fig. 47, there is always then a liability of their working loose.

The mechanical details of this mode of connection have been the subject of much study and this tendency to loosening considerably lessened.

Large bolts and large washers are essential;

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

both the gripping and contact surfaces are then improved.

The older forms of Leclanche cells have lead caps cast on them in which is also cast a threaded bolt to hold nuts for clamping wires, Fig. 48.

In the case of home made batteries this method can be employed to advantage.

The top of the carbon is first filed to a wedge shape or partly drilled with a few large holes. This ensures the grip of the lead casting.

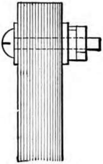

FIG. 47.

Moulds are then made either of hardwood if for a few carbons, or of casting sand or even clay.

The bolt being set down in a hole with a portion of the bolt projecting, waste is packed around it in the hole to prevent the lead from getting on the thread where the nuts will be screwed.

The carbon, top end down, is set into the mould a hole being drilled if preferred for the bolt and the lead poured in.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Or the carbon may be held upright and a mould built around it of asbestos and wood into which the lead is poured.

In any event the carbon end with its lead cap is to be immersed in melted paraffin and kept in it for a few minutes.

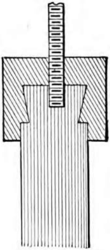

FIG. 48.

The superfluous wax is to be scraped off the bolt or poor connections will result.

Where a carbon is to be used without a lead cap or other metal coating, it may be waxed as follows:

The end of the carbon to be waxed is held in a blue gas-flame until quite hot. It is then plunged into wax or a piece of wax held against it until it ceases to smoke.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

The heat applied in this way seems to cause the wax to penetrate the carbon more readily than if the latter be simply dipped.

Electroplating Carbons. A saturated solution of copper sulphate is poured into an earthenware or glass jar. Crystals of the sulphate may be spread over the bottom if many carbons are to be plated.

A plate of clean copper is bent in the form of the letter **U** and placed in the jar, one end having a wire attached.

The carbon is then inverted into the solution so that its part to be plated stands between the legs of the **U** but does not touch the copper.

The copper plate is connected to the carbon plate of a battery cell and the carbon in the jar to the zinc of the same cell.

Copper will be deposited on the carbon and the thickness can be regulated by the length of time the current is allowed to flow.

It is not advisable to use more than two or three volts e.m.f. for plating the carbon or the copper deposit will be rough and easily removed.

When sufficient copper is deposited, the carbon is removed, washed, and dried. The wire can then be soldered on to this copper shell.

Platinizing Silver. The thin silver plate for a Smee cell may be prepared as follows:

The plate should be of thin silver foil about five one-thousandths of an inch or less in thickness.

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Cut it to size and lay each piece one at a time in a porcelain dish or a soup plate mounted over a flame. A gas jet or alcohol lamp will answer.

A solution of chloride of platinum is poured over the silver and the dish is kept warm until the silver is thoroughly coated.

The silver foil is then removed and dried.

When used it is hung from a strip of hard wood, or clamped between two strips. Connection is made by also clamping the end of a copper wire or a strip of sheet copper to which a wire has been soldered.

A good size for the sheet is 5 inches long by 3 inches wide.

Copper Oxide Plates. Copper oxide plates for Lalande cells may be made as follows:

Mix 16 parts black oxide of copper, 1 part chloride of magnesium and 1 part oxide of magnesium into a paste with water. Bend up a tray the desired size of the plate from iron wire gauze. The latter must be unpainted and clean.

Lay the tray on a smooth surface and spread a layer of the paste over the bottom of it. Bend a length of No. 14 B. & S. copper wire into a flat spiral, lay it on top of the paste and work on more paste to the level of the gauze tray edges A length of the wire is left at the top for connections.

Smooth off the surface and leave to set in a warm place.

Trays of sheet iron or copper, may be used

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

instead of the iron gauze if desired. In the latter case projecting lugs may be left, the plate then being fixed to a battery cover as in the case of the carbons of a Grenet cell. An oxide plate goes on each side of the central zinc.

Testing the Battery. In testing the e.m.f. of a cell with a voltmeter the instrument must have a high resistance or there will be a drop of e.m.f. across it.

The voltmeter should measure 100 ohms per volt for accurate work and not less than 65 ohms per volt for ordinary tests.

Many of the testing instruments on the market are inaccurate for this reason. The error is not so pronounced in testing cells of low internal resistance such as storage cells, but for primary cells it is often considerable.

The importance of testing the e.m.f. of a cell is evident when it is considered that one cell which has deteriorated in a battery will reduce the output of the battery not only by its own subtraction, but by adding resistance.

A simple method of comparing the e.m.f. of a number of cells is as follows:

A cell known to be in good condition is taken as a standard and connected in reversed series with another cell and a voltmeter. By reversed series is meant that the carbon of one is connected to the carbon of the other.

If both cells are equal the voltmeter needle will

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

not move. The e.m.f. of one cell being in opposition to the e.m.f. of the other, if both are equal no current flows through the circuit.

Any movement of the voltmeter needle will be due to the difference between the two e.m.fs.

As it is not necessary in this comparative test to ascertain the exact difference, a simple galvanometer will answer.

Such can be readily constructed by winding 20 to 30 turns of fine insulated wire over and around the case of a compass parallel with the needle. The wire may be of No. 36 B. & S. or finer.

A testing outfit of a good cell and simple galvanometer is quickly made and will take the place of an expensive instrument.

Practical tests to determine the efficiency of a cell are made first on open circuit and second, across the terminals while the cell is working through a known resistance.

Where a reliable voltmeter is at hand fulfilling the above conditions as to resistance many tests may be made of great value.

For testing current an ammeter is desirable but not absolutely necessary, as the voltmeter may be used.

A resistance coil of known value is put in series with the cell. The e.m.f. is measured across the ends of this coil. By ohms law the current flowing is found by dividing this e.m.f. by the resistance of the coil.

For example, let the coil measure three ohms

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

and the e.m.f. across it be one volt. Then one divided by three is one-third, or one-third of one ampere.

It is always a bad plan to put any cell on a short circuit through an ammeter except in the case of a cell of known high resistance such as the gravity Daniell.

To find the internal resistance of a cell, there are several methods, these can be studied in any large book on testing.*

One of the simplest for cells of high resistance is as follows:

First note the e.m.f. on open circuit.

Then put in series with the cell and voltmeter a coil of known resistance sufficient to reduce the e.m.f. to one-half that on open circuit.

The resistance of the voltmeter must be known.

To calculate, add the resistance of the coil to the resistance of the voltmeter and subtract *twice* the resistance of the voltmeter.

The answer will be the internal resistance of the cell.

For example, let the voltmeter be 100 ohms and the coil 106 ohms. Then $100+106 = 206$, and this less twice 100 equals 6 ohms.

To test the efficiency of the cell, it is put on a circuit which is alternately opened and closed. The circuit contains a resistance which in the case

---

* Kempe, Handbook of Electrical Testing; Schneider, Electrical Instruments and Testing.

Digitized by Google Original from UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

of the primary cells described may be about one-half ohm.

The circuit is closed one-half the time by means of a motor or clockwork attachment.

Readings of current and e.m.f. are taken periodically and plotted on paper ruled in small squares. The plottings or dots are connected by a line which forms a curve and shows graphically the performance of the cell.

A rough test is often made by connecting up a bell with the cell and noting how long it rings.

Combination Switch. There are cases, especially in experimental work, when it is desired to make various combinations of battery cells without unclamping or disconnecting a lot of wires. For instance, if the battery is all connected in series, and a multiple arrangement becomes necessary, the handling of wires in a large battery would be considerable.

There have been several switches designed for this purpose, but none is capable of much variety of combination. That is, without the switch be extremely complicated and therefore unreliable.

A switchboard which is quite adaptable although not automatic in any respect is shown in Fig. 49.

The one in the figure is for eight cells of battery but the number for which it can be made is practically unlimited. It operates on the peg principle in a similar manner to the telegraph switchboards.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

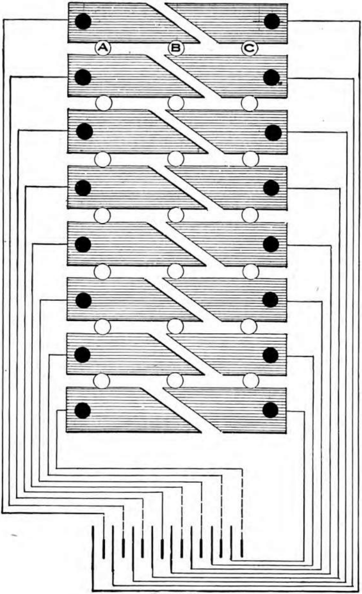

FIG. 49.

A number of pairs of brass strips are mounted on an insulated base, perhaps waxed wood.

There is one pair of these strips for each cell in the battery.

Holes are bored in the brass and the wood base as shown by the rows of circles *A B C*, and by the black discs.

Brass plugs are turned to fit these holes which are all the same size and about three-sixteenths of an inch in diameter.

Inserting a plug in a hole between two strips connects the two strips together.

By referring to the figure it will be seen that the negative terminals of the battery cells each go to a brass strip on one side of the switch and the positive terminals to strips on the other side.

If no plugs are in the holes the battery is on open circuit.

To clearly understand the switchboard, the strips may be taken to actually represent plates of the battery.

The outside circuit is connected by means of a pair of plugs provided each with a flexible cord.

Suppose it is required to connect four cells in multiple to an outside circuit. A plug is placed in *each* hole *A C* between the strips as shown in Fig. 50 by the black discs. This connects all the negative terminals together and all the positive terminals together.

Two plugs with flexible cords attached to the

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

outside circuit (shown as dotted lines) are placed, one in each side of the board.

These two plugs, their cords, and the outside circuit are thus connected to the battery as can be traced in the figure. The whole switchboard is not shown in these examples to avoid complication.

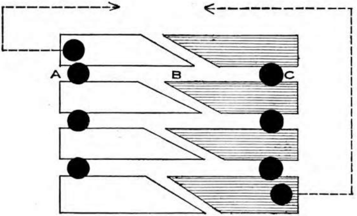

FIG. 50.

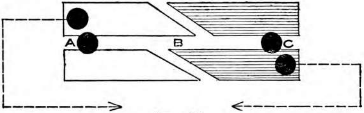

FIG. 51.

Fig. 51 gives the connections for two cells in multiple to the outside circuit. *Cell plugs not* *shown by black discs must be removed* or a short circuit may result.

By moving the flexible cords and plugs, any pair or multiple of cells may be selected. Two or more circuits may also be connected up to the limit of the battery by using more than one pair of cords.

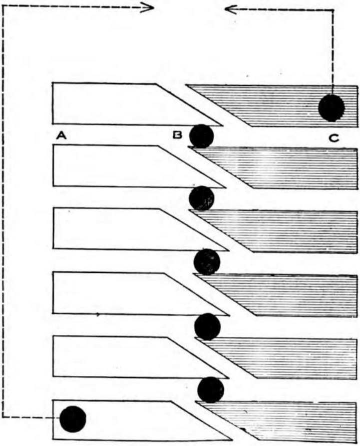

FIG. 52.

In order to make the device more graphic, the strips on one side have been left unshaded. They of course represent elements of the same polarity.

The series arrangement is in Fig. 52, the plugs

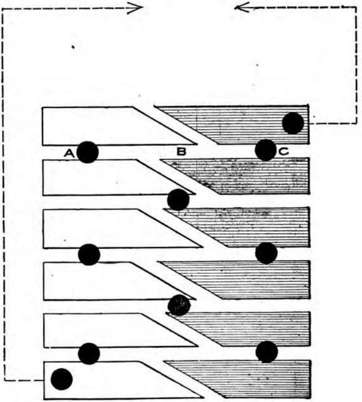

FIG. 53.

being in holes of the *B* row. The plugs in the *A* and *C* rows have been first removed. The series connection is easy to trace out the circuit passing through white and shaded strips alternately. By

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

shifting the flexible cords (shown by dotted lines and black discs) any number of cells may be put in series.

That the switchboard is capable of many combinations is made still more evident by Fig. 53. Here the cells are connected in pairs by plugs in the *A* and *C* rows and the pairs in series by plugs in the *B* row.

The flexible cords with plugs may each be replaced by a lever switch. The arm of each switch will be connected to the outside circuit. The contacts of each switch will be connected to the brass strips. The contacts of one switch will be connected to the strips on one side, and the contacts of the second switch to the strips on the other side.

Each switch will have as many contacts as there are strips.

The actual dimensions of the parts are governed by the class of battery connected to it. For a storage battery of large size the strips and plugs would have to be large to carry the current.

But as primary cells are under consideration here a few general dimensions will be as follows:

The base, of hardwood soaked in paraffin wax or painted with insulating waterproof paint. One-half inch of thickness is ample, if very long the board should be braced by slats screwed to the under side.

The brass strips may be five-eighths wide by one-sixteenth or even one thirty-second of an inch

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

thick. The holes should be drilled after the strips are screwed down to the base.

The plugs must be turned taper and at the smallest diameter three-sixteenths of an inch.

Brass screws should be used throughout, either flat head or round head as preferred.

Polechanging Switch. In order to conveniently reverse the direction of current flow from a battery a polechanging switch is necessary.

In Fig. 54 is shown one form of this switch, which can be procured mounted on a hard rubber or wood base with binding posts for connections.

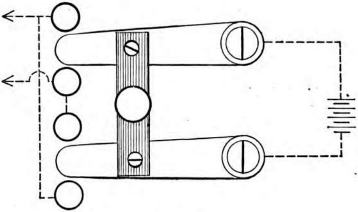

FIG. 54.

The figure shows the connections to battery on the right and outside circuit on the left.

Binding posts and base are not illustrated in order to lessen complications in the sketch.

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

The form of switch used in electric light work and known as a double pole double throw knife switch is also suitable for a current reverser.

In connecting it up, the battery is connected to the central binding posts, that is, those in the base of the blade hinges. The two outside posts at the extreme left and right of the base are joined up as follows:

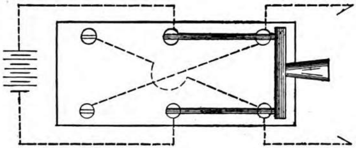

FIG. 55.

The top right hand post is joined to the bottom left hand post. The bottom right hand post is joined to the top left hand post Fig. 55.

Pieces of insulated copper wire are used for these connections or straps.

By throwing the knife blades either right or left, the battery is reversed in relation to the outside circuit, which may be connected to the binding posts at either right or left of the knife hinge posts.

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Digitized by Google
Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

Digitized by Google

Original from
UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN