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The Storage Battery

Madison

How to Make and Use
THE STORAGE BATTERY

EMBRACING ITS

HISTORY, THEORY, MAINTENANCE
AND THE INSTALLATION
OF PLANTS.

BY P. B. WARWICK.

ILLUSTRATED.

LYNN, MASS.:
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1896.

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How to Build a 50-Light Dynamo. A. E. Watson,	.50
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CHAPTER I.

THE DISCOVERY OF THE SECONDARY CELL.

The idea of electrical storage is not new, as it may be traced back to 1801, when Gautherot demonstrated the fact that platinum or silver wire when used in electrolysis of saline solutions developed secondary currents.

A little later Ritter constructed his secondary pile, which consisted of discs of copper separated by cloth, moistened with sal ammoniac solution.

In 1842, Sir William Grove constructed his classical gas battery. Michael Faraday, Wheatstone, De LaRue, Niaudet and others were also early operators in the field, but it remained for Gaston Planté, in 1860, to commercially appreciate the invention he had discovered.

Camille Faure, in 1880, placed before the public his red lead cell and it may be said with safety that although others had experimented, to

Gaston Planté and Camille Faure, belongs the honor of *commercially* discovering what will be in the near future, the most commercially useful invention of the electrical age.

One of the most important uses to which the storage cell can be put is as an auxiliary to the dynamo for incandescent lighting, giving a reliable, brilliant light, always steady, even, and on tap all the time. The lamps are never extinguished as is often the case with lamps taking their current direct from a dynamo, because of accident to anything connected therewith. The life of the lamp is increased over 50 per cent. because of the absolutely steady current given out through the storage cell auxiliary.

It can be added to any system now in use, running the dynamo during the day, to charge the battery and at night using one as auxiliary to the other. A dynamo running five hours at night can by running in the daytime, ten hours, (charging a battery of sufficient capacity,) be made to give three times its lighting capacity, without over-loading or over-speeding.

A lighting system taking current direct from the dynamo is like a gas ·light system without the gas holders—subject to extremes of fluctuation, making very unsteady and poor light.

The storage battery also fills an important place as a dividend earner for long distance incandescent lighting and for lighting in places where there is no incandescent system. For example :— A person owns an arc plant and does street lighting. There would not be sufficient revenue from lights to pay for the putting in of an incandescent plant. He places a small storage battery of, say 100 ampere hours' capacity in a central station, and charges his batteries either in the day-time or at night on the same circuit as his arcs are running on—batteries being in series with the lamps.

As the average time of running for arc work is ten hours per night with the standard 2000 candle power or 10 ampere system, this will equal 100 ampere hours, leaving batteries in best condition ready for the day's work.

There is a large field for storage batteries in telegraph work, railway signaling, burglar, police and fire alarm systems, and the advantages of storage over primary batteries can be seen by the following simple calculation, which anyone can make for himself :—

If A = the voltage of primary.
B = the average working current.
C = the annual cost of maintenance per cell.

Then $\frac{c \times 1000}{a \times b \times \text{No. of hours per year}}$ = cost per kilo-watt hour of electric energy furnished by primary battery. This compared with the cost per kilo-watt hour of the current furnished the local electric light and power company, (allowing 10 per cent. for loss of current in the storage batteries,) the result will show that in most cases the cost of electrical energy furnished by primary cells is 20 to 25 times as great as that obtained from storage batteries and that in many cases the comparative cost of current obtained from the primary battery is even much greater than this.

There are other advantages however besides the cost of maintenance.

In the first place the primary cost of the storage battery is less—they occupy only about ⅛ of the space, the electro-motive force and internal resistance is practically constant—you have no corroding connections—no creeping of salts and practically no evaporation, and in fact all the attention required is simply to see that the charging switch is thrown for the proper length of time.

The Western Union and Postal Telegraph—the Gold Stock Telegraph Companies—the American Bell Telephone and other like companies, have now adopted the storage battery almost entirely in their larger stations in place of gravity or like batteries.

For example:— The Western Union Company in their large office at Atlanta, Ga., have displaced 8000 gravity with 700 storage cells.

The City Hall at Philadelphia has also a very neat installation of storage cells to operate their police telegraph system.

Mr. Lemon, manager of the Baltimore Postal Telegraph Company, referring to the operation of his plant, in the Telegraph Age of March 16, 1894, says:— "There is no comparison between storage and primary cells."

Another use, and one that has been seldom thought of, is electro-plating, electrotyping and in fact all electrolytic work.

One of the greatest desiderata in electroplating is the maintenance of a constant potential or electro-motive force which can be easily effected by keeping the speed of the dynamo and the resistance of the circuit absolutely uniform.

This at first sight appears an easy matter, but as a matter of fact, the speed of the dynamo can not be kept uniform, owing to the inefficiency of steam engine governors, as every variation of speed is exaggerated in the line and counter shaft.

Such variations of speed are followed by changes in the electro-motive force of the current.

As the nature of an electrolytic deposit is affected by the density of current over the surface to be deposited upon, it follows that any agency that will insure a steady current will insure a good deposit also, and as one of the functions of storage batteries is to keep both voltage and current constant, they are well adapted for electrolytic work.

In using a storage battery in connection with electro-plating and electrotyping operations, the battery is arranged in multiple or parallel with the depositing tank.

All the time deposition is in progress the battery is receiving current, approximately equal to that passing into the electrolytic tank, by this means the battery becomes charged and is enabled, in the event of failure of power, to furnish current for the next interval of 12 or 14 hours.

The importance of this to firms located in buildings where power is furnished only during the 10 working hours of the day is self-evident.

CHAPTER II.

CHEMISTRY OF LEAD—LEAD COUPLES.

The procedure of forming a lead-lead couple is at first sight extremely simple.

We take two coiled plates of lead separated from one another and immersed in diluted sulphuric acid, a current is sent through from one lead plate to the other, the final result is that one becomes covered with a coating of lead peroxide while hydrogen is given off against the other.

On the view that sulphuric acid merely serves to decrease the resistance and so facilitate the electrolysis of the water, the ready explanation would be given that the two elements of water are simply separated at the poles.

But it seems more in accordance with the facts of electrolysis to suppose that the sulphuric acid, $H_2 So_4$, is itself the electrolyte and that the oxygen results from a secondary chemical reaction.

As a matter of fact if water be employed no peroxide is formed but only the hydrated protoxide—even though a current from 25 Bunsen cells be used, the addition of a single drop of sulphuric acid is sufficient to start the formation of puce-colored peroxide.

The reaction which takes place in charging a Planté battery may for convenience, be divided into two stages.

$$Pb \left\{ \begin{matrix} SO_4\ H_2 \\ SO_4\ H_2 \end{matrix} \right\} Pb_y = Pb_{x-1} \left\{ \begin{matrix} PbO_2 \\ \end{matrix} \right\}$$

$$\left\{ \begin{matrix} SO_3 \\ SO_3 \end{matrix} \right\} \left\{ \begin{matrix} H_2 \\ H_2 \end{matrix} \right\} Pb_y$$

and

$$2SO_3 + 2H_2O = 2H_2SO_4.$$

But it may be that the lead sulphate is always formed in the first instance and decomposed on the continuation of the charging current thus :—

$$Pb_x \left\{ \ SO_4H_2 \ \right\} Pb_y = Pb_{x-1} \left\{ \ SO_4Pb \ \right\}$$

$$\left\{ \ H_2 \ \right\} Pb_y$$

afterwards

$$Pb_{x-1} \left\{ \ SO_4Pb \ \right\} \left\{ \ SO_4H_2 \ \right\} Pb_y = Pb_{x-1}$$

$$\left\{ \ PbO_2 \ \right\} \left\{ \begin{matrix} SO_3 \\ SO_3 \end{matrix} \right\} \left\{ \ H_2 \ \right\} Pb_y$$

and

$$2SO_3 + 2H_2O = 2H_2SO_4.$$

It seems most likely that both of these reactions may take place according to varying density or other circumstances of the current.

The coating of peroxide interposes a great difficulty in the way of further oxidization of the metallic lead.

For this reason Planté needed successive periods of repose and charging to completely form his elements.

To obviate this waste of time and energy, Camille Faure coated his plates mechanically with minium or red lead, (oxide of lead,) and converting this into spongy peroxide and spongy lead respectively, by the current.

Now the first thing that happens when the plates are immersed in dilute sulphuric acid is a purely chemical action.

The minium suffers decomposition according to the formula.

$$Pb_3O_4+2H_2SO_4=PbO_2+2PbSO_4+2H_2O$$

But as both the lead sulphate and the lead peroxide are insoluble, this change takes time to penetrate, as the action is mainly at the surface.

In a lead cell it is evident that the amount of energy to be stored is mainly dependent on the amount of peroxide present.

This appears to be obtained with the smallest amount of loss when the current is not too strong.

From the experiments of Dr. Gladstone, Prof. Tribe, Camille Faure and others, it is shown conclusively that the best results were obtained by a current density of about 6½ milliamperes per square centimeter calculated on the original surface of the plates.

During a discharge the sulphuric acid that was discharged by the sulphate of lead becoming oxidized, once more attacks the oxide according to the equation,

$$PbO+H_2SO_4=PbSO_4+H_2O.$$

The Dujardin and Warwick process of applying active material consists in depositing and oxidizing in an alkaline nitrate bath and is hastened by forcing air through the solution, which is composed of water, 10 parts; sulphuric acid, 2 parts; alkaline nitrate of soda, potash or ammonia, 1 part.

The author, of Cleveland, Ohio, while in the employ of the P. W. Storage Battery Company of that city, produced several very remarkable cells in this way, the plates being solid masses of active material held together by an alloy of cadmium and lead tape. These cells have a very long life and will stand extremely rough usage, one in the writer's possession having been short circuited over 5000 times, this at the rate of one discharge per diem would equal 5000 days or nearly 14 years of actual work, Camille Dujardin and M. Baillehache in Paris have obtained results from this type of cell that gave an electrical efficiency of 97 per cent.

CHAPTER III.

BASIC PATENTS.

Camille Faure, Jan. 3, 1882, applying active material.

J. S. Sillon, June 13, 1882, an electrode for secondary batteries having one or more holes or receptacles to receive and hold active material.

J. W. Swan, April 4, 1882, method of preparing plates.

C. F. Brush, July 4, 1882, active material mechanically applied to conducting supports.

C. F. Brush, July, 1882, applying active material.

C. F. Brush, August 8, 1882, process of making secondary battery elements.

N. DeKabath, August 22, 1882, compound electrode and separator.

C. F. Brush, Sept. 5, 1882, secondary battery element.

J. A. Maloney, C. H. Koyl, Oct. 17, 1882, porous plate, storage battery.

C. F. Brush, Oct. 17, 1882, secondary battery element.

Alfred Haid, Feb. 6, 1883, secondary battery element.

J. A. Maloney, Feb. 6, 1883, construction of secondary battery.

T. A. Edison, March 6, 1883, electrodes of secondary batteries.

C. F. Brush, March 13, 1883, secondary battery element.

N. S. Keith, March 13, 1883, secondary battery construction.

T. A. Edison, March 13, 1883, electrode for secondary battery.

C. F. Brush, April 24, 1883, method of forming secondary battery.

Elements, E. T., and E. E. Starr, April 24, 1883, construction of secondary batteries.

305,835, Sept. 30, 1884, J. R. Morgan, accumulator.

3,061,105, Oct. 14, 1894, W. Lachlan, construction of secondary batteries.

300,052, June 10, 1884, A. G. Davis.

301,351, July 1, 1884, D. C. Fitsgerald.

294,464, March 4, 1884, A. Haid.

307,461, Nov. 4, 1884, A. S. Hinckley.

291,576, Jan. 8, E. J. Molern and J. C. Cebrian.

297,457, April 22, W. A. Shaw.

292,142, Jan. 15, C. A. Smyth.

299,177, May 27, W. Stanley.

300,933, June 24, G. L. Winch, secondary battery.

295,456, March 18, E. T. Starr, secondary battery and constructing plates.

292,467, Jan. 29, W. E. Case, secondary battery element.

299,021, May 20, R. P. Sellon, secondary battery charging apparatus.

291,465, Jan. 1, J. S. Beerman, W. Taylor, F. King, P. B. Warwick, secondary battery Regulator.

291,850, Jan. 8, E. R. Knowles, storage battery, complete system.

298,348, May 13, storage battery elements.

1885.

312,802, Feb. 24, C. S. Bradley, secondary battery.

320,252, June 16, J. DuShane, secondary battery.

331,407, Dec. 1, E. Jones.

311,007, January 20, S. Kalisher.

311,008, January 20, S. Kalisher.

315,339, April 7, E. T. Reichert.

315,340, April 7, E. T. Reichert.

524,597, August 18, J. S. Sellon.

316,407, April 21, W. A. Shaw.

316,408, April 21, W. A. Shaw.

316,409, April 21, W. A. Shaw.

327,341, Sept. 27, E. T. and E. E. Starr.

312,599, Feb. 17, J. W. Swan.

318,898, May 26, J. W. Swan.

310,724, Jan. 13, L. H. Rogers, secondary battery and transporting same.

311,445, Jan. 27, S. Phillipart.

314,892, March 31, E. T. Starr.

325,120, August 25, J. S. Sellon.

321,759, July 7, J. S. Sellon.

223,890, August 4, E. T. and E. E. Starr.

1886.

347,754, August 17, H. Woodward, assignor to P. B. Warwick, battery plate.

342,594, May 25, C. D. P. Gibson, storage battery.

352,708, Nov. 16, O. A. Moses, storage battery.

348,625, Sept 7, S. Farbaky & S. Schenck, storage battery.

341,600, May 11, T. Pitkin.

341,860, May 11, C. Sorley, storage battery.

353,511, Nov. 30, C. Sorley, storage battery.

374,258, Aug. 10, E. T. Starr, storage battery.

347,252, Dec. 14, V. Sass and others, storage battery.

342,385, May 25, W. H. Remington, storage battery.

337,298 and 9, March 2, C. F. Brush, (2) storage battery.

345,124, July 6, A. DeVerloy, E. Commelin, G. Bailehache, storage battery.

1887.

359,900, March 22, E. T. Starr, charging secondary batteries.

357,627, Feb. 15, G. B. Prescott, cut out for secondary batteries.

367,630, Aug. 2, W. Hochhausen, electric distribution by secondary battery.

259,901, March 22, E. T. Starr, mechanism for charging secondary battery.

359,248, March, S. Farbaky and S. Schenck, positive plate for secondary batteries.

362,639, May 10, W. I. Ludlow, working and forming secondary battery.

370, 134, Sept. 20, O. C. Flick.

359,072, March 8, W. W. Griscom, secondary battery.

372,468, Nov. 1, C. Hering, secondary battery.

359,934, March 22, W. Main, secondary battery.

359,877, March 22, A. V. Meserole, secondary battery.

371,358, Oct. 11, A. Reckenzaun, secondary battery.

368,608, Aug. 23, A. E. Peyrusson, secondary battery.

362,640, May 10, W. I. Ludlow, secondary battery.

359,876, March 22, A. V. Meserole, preparing plates for secondary battery.

1888.

389,186, Sept. 11, C. Askew and J. H. Pumpelley, secondary battery.

388,335, Aug. 21, J. Beattie, Jr., secondary battery.

380,989, April 10, H. Carpenter, secondary battery.

380,554, April 3, N. de Benardos, secondary battery.

394,471, 394,474, Dec. 11, L. Duncan, secondary battery.

382,420, May 8, 383,216, May 22, L. Epstein, secondary battery.

383,560, May 29, C. A. Faure, secondary battery.

363,562, May 29, C. A. Faure, secondary battery.

389,882, Sept. 25, C. A. Faure, secondary battery.

385,558, July 3, F. King, secondary battery.

381,941, May 1, A. V. Meserole, secondary battery.

393,575, Nov. 27, L. Paget, secondary battery.

393,576, Nov. 27, L. Paget, secondary battery.

393,577, Nov. 27, L. Paget, secondary battery.

385,200, June 26, A. Reckenzaun, secondary battery.

383,150, May 22, S. Russell, secondary battery.

377,642, Feb. 7, J. S. Sellon, secondary battery.

383,193, May 22, J. S. Sellon, secondary battery.

386,898, July 31, J. S. Sellon, secondary battery.

378,629, Feb. 28, M. Stecher, secondary battery.

392,244, Nov. 6, H. Walter, secondary battery.

385,390, July 3, S. L. Trippe, secondary battery.

1889.

408,367, Aug. 6, N. B. Aldrich, secondary battery.

408,287, Aug. 6, T. D. Bottome, secondary battery.

409,448, Aug. 20, C. S. Bradley, secondary battery.

404,168, May 28, H. Cameron and T. Harris, secondary battery.

412,727, Oct. 15, H. Carpenter, secondary battery.

416,573, Dec. 3, D. S. Covert and J. K. Pumpelley, secondary battery.

402,006, Apr. 23, C. Desmasures, secondary battery.

406,822, July 9, H. Dey, secondary battery.

413,339, Oct. 22, R. Eckeymeyer, secondary battery.

408,002, July 30, V. H. Ernest, secondary battery.

409,178, Aug. 20, C. A. Faure, secondary battery.

400,842, April 2, W. Griscom, secondary battery.

401,744, April 23, W. Griscom, secondary battery.

406,439, July 4, W. Griscom, secondary battery.

416,605, Dec. 3, T. J. Haslam, secondary battery.

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399,535, March 12, J. G. Huber, secondary battery.

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415,327, Nov. 19, P. Kenedy and C. J. Diss, secondary current.

397,650, Feb. 12, W. Kingsland, secondary battery.

400,226, Mar. 26, I. Kitsee, secondary battery.

406,916, July 16, I. Kitsee, secondary battery.

399,052, Mar. 5, E. R. Knowles, secondary battery.

401,953, April 23, W. P. Kookogey, secondary battery.

417,055, Dec. 10, C. H. Togan, secondary battery.

396,213, Jan. 15, O. Tugo, secondary battery.

396,214, Jan. 15, O. Tugo, secondary battery.

412,639, Oct. 8, F. M. Lyte, secondary battery.

401,389, April 9, W. Main, secondary battery.

401,290, April 9, W. Main, secondary battery.

408,666, Aug. 6, J. F. McLaughlin, secondary battery.

414,438, Nov. 5, H. G. Osburn, secondary battery.

415,331, Nov. 19, C. Payen, secondary battery.

398,075, Feb. 19, J. Pederson, secondary battery.

403,957, May 28, J. B. Price, secondary battery.

416,299, Dec. 3, J. K. Pumpelley, secondary battery.

396,367, Jan. 15, I. L. Roberts, secondary battery.

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414,953, Nov. 12, W. Roberts, secondary battery.

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396,770, Jan. 29, J. S. Sellon, secondary battery.

396,958, Jan. 29, J. S. Sellon, secondary battery.

401,466, April 16, J. S. Sellon, secondary battery.

397,443, Feb. 5, W. A. Shaw, secondary battery.

415,981, Nov. 26, W. F. Smith, secondary battery.

11,047, Dec. 17, J. W. Swan, re-issue secondary battery.

406,969, July 16, C. H. Thompsen, secondary battery.

398,194, Feb. 19, I. A. Timmins, secondary battery.

405,751, June 25, J. T. Van Gestel, secondary battery.

410,680, Sept. 10, J. T. Van Gestel, secondary battery.

418,483, Dec. 31, A. S. Woolf, secondary battery.

415,600, Nov. 19, J. A. Wotton and W. R. Polk, secondary battery.

408,986, Aug. 13, H. G. Morris and P. G. Salom, apparatus for filling plates or grids.

1890.

434,376, Aug. 12, G. W. Cochran, secondary battery.

422,504, March 4, S. C. C. Currie, secondary battery.

422,505, March 4, S. C. C. Currie, secondary battery.

418,700, Jan. 7, H. C. Dey, secondary battery.

431,447, July 1, T. S. Dixon, secondary battery.

431,341, July 1, T. M. Foote, secondary battery.

441,413, Nov. 25, T. E. Hatch, secondary battery.

429,273, June 3, Carl Hering, secondary battery.

429,912, June 10, Carl Hering, secondary battery.

429,913, June 10, Carl Hering, secondary battery.

429,914, June 10, Carl Hering, secondary battery.

434,444, Aug. 19, T. H. Hicks, secondary battery.

422,216, Feb. 25, W. B. Hollinshead, secondary battery.

439,594, Oct. 28, W. B. Hollinshead, secondary battery.

423,324, Mar. 11, W. A. Johnson and J. N. Smith, secondary battery.

441,958, Dec. 2, C. W. Kenedy and H. Groswith, secondary battery.

443,456, Dec. 23, I. Kitsee, secondary battery.

443,457, Dec. 23, I. Kitsee, secondary battery.

437,848, Oct. 7, H. Lampert, secondary battery.

440,175, Nov. 11, F. Marx, secondary battery.

439,324, Oct. 28, E. J. Mason, secondary battery.

425,818, April 15, J. F. McLaughlin, secondary battery.

419,862, Jan. 21, J. F. Mehren, secondary battery.

427,789, May 13, F. F. Nevins, secondary battery.

425,902, April 15, G. Phillipart, secondary battery,

425,957, April 15, G. Phillipart, secondary battery.

442,390, Dec. 9, J. K. Pumpelly, secondary battery.

442,391, Dec. 9, J. K. Pumpelly, secondary battery.

438,827, Oct. 21, E. N. Reynier, secondary battery.

434,093, Aug. 12, P. Schoop, secondary battery.

424,152, March 25, H. Wardwell, secondary battery.

443,556, Dec. 30, H. Wardwell, secondary battery.

434,224, Aug. 12, H. Woodward and P. B. Warwick, secondary battery.

439,301, Oct. 28, J. F. Mehren, secondary battery.

1891.

451,445, May 5, T. H. Aldrich, secondary battery.

445,422, Jan. 27, C. F. Brush, secondary battery.

445,542, Feb. 3, H. T. Cheswright, secondary battery.

447,279, Feb. 24, S. C. C. Currie, secondary battery.

453,995, June 9, S. C. C. Currie, secondary battery.

462,693, Nov. 10, N. H. Edgarton, secondary battery.

451,921, May 12, J. Emmner, secondary battery.

453,695, June 9, W. Griscom, secondary battery.

446,527, Feb. 17, A. M. F. Laurent, and I. A. Timmins, secondary battery.

458,424, Aug. 25, O. Tugo, secondary battery.

458,425, Aug. 25, O. Tugo, secondary battery.

462,449, Nov. 3, J. H. Palmer, secondary battery.

456,843, July 28, H. Pieper, secondary battery.

464,665, Dec. 8, I. L. Roberts, secondary battery.

454,187, June 16, J. S. Sellon, secondary battery.

459,535, Sept. 15, W. L. Silvey, secondary battery.

454,091, June 16, D. Tommasi and C. Theryc, secondary battery.

461,858, Oct. 27, M. Waddell and J. B. Entz, secondary battery.

451,540, May 5, George A. Washburn, secondary battery.

451,541, May 5, George A. Washburn, secondary battery.

1892.

480,883, Aug. 16, E. P. Usher, storage battery.

480,885, Aug. 16, E. P. Usher, storage battery.

488,233, Dec. 20, G. A. Washburn, storage battery.

479,753, July 26, A. E. Colgate, secondary battery.

473,146, April 19, H. E. Dey, secondary battery.

473,147, April 19, H. E. Dey, secondary battery.

486,094, Nov. 15, R. Eickemeyer, secondary battery.

467,573, Jan. 26, J. B. Entz and W. A. Philips, secondary battery.

478,230, July 5, J. H. Gerr and C. E. Long, secondary battery.

481,560, Aug. 30, W. W. Griscom, secondary battery.

477,182, June 14, H. H. Lloyd, secondary battery.

485,013, Oct. 25, W. Main, secondary battery.

470,701, Mar. 15, G. F. Parker and C. E. Craps, secondary battery.

11,238, April 26, I. L. Roberts, re-issue, secondary battery.

477,914, June 28, W. Silvey, secondary battery.

484,120, Oct. 11, W. Silvey, secondary battery.

471,590, Mar. 29, C. F. Winkler, secondary battery.

471,592, Mar. 29, C. F. Winkler, secondary battery.

488,726, Dec. 27, N. Vladmiroff, secondary battery.

476,483, June 7, E. C. Paramore, secondary battery plates.

469,129, Feb. 16, C. P. Elieson, storage battery.

482,043, Sept. 6, P. Kenedy and C. J. Diss,
482,044, storage battery.

482,979, Sept. 20, E. R. Knowles, storage battery.

483,562, Oct. 4, E. R. Knowles, storage battery.

483,563, Oct. 4, E. R. Knowles, storage battery.

1893.

507,139, Oct. 24, C. W. Kennedy, storage battery.

496,126, April 25, F. A. LaRoche, storage battery.

504,455, Sept. 5, C. J. Reed, storage battery.

509,266, Nov. 21, E. P. Usher, storage battery.

509,267, Nov. 21, E. P. Usher, storage battery.

509,268, Nov. 21, E. P. Usher, storage battery.

509,269, Nov. 21, E. P. Usher, storage battery.

509,270, Nov. 21, E. P. Usher, storage battery.

509,271, Nov. 21, E. P. Usher, storage battery.

509,272, Nov. 21, E. P. Usher, storage battery.

489,115, Jan. 3, C. R. Arnold, secondary battery.

493,817, March 21, L. Bristol, secondary battery.

491,878, Feb. 14, N. H. Edgarton, secondary battery.

501,723, July 18, F. King, secondary battery.

500,394, June 27, F. King and E. Clark, secondary battery.

505,467, Sept. 26, I. Kitsee, secondary battery.

490,254, Jan. 17, H. H. Lloyd, secondary battery.

502,824, Aug. 8, L. Morse, secondary battery.

499,848, June 20, F. O. Norton, secondary battery.

495,638, April 18, L. B. Rowley, secondary battery.

500,622, July 4, W. L. Silvey, secondary battery.

504,370, Sept. 5, W. L. Silvey, secondary battery.

507,463, Oct. 24, C. A. Smythe, secondary battery.

500,978, July 4, C. Theryc and A. Oblasser, secondary battery.

Note.—The foregoing Patents are copied from the Records of the U. S. Patent Office, Washington, D. C., and can be relied upon as being absolutely correct.

CHAPTER IV.

HOW TO MAKE A PRACTICAL STORAGE BATTERY.

In presenting this chapter to our readers it is not the intention of the writer to give a scientific and theoretical description of, or to comment on the merits or demerits of the different types of storage cells in use at the present time, but to give a practical and cheap method of making and operating a storage battery of sufficient size to light a dwelling house, store or factory in connection with a small dynamo, such as the 10-light Watson dynamo, described in *Bubier's Popular Electrician*, which in turn may be driven by either a small steam, gas or gasoline engine, or wind or water motor.

We will assume that the amateur has already at his command a dynamo and power and wishes to supply 20 lights of 16 c. p. for a period of 5 hours when the dynamo is not running, or else desires to augment his plant so as to supply some 30 lights from 1 h. p. dynamo which is perfectly practical.

As a 50-volt 16 c. p. lamp takes 1 ampere to light it to incandescense, and our dynamo will be able to charge 10 hours a day with a current of 10 ampere, 10 amperes × 10 hours = 100 hours, we will therefore require a reservoir or storage battery of 100 ampere hours capacity, which the amateur can manufacture as follows.

First procure a piece of hard wood 7 x 6 x 1 inches, a stout table, a hammer, a pair of old snips or shears, a blow pipe and gas jet, or a soldering iron, and it will also be necessary to have some means of crimping or corrugating, which can be done very handily in the feed or back gears of a small lathe, or with a fluting iron borrowed from the laundry.

These are all the tools required—except common sense.

The necessary material can be procured from the nearest lead works.

A quantity of lead tape—also known as torpedo lead $\frac{1}{64}$ inch thick by $\frac{3}{8}$ inch wide, and also a smaller quantity $\frac{3}{8}$ x $\frac{1}{4}$ strip lead of the sort called chemical or desilverized lead.

If strip lead $\frac{3}{8}$ x $\frac{1}{4}$ cannot be obtained, procure some 8 or 10 lbs. sheet lead and cut it into strips $\frac{3}{8}$ inch wide and 28 inches long.

Now fasten the piece of hard wood to your table by four stout screws and proceed to make up a series of frames out of your $\frac{3}{8}$ x $\frac{1}{4}$ strip lead, same as Figure 1, by bending around the block, tapping the corners gently until they are square. When you have made 7 of these frames join the two ends with the soldering iron or blow pipe—the latter preferred—first inserting a small piece of strip lead, as shown at B, Figure 1; now cut off a quantity of strips of tape lead 6 inches long, part of which must be run through the gears or crimping iron or corrugated like Figure 2. Now lay one of the frames, Figure 1, on the table on a flat slab of stone or iron, and pack it full of plain and corrugated lead strips, alternately, as tightly as possible until the frame is like Figure 3.

Now take your soldering iron or blow pipe and solder or burn the ends of the strips, as S S, Figure 3, to the frame; if you solder, use the poorest solder possible, 4 of lead to 1 of tin, and rosin for a flux—do not use fine solder, like ½ and ½, for if you do the tin will eat out so much quicker. If the amateur has a blow pipe and is able to use it, he can burn or fuse the edges together, which is the best way, and, if possible to do it, always burn or fuse the positive plates, as these are the ones that deteriorate; as a matter of fact, the negatives will last 20 years.

The plates being now made, it is necessary to get the active material.

There are three methods of doing this. First by applying it mechanically in the form of a paste, paint or cement, and this is termed the

Faure process, after Camille Faure, who was the inventor of the method; secondly, by an electrical method of forming active material by electricity, called the Planté or corroding process, which consists in simply charging and discharging a current until the positive plates are oxidized or corroded, which takes a long time.

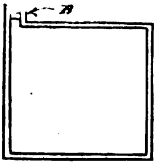


Fig.1

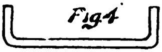


Fig.4

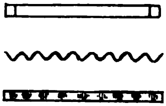


Fig.2

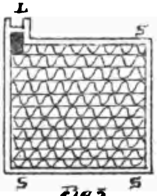


Fig.3

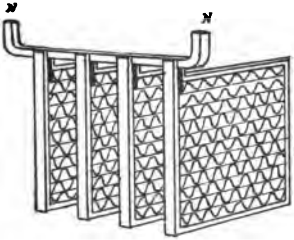


Fig 5

The third method is the Warwick process. It consists of depositing or plating active material into the spaces between the ribbons of lead. As this process is patented, owned and worked by the P. W. Storage Battery Company, of Cleveland, O.,—who, however, will supply batteries, plates and material, by special agreement, to the readers of this book at lowest prices—and as this method requires considerable practical experience and plant and the Planté process takes a 150 hours charging, we will describe here only the Faure method as being the simplest for amateurs.

Take sufficient dry oxide of lead —red lead—for the positive plates—12 oz. to the plate—and mix to the consistence of thick batter or paste with dilute sulphuric acid and water—1 in 10 parts--and with an old table knife work the mass firmly into the plates.

When you have filled the three positive plates with this mixture, paste the four remaining plates with a mixture of litharge or yellow lead, acid and in the same way.

Now take a piece of cellulose fiber $\frac{3}{16}$ inch thick—or if you cannot obtain this, take common cardboard and soak it in silicate of soda and let it dry—and lay on the table first a negative with the lug L, Figure 3, on the left hand, then a layer of cardboard, asbestos cloth or cellulose fibre, $\frac{3}{16}$ inch thick, then a positive plate—red—with the lug to the right hand, then more separating material, then another negative—yellow—plate and so on until you have seven plates, four negatives and three positives, with the lugs going different ways, alternately.

Now tie the elements with a stout cord and take a long strip of lead like Figure 4 and solder or burn all the negatives; do the same with the positives and your battery is ready to charge.

Procure a water-tight box, large enough to hold the plates, and line it with pitch or asphaltum, or, better yet, asphalteck, or P. & B. compound, so as to make it acid tight, and when hard place your elements or plates therein, being very careful that positive and negative plates are not short circuited.

Now in a crock or tub mix some electrolyte, or acid and water—sulphuric—one part acid, four parts of water, being careful to pour the acid into the water and not vice versa, stirring very steadily until mixed.

When the solution is cold, fill your cell up with it until the plates are well covered and add a little baking or carbonate of soda to the solution; about 2 ozs. is plenty.

Now connect the positive plates with the positive wire and the negative plates with the negative wire of the machine and pass a current of 10 amperes for 48 hours and your cell is finished.

A cell constructed in this way will give 2.2 volts and will hold 100 ampere hours.

Therefore, 25 or 26 will light your 50 or 52-volt lamp and when connected in series will run 1 lamp for 100 hours, 2 lamps for 50 hours, 4 lamps for 25 hours, or 20 lamps for 5 hours.

The cost of making these plates is approximately 20c. each, the cost of material varying a little in different localties.

Lead tape can be secured also at 6c. to 7c. per lb. from most any electrical supply house.

The red lead and litharge you can get from any wholesale druggist. who will furnish your sulphuric acid.

If you want to use your storage cell for portable work, you can obtain a dry or semi-dry electrolyte, to replace the acid and water, from the P. W. Storage Battery Company, of Cleveland, Ohio, who are the owners of patents on that substance.

The Watson dynamo should be shunt wound or else under compounded, and is then one of the most suitable machines for this class of work.

The writer has a small plant in actual operation in Cleveland, Ohio, consisting of a "Warwick" dynamo, 25 storage cells and gasoline engine with automatic switches. The cost of plant was:

1 h. p. gas engine, castings, .	$25 00
1 h. p. dynamo, castings, . .	5 50
25 storage cells in glass jars .	70 00
Labor on dynamos $10, engine $15,	25 00
	$125 50

This plant supplies 30 lights every night; 20 lights produce 10.00 per week and at the cost of running is $\frac{1}{8}$ of 1c. per lamp hour, or 2c. per h. p. hour.

CHAPTER V.

SOME MODERN TYPES OF STORAGE BATTERIES.

Chesswright Improved Planté *Elements* as made by Messrs. Bitts and Co., of Carcassone, France, out of chemically pure lead, see Fig. 6.

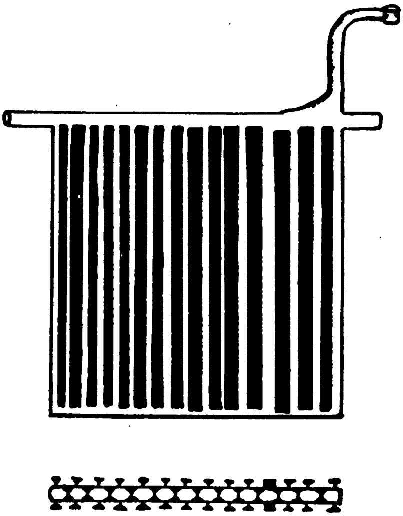
Each element is so constructed that its interior is quite hollow and is divided into vertical channels by thin lead partitions running throughout the whole length of the plates.

By passing the lead sheets through suitable shaped rollers each surface is closely corrugated into a series of raised dovetailed shaped rims.

By treating the plates in this way a large increase in the amount of active surface is obtained which is said to be at least four times as large as a piece of plain lead of same dimensions.

M. DeKabath devised a cell which has had somewhat extensive use in France. A portion of plate is shown in Figure 8.

As shown in cut it consists of a thin perforated lead chamber packed tightly with a large number of lead strips, each alternate strip being corrugated to increase the active surface and allow the free circulation. 12 of these put into a cell or case, having a weight of about 84 pounds to the complete cell.



Cheswrights Per Oxide Plate.

FIGURE 6.

Epstein's Battery. — Epstein's Improved Planté Element is a deeply grooved plate, (Figure 9,) the process of forming being what is known as the rotting process, accomplished by boiling the lead plate in a weak solution of nitric acid and afterwards putting them under the current for charging for a few hours. These plates are said to possess a capacity of from 140 to 170 ampere hours per positive plate.

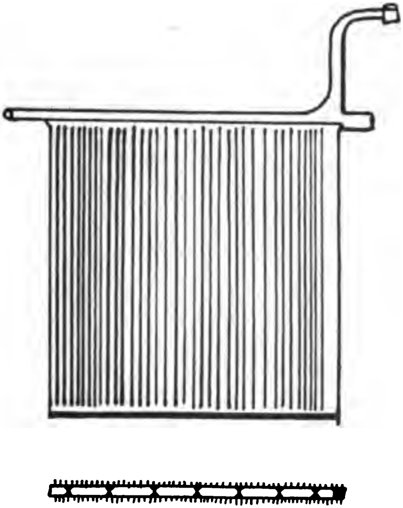
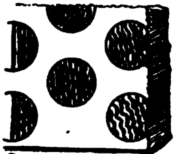


FIGURE 7.

Woodward's Spongy Battery.—The plates in this type of battery are of a very porous or celluar nature. They are prepared by pouring melted lead upon coarse salt or other similar substance, thoroughly mixing while hot and pressed into desired shape. When cold the salt is dissolved out, resulting in a highly spongy element, which is readily formed by the Planté method.

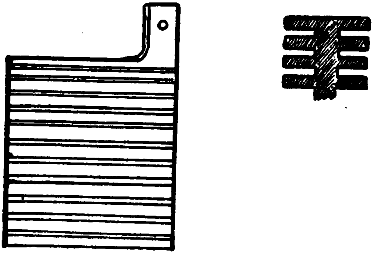
This plate is mounted horizontally for traction work by interposing porous plates of earthern-ware or other suitable insulating material between them.



De Kabath. Plat.

FIGURE 8.

Another form of this plate is made by filling a tube of suitable material with lead filings, chips, or turnings.



Epstein's Element

FIGURE 9.

M. M. Simmins and Reynier formed a plate consisting of a strongly compressed mass of lead wire with a strong metal frame and supporting trunnions cast around it.

The rigid metallic envelope effectually resists all distorting influence caused by the current and is but slightly affected by the weakening action of the oxidization.

E. P. S. Patents comprise patents taken out by Messers. Sellon, King, Volckmar, Phillippart, Parker, Swan and others for various forms of grids, frames or plates, in connection with Faure's original discovery.

FIGURE 10.

Accumulators made under the above patents have now been extensively used for many years, both in this country and abroad.

After experience gained from a very large number of experiments the present form of grid, Figure 10, was adopted.

The grid is cast in a steel chill or mold, giving a double dove-tail, which form tends to key firmly the pellets of active material.

Note. E. P. S. batteries are now manufactured in England solely by the Foreign and Colonial Electrical Power Storage Co., Limited.

A still more recently improved form of plate, first introduced by this Company, has a very thin perforated film of metal running across each aperture midway between its outer edges, the negative plates are pure lead as are also the positives.

When cast and cleaned up the plates are filled in with a paste made of minium and dilute sulphuric acid.

The paste is pressed in with a trowel and the superfluous material scraped off level with the outer surface of the grid.

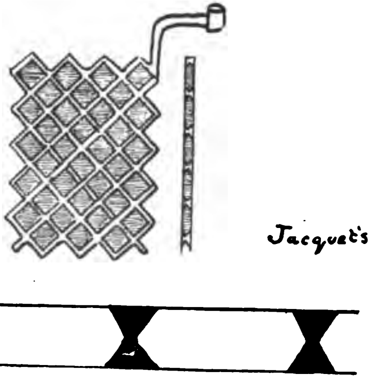
When dry, the plates are partly formed or hardened by being subjected to the electric current while in a bath of sulphuric acid. They are then removed and placed in a suitable frame and their lugs are fastened together.

Thus treated, they are ready for sale, the purchasers in all cases doing the actual forming.

The Dujardin and Warwick System of Formation.—The Dujardin elements are rendered active by a combined depositing and oxidizing action performed by electrolysis in an alkaline bath of nitrates composed of 10 kilogrammes of water, 2 kilogrammes of sulphuric acid, 1 kilogramme of alkaline nitrate (of soda, ammonia, potash or other suitable alkali).

By the passage of an electric current, nitrate of lead is formed and by the acid of the bath this is converted in a continuous manner into sulphate of lead and afterwards into peroxide of lead.

In some hours without discharging or reversing the current, the positive plates become coated with an adherent layer of crystalline peroxide of lead, which may be a millimeter thick and of great electrical capacity.



Jacquet's Grid

FIGURE II.

To increase and regulate the formation of the salts of lead, it is well to introduce large volumes of air into the liquid, which is accomplished either by forcing air into the bath or by raising or lowering the plates or by other convenient means and the reaction is thereby doubled.

Jaquet's double grid is a form of grid which which possesses some novel features.

Not satisfied with the method of keying in the active material by making the elements in halves, then forming them together either by soldering or riveting, they have worked out a plan for casting a complete double dove-tailed element in one piece.

Figure 11 shows the appearance of this form of electrode. The grids are made of an inoxidizable white metal and from their peculiar shape are far more rigid and thus less liable to bend or buckle than ordinary cast plates.

Ernst Intercirculatory Storage Battery.—The fundamental principle involved in this element is an absorbent core having an expansive action. This flexible core is made of asbestos fiber, wool, hair or other similar substance and it ramifies through the interior of the active material in such a manner that the oxide or spongy lead is retained in close contact with the wall of the holder or metallic plate, giving perfect electrical contact and conductivity.

The elastic core presents a yielding surface to the active material so that any jolting or concussion occurring when the batteries are used for traction purposes does not tend to dislodge or break up the soft lead or oxide.

The battery elements are built up horizontally, being placed one above the other.

No lead burning or soldering of any kind enters into the construction of these plates, the elements being held together at the requisite distance apart by means of india rubber washers and vulcanite bolts and washers.

Knowles' elements consist of solid blocks of active material firmly clamped between two perforated plates made of inoxidizable alloy.

These conducting plates ars held together by rivets which pass through the active material.

The perforations allow the electrolyte a fairly free access to the oxides and spongy lead.

As the slabs of active material are free to expand or contract in any direction throughout their mass, these elements are said never to warp or buckle even when seriously overcharged or over discharged.

Gibson's Battery is so constructed as to form in a simple and economical way an accumulator, capable of withstanding a considerable amount of rough treatment without the active material being jolted out or disintegrated.

The plates are formed of ordinary rolled sheet lead. A large number of small loops are forced or stamped out from the sheet itself, parallel rows of these projecting loops entended across the plate, each alternate row being half a loop in advance of the others. To add strength to the plates, the edges on all sides were turned up in the form of a rim.

After the stamping process, the elements were filled in to a uniform level either with oxides of lead in the form of a paste or the oxide is merely dampened and pressed in.

By the arrangement of loops, the active material is effectually keyed in.

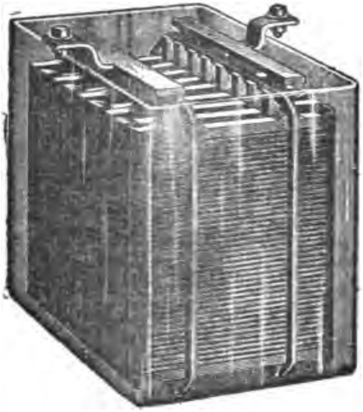
The American or Morrison Storage Battery.—The plate for this cell consists of a ribbon of lead folded on itself, until of sufficient size for the plate.

A slot is mortised on the ends of the strip and the frame of lead is passed around and clamps the tape firmly together.

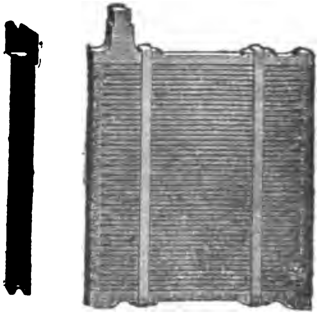
The plates are then pickled in a solution of nitro-muriatic acid for about four hours, the pickle being nearly boiling.

They are then taken out and allowed to dry in the sun and then formed by the Planté process.

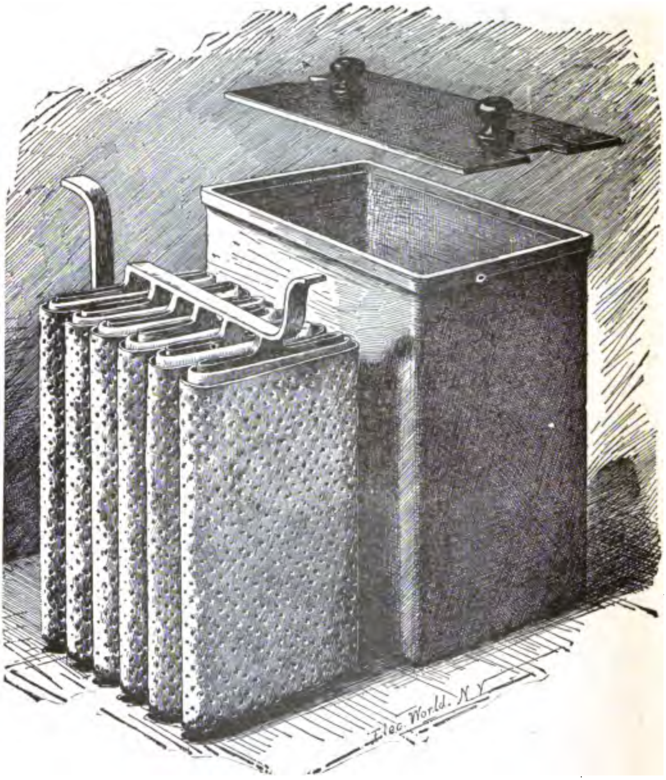
The American Battery Company has also made this plate by pasting, according to the Faure process. They have given very fine results, being remarkably free from sulphating, and when looked after and not allowed to buckle and except to cutting through evaporation of electrolyte, give good results.



THE AMERICAN BATTERY.



AMERICAN BATTERY PLATE.



FORD-WASHBURN STORAGE BATTERY.

The Ford-Washburn Store Electro Battery.—This battery is probably unique, consisting as it does, of a porous cup, enclosed loosely in a perforated envelope of lead, the space between the porous cup and lead being packed tightly with litharge. This forms the negative element.

The positive element consists simply of a sheet of perforated lead, folded on itself with a thick casting in the center for connecting. This is slipped into a porous cup and the whole is immersed in electrolyte, contained in a suitable jar.

But owing to its great weight it is not suitable for portable work, but where a battery can be set on a shelf and not interfered with, it will give much better results, as will be seen by the curves on Figures 13, 14 and 15.

The principal fault with this type of battery is that the peroxide or positive plate being on the inside of the porous cup, when it expands cracks the porous cup and the paste gradually filters through it, leaks through the cracks and finally makes contact with the negative active material on the other side of the porous cup, causing a dead short circuit which can not readily be discovered or remedied. Another fault is the fact, that the only means of access the electrolyte has to the positive active material is by filtration, through negative material and porous

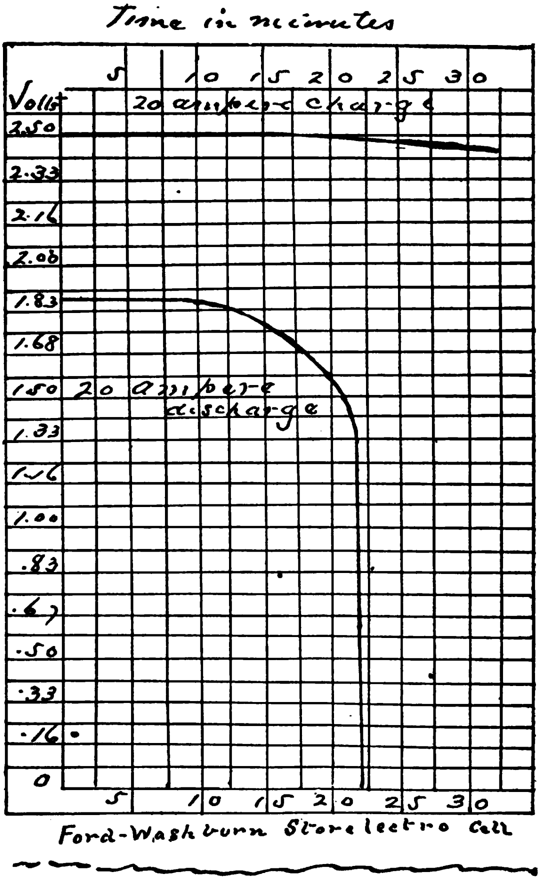

Time in minutes
5 10 15 20 25 30
Volts
20 ampere charge
2.50
2.33
2.16
2.08
1.83
1.68
1.50
20 ampere discharge
1.33
1.16
1.00
.83
.67
.50
.33
.16
0
5 10 15 20 25 30
Ford-Washburn Storelectro Cell

FIGURE 12A.

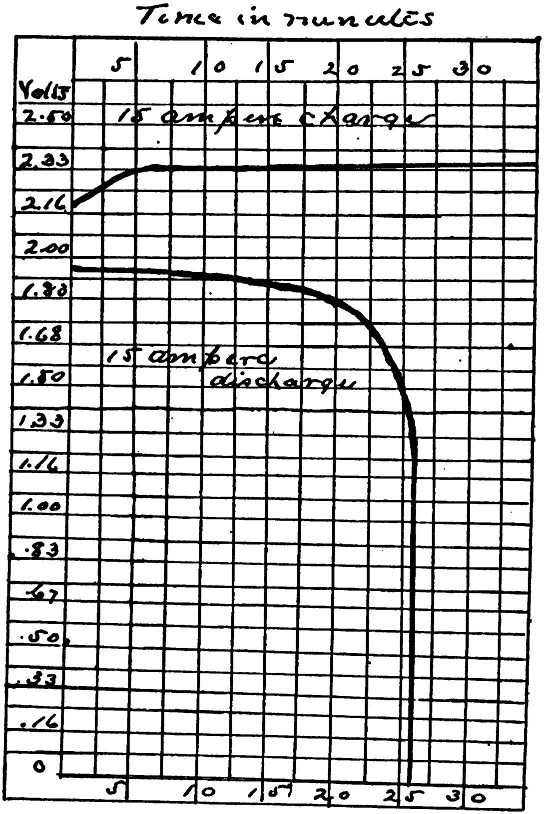

Time in minutes
5
10
15
20
25
30
Volts
2.50
2.33
2.16
2.00
1.83
1.68
1.50
1.33
1.16
1.00
.83
.67
.50
.33
.16
0
15 ampere charge
15 ampere discharge

FIGURE 12P.

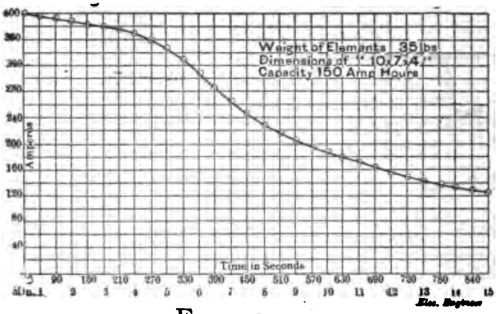


FIG. 13.

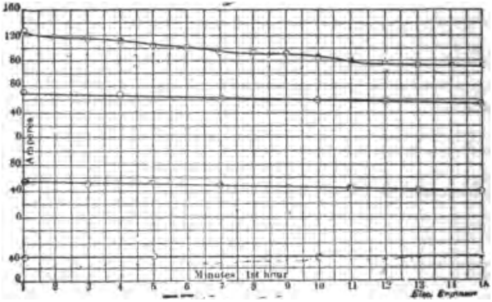


FIG. 14.

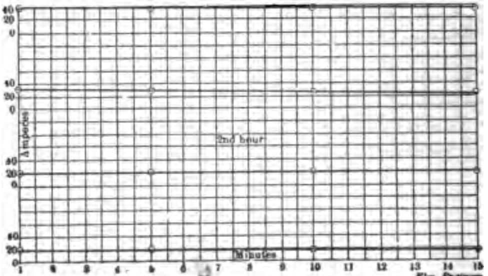


FIG. 15.

cup. Should the electrolyte evaporate below top of elements and free circulation being impossible, the strength of acid varies with the discharge or charge and the E. M. F. falls rapidly when discharging. Figs. 12A and B show the curves of a 15 or 20 ampere discharge.

The Hess Storage Battery.—This storage battery, which is manufactured by the Hess Storage Battery Company, is claimed to differ fundamentally from other storage batteries through the employment of a double electrode.

The active material in this battery is not pasted upon a single lead plate, exposed directly to the action of the electrolyte, but the lead plates are in pairs, forming what is termed a double electrode or conducting body for the active material, which is interposed between the two plates. These plates are perforated and are entirely covered with an insulating material, excepting those portions of the inner faces of the plate indicated by the light lines.

The perforations of the plates are filled with a non-conducting material of great porosity, composed of quartz sand, the particles of which are held together by asphalt. These plates are used in pairs—two being necessary to form one electrode. They are put together with the exposed lead surfaces facing each other, and are so arranged that the exposed lines, both vertical and horizontal, of one plate are not directly opposite the corresponding lines on the other plate, but half a space removed, thus reducing the dimensions of the squares formed by the exposed lines one-half and doubling the amount of conducting surfaces. By this arrangement it is claimed that no more metal is required for a double electrode than is customarily used in the accumulator type of pasted grid. The plates are provided with projecting ribs, which form a space for the introduction of the active material.

The electrodes are assembled in the usual manner, the double electrode with its two plates representing one element. The insulators or separators between the electrodes are hard rubber strips, with buttons at intervals of two inches. The object of using separators of this peculiar construction is to allow a free circulation of the electrolyte from all parts of the cell between the plates. The electrodes are held together, soft rubber washers being used to allow for expansion.

After the assembling of the electrodes they are placed in a cell, which is constructed of wood and lined with thin sheet lead. The electrolyte is then introduced, completely immersing the electrodes, and then the plates are ready for receiving the active material.

In the application of the active material an appliance called a conveyor is used. The illustration shows the conveyor applied to a single cell, but in setting up a battery installation the material is applied to the entire set of cells by the operation of a continuous conveyor. This conveyor forces the active material into tubes or conductors, which register with the spaces between the two plates of each electrode; from these conductors the active material falls between the plates, until the space is filled, thus being brought into contact with the exposed conducting surfaces of the plates, and the cell is now ready for the charging current.

The manufacturers claim that the Hess storage battery is the only one in which there are no exposed metallic surfaces, in which the conducting plates are protected from consumption, and that has a protection to prevent disintegration and falling of the active material, without the necessity of filling up the spaces between the electrodes. Other claims are that it is the only storage battery to which the active material is fed after the plates are immersed in the battery fluid, and in which the perforations of the conducting plates are filled with a non-electric conducting porous material.

The P. W. Storage Battery.—The plate for this cell is made circular in the following manner: See Figure 16.

First a mandrill is placed between centers of the lathe or other suitable machine and two ribbons of lead are wound one on top of the other, one ribbon being corrugated, the other plain.

When the desired size is reached, a frame of cadmium lead alloy is clamped around and the joint burned. The plate is then formed by the Planté process, pasted, or by the Dujardin-Warwick method of electrically depositing or plating from salts of lead.

FIGURE 16.

These cells are capable of withstanding a discharge due to short circuit, or from overloading. 5,000 short circuits have been taken from one of these batteries, and it was then in apparently as good condition as when the test was commenced.

The tensile strength of the lead ribbon being

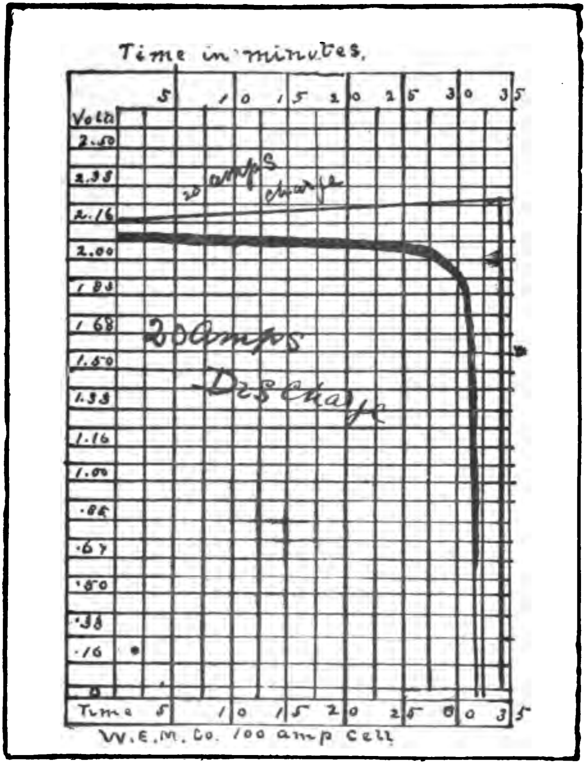


FIGURE 17.

99 per cent. of the original measurement, short circuits within the cells are an impossibility, owing to the fact that a perforated insulating separator is put between pairs of the plates, and

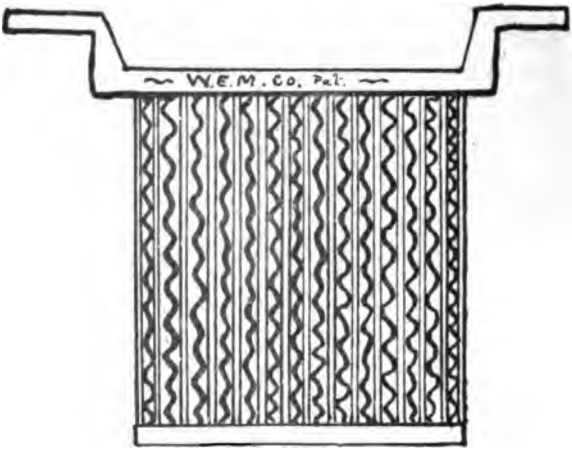


FIGURE 18.

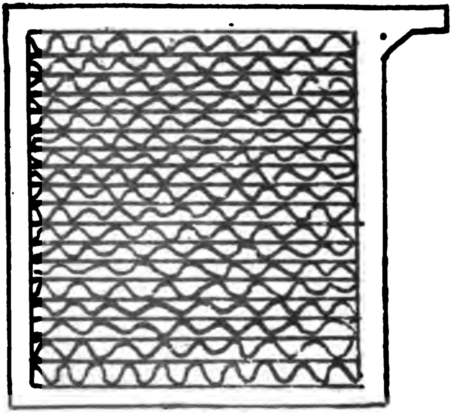


FIGURE 19.

the peculiar construction of the plate prevents buckling, as expansion must take place on all sides equally.

The Warwick Storage Battery.—These cells are a modification of the P. W. cell and are put up in two distinct types, one being for station use and the other for portable or traction use.

The portable cell is made by taking a square or oblong frame of chemically pure de-silverized lead. This is packed securely with alternate strips of corrugated and plain lead, 1-64th of an inch in thickness.

Figure 17 shows the curved lines of the discharge of a 100 ampere P. W. Storage Battery.

The plates are separated when formed by two sheets of cellulose fibre, impregnated with dialyzed silicious acid. In the center between the two sheets is a thin sheet of perforated hard rubber, celluloid or other suitable material.

The station type of plate is shown at Figure 18, and consists of a simple strip of lead, plain or corrugated alternately. The plates suspended in a frame. The idea of this is to allow a free expansion of the positives, which in some cases reaches $\frac{1}{10}$ of their original length.

The features of these plates are that they will not buckle, there is no paste to fall out, and long life. The efficiency is also very high.

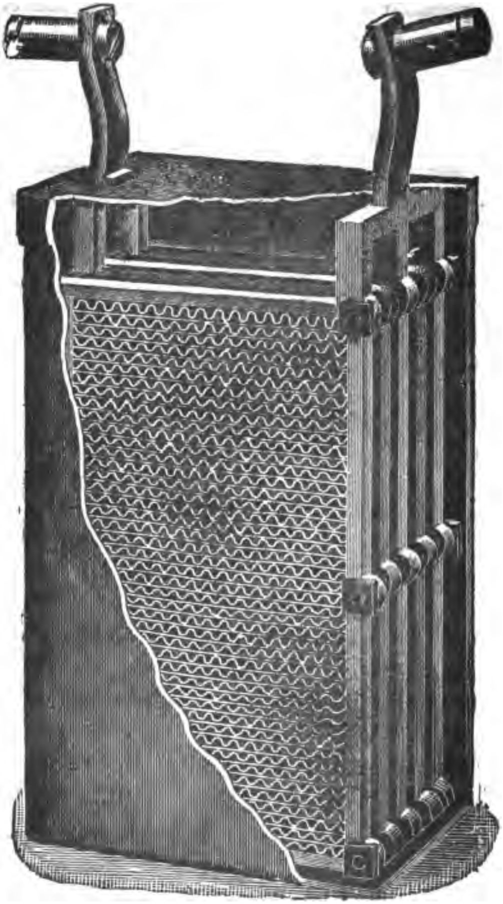


FIGURE 20.

When desired, cells of either type or those of the P. W. Co. are supplied with dry electrolyte. This is a great convenience for traction or portable purposes. The phonograph type is shown in Figure 19.

Fig. 20 shows the Dujardin-Warwick Traction Cell. Fig. 21 shows a plant of the Warwick Storage Cells in operation in Moscow, Russia.

The Chloride Accumulator.—Instead of cementing lead oxide paste into or against a lead framing in order to obtain the necessary active material, the latter is obtained by a strictly chemical process. Lead chloride is taken, mixed with a given proportion of zinc chloride, and this mixture is then fused and cast in small squares in suitable moulds. When thus cast the product is of whitish color and vitreous character, being quite brittle.

For the negative plates, these blocks are about $\frac{3}{4}$ inch square and $\frac{5}{16}$ inch thick, and are cast in groups of four, these groups being united by portions having say $\frac{3}{32}$ to $\frac{1}{8}$ inch thickness. For positives the fused mass is cast in separate lozenges, each lozenge having a beveled V shaped periphery. These cut squares or lozenges are then placed in a suitable mould and a molten mixture of lead and antimony, in proper proportions, is cast about them under high pressure,

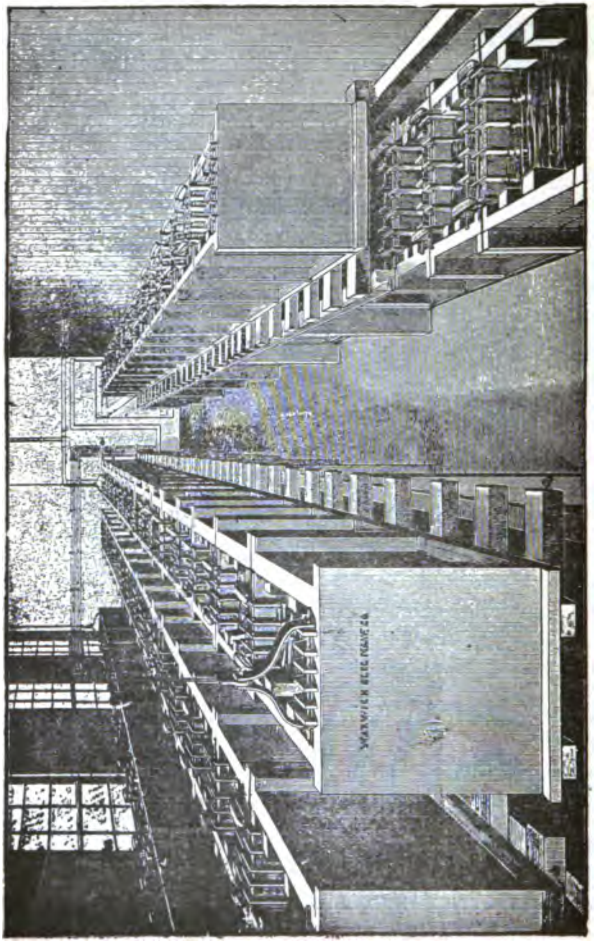


FIGURE 21.

thus fixing them securely in a firm lead framing of somewhat more than the usual density. (The feature of casting under pressure is an improvement in manufacture, due to Mr. H. Lloyd, who is connected with the American makers, and the process is protected by patents granted to him.

The connecting sheets of the squares making up a group and the V shaped bevel of the lozenge serve to make their solidity of fixation exceedingly good.

The frameworks containing the chloride castings are then placed in a dilute solution of zinc chloride together with plates of zinc, the frames and zinc plates being alternated with one another and in metallic contact. This combination is the equivalent of a primary battery "dead short circuited." The chemical reactions which occur result in the removal of the zinc chloride and the chlorine of the lead, and there remains finally the dense framing containing squares or lozenges of spongy lead, which plates are then "formed" in practically the usual manner.

If a section of the spongy lead thus made be examined it is found that the metal is in a crystalline condition, and that the crystals are all uniformly arranged with their longer axes perpendicular to the surface of the plate. This provides interstices, so that the changes of volume occurring in the chemical reactions of electrolysis may take place without exerting lateral pressure upon the crystals or otherwise crowding them into a condition of break up. These crystals are not, of course, mechanically and irregularly bound together, but are related to one another according to the laws of molecular formation, and are, consequently, much more strongly bound together than if they had been mechanically combined.

Furthermore, this crystalline structure presents the maximum obtainable surface for the given mass, an infinite number of intercrystallic channels passing all through the material and the entire plate being of the same thoroughly spongy consistency, except in those small proportions where the continuous lead framing is encountered.

The effect of this extreme porosity and surface area is to give the battery a maximum capacity for given weight and size of cell, an item of great importance when considered with reference to the demands of traction. Very heavy discharges also can be taken from this battery, owing to the interstices between the crystals permitting changes of volume to occur without mechanical violence to the structure.

While the method of construction thus described seems to accomplish its anti-disintegrating function perfectly, it has been thought best by the manufacturers, in order that there shall be no doubt about the matter, to introduce between the plates a thin sheet of acid-proof fabric so that any small particles which might fall away could not make metallic contact with two adjacent plates and thus short circuit the cell. The fabric chosen for this purpose is woven asbestos cloth. It might be thought that the introduction of this asbestos would considerably increase the internal resistance of the cell, but the fact is otherwise, the resistance of the cell being not appreciable higher than that of other lead cells.

This is undoubtedly due to the fact that the larger part of the resistance of most lead cells is that caused by poor contact between the lead framing and the paste placed in it.

In the chloride battery this contact is exceptionally good, owing to the pastilles of chloride being so firmly bound by the framing cast under pressure as to compensate for any resistance due to the asbestos.

These batteries are, and have been for several years, operating successfully and in very large numbers in the city of Paris, as a source of current for lighting purposes.

A large plant has been in operation in Cleveland, O., in the building of the Provident Life & Trust Co. for a year past, and a very large one has been installed at the station of the Germantown Electric Light Company, where it is said to have given, thus far, entire satisfaction.

CHAPTER VI.

LEAD, ZINC, COPPER, ALKALINE AND OTHER STORAGE BATTERIES.

The previous chapters have dealt with storage cells of lead and lead peroxide.

This chapter will treat of some of the other forms not so well known, but which deserve some consideration on account of the novelty of the methods of constructing them and the promising results from some of them.

The lead-zinc type is a fully charged peroxide lead plate and a zinc plate immersed in a solution of dilute sulphuric acid.

This form of construction gives a very high electromotive force.

The chemical reactions during the charging operation are probably fairly represented by the equation.

$$PbO_2+ZnSO_4+2H_2O=PbO_3+Zn+2H_2SO^4$$

According to Emile Reynier, the chemical reactions of a discharge have two phases, which may be stated thus: At the outset, one equivalent of sulphate is carried to the negative element as represented by the equation.

$$PbO_2+Zn+2H_2SO_4=PbSO_4+ZnSO_2+2H_2O$$

During the second phase another equivalent of zinc is sulphated at the negative pole and an equivalent of hydrogen reacts upon the positive elements, during which operation the active material resolves itself into metallic lead and sulphuric acid, as shown by the following equation.

$$2PbSO_4+Zn+H_2O=ZnSO_4+2Pb+H_2SO_4$$

Immediately after a charge, the electromotive force developed by a zinc peroxide couple may react 2.7 volts.

During a discharge the internal resistance of this form of cell is found to vary between very wide limits.

At the commencement it is about the same as that of a lead peroxide couple, but as the discharge proceeds the resistance is being continually augmented, owing to the conversion of the highly conducting acid electrolyte into sulphate of zinc solution, which has a much higher specific resistance.

Reynier Lead-Zinc Cell.—Reynier lead-zinc cell consists of an ordinary Planté or Faure peroxide plate in conjunction with thin sheets of lead on which a thick layer of electrolyzed zinc has been deposited.

By the utilization of pure electrolyzed zinc, many of the difficulties of local action were eliminated.

A battery of this description introduced in the year 1884 was constructed as follows:

Each cell contained four peroxide plates of the Planté type which presented an extensive active surface and three negative elements made of smooth sheet lead covered with electrolyzed zinc which had been deposited from an acidulated bath of sulphate of zinc.

Accidental contact between the electrodes was prevented by glass insulating tubes, secured to the negative plates by lead strips.

All the elements were provided with separate and substantial terminals.

Two brass rods, terminating in a clamping screw connected the terminals of like polarity.

By careful insulation of the trough and all other parts of the cell, the employment of pure zinc and the elimination of all impurities from the electrolyte, a cell was produced in which the loss from leakage and local action was exceedingly small.

The following particulars of a cell of this construction are given by M. Reynier.

Total area of active positive surface, 200 sq. decimeters. Total area of active negative surface, 150 sq. decimeters.

Weight	of positive	elements,	8.2	kilogrms.
“	“ negative	“	1.4	“
“	“ c'nt'n'g trough		2.7	“
“	“ electrolyte		4.4	“
“	“ connectors		0.46	“
Total weight of complete cell,			17.16	“

And the following results were obtained:

Electromotive force, 2.36 volts.

Mean internal discharge, 0.02 ohm.

Rate of discharge, 25 amperes.

Rate of charge, 5 to 10 amperes.

Capacity of cell after 200 hours formation, 152 ampere hours.

The total amount of energy stored in this cell was found to be 130,000 kilogrammeters, or at the rate of 7,600 kilogrammeters per kilogram of complete cell; according to Reynier a lead zinc accumulator should store 15,600 kilogrammeters per kilogramme of cell. But as these cells when used commercially have to be constructed to withstand rough treatment, the elements are made much shorter and more massive than theory would indicate.

M. Reynier gives the following as the calculated and practical weight of a cell of 130,000 kilogrammeters of energy.

	Calculated Weight. Kilogrammes.	Actual Weight. Kilogrammes.
Lead	2.500	8.000
Zinc	0.550	1.390
Oxygen	0.180	0.180
Acid and water	1.140	4.400
Cell, etc.	1.105	3.160
	5.475	17.130

He also gives the following as representing the relative capacity of various types of storage cells.

Planté's original 1,500 kilogrammeters per kilogramme of plates.

Faure's early form 3,000 kilogrammeters per kilogramme of plates.

Faure's grid form 4,400 kilogrammeters per kilogramme of plates.

Reynier's lead-zinc 7,600 kilogrammeters per kilogramme of plates.

M. Reynier gave much attention to storage batteries and communicated many papers on this subject to the French Scientific Societies. Among his numerous literary efforts were "Les Piles Electriques et Accumulateur" and "Traite de L'Accumulateur Voltaique."

The latter has been translated into English.

Dr. Oliver Lodge in 1884 patented in England, the use of sulphate of mercury in zinc storage cells.

He also demonstrated that when a peroxide of lead and zinc-couple were immersed in dilute sulphuric acid a steady electromotive force of 2.5 volts was obtained, which he claimed was the highest electromotive force that he had obtained from any practical voltaic cell.

M. Tamine of Brussels uses in his lead-zinc accumulator a saturated solution of sulphate of zinc to which is added a certain percentage of sulphuric acid and a similar quantity of sulphate of ammonia.

By the addition of sulphate of ammonia all sulphating of the elements, during repose, is entirely prevented.

An electromotive force of 2.3 volts per cell is obtained from this cell.

Bailly Battery. — M. Phillimond Bailly of Ermond, France, introduced a lead-zinc storage cell in which the positive elements were masses of lead wool and the negatives were amalgamated sheets of zinc.

Hedges Lead-Zinc Cell. —Mr. Killingworth Hedges, in 1887, exhibited to the British Association a lead-zinc battery whose positive element was of the Planté type.

The maximum amount of surface for peroxide plate was obtained while the total weight was much reduced and the available electromotive force increased by using a strip of zinc for the positive plate instead of lead as in most modifications of the Planté cell.

The peroxide plate was constructed on M. Bailly's method.

The current was led from the zinc plate by causing it and its connecting wire to dip in mercury. This plan helps to keep up the amalgamation and tends to stop local action.

The Lalande and Chaperon Battery.— The partial reversibility of a copper-zinc voltaic couple has been known for many years, and this form of cell may be considered as a secondary or storage cell inasmuch that when the electrical energy has been obtained from it by the destructive decomposition of the metalic zinc and the copper salts, it may be restored to approximately its original condition by passing an electric current through it.

Very little had been done in the way of utilizing this cell as a storage cell but as a primary generator it was' in a degree, a commercial success.

The energy contained in a copper-zinc potash cell is very large, far superior to that stored by a lead accumulator of the same dimensions.

As an electrolyte, potash may be employed in concentrated solutions of 30, 40 or even 60 per cent.

Solid potash is found to dissolve zinc to the extent of more than ⅓ of its own weight.

In these cells, the weight of oxide of copper employed exceeds by nearly one quarter the weight of zinc which is brought under action.

The deposited copper oxidized quite readily by simple exposure to damp air, and can then be used again. An oxidizing flame produces the same result very rapidly.

By treating the exhausted cell as an accumulator by passing a current through it in the opposite direction, the various products are restored to their original condition, the copper absorbs oxygen, the alkali is revived and the zinc is deposited.

The Thomson-Houston Zinc Copper Cell. Professors Elihu Thomson and E. J. Houston, in a paper in the Journal of Franklin Institute, suggested a form of storage cell bearing some resemblance and analogy to the well known Daniels Gravity Cell, and claimed that the storage of electrical energy in lead cells was inconvenient and not economical, because of the extent of conducting surface required to be acted on rendering it cumbersome. The loss of energy due to the evolution of gas during the operation of charging, lack of constancy and duration of current involved in charging, the limited capacity for storage due to the proportion of active material being but a fraction of that present.

In their system of electrical storage, the duration of the electrolytic action and consequent capacity for storage was independent of extent of surface and depended only upon the mass of material to be acted upon.

They employed a saturated solution of zinc sulphate in a suitable vessel, at the bottom of which was placed a plate of copper with an insulated conducting wire. Near the top of the solution was placed a second plate of copper, hard carbon, or in fact, of any substance or metal that is unchanged by contact with zinc sulphate solution and less positive and metallic zinc.

The cell after charging becomes a copper zinc gravity cell and continues a source of electrical energy until a reconversion of all the copper sulphate into zinc sulphate has been effected, metallic copper being deposited on the lower plate and the deposit of zinc being removed from the upper.

The cell may be covered to prevent evaporation and since no new material need now be added, a restoration to an active condition is at any time possible.

The Copper, Zinc and Alkaline Storage Cell, as devised by Michael Faraday, was found to polarize after it had been in action for a short time, when it had become exhausted, that is to say, when the potash solution had become saturated with zinc and the oxide disappeared from the surface of the copper, the cell could be regenerated by the passage of an electrical current through it.

As the oxide of copper formed under these conditions was soluble in the potash solution, copper was deposited on the negative element at the same time as the zinc and this gave rise to violent local action to such an extent that the regenerated cell soon became exhausted.

MM. Dismasures, Commelin and Baillehache succeeded in overcoming most of the difficulties incident to Faraday's cell and produced a reversible couple which promised well.

The positive element is composed of pure metallic copper obtained by electrolytic reduction of copper oxide in the form of a thick muddy substance which under heavy pressure appeared like a solid block of copper, but only about two-thirds the specific gravity of ordinary sheet copper and is of a highly porous nature, possessing most of the elements of a good depolarizer and at the same time are of high electric conductivity, producing a couple giving fairly good results, as the copper being dissolved less quickly by the alkaline solution is not deposited so rapidly on the zinc.

If the copper is covered by parchment-paper or other like fibrous material, the regenerating process is effected with difficulty, the whole of the dissolved zinc being deposited, the porous copper absorbs the oxygen, producing a cell which can be charged and discharged indefinitely.

In a modification of this cell, a thin plate of silver obtained in the same way as the copper plate, was substituted for it, and a large increase in available electro-motive force was obtained and light and compact batteries were made.

A portable hand lamp constructed on this principle, and weighing three pounds, gave an output of fifty-watt hours—of this weight five ounces were silver.

While in this form of cell local action would take place, it was to only about five per cent., if the ampere capacity was used within twenty-four hours after charging.

Entz and Phillips Copper Zinc Elements were produced by Messrs. Entz & Phillips at Schenectady, New York, and consists of a copper core enveloped by a woven network of very fine copper wire filled with oxide of copper, the whole being protected by a sheeting of cotton or hemp, woven around it, which prevents metallic contact, should the elements touch each other. The compound copper plate forming the positive element and a sheet or rod of wire, the negative, dilute sulphuric acid being the electrolyte.

To recharge, it is either heated or an electric current is passed through it in the ordinary way.

As the copper network retains the active material under all conditions, the elements withstand very heavy discharging without injury.

Main Lead-Zinc Storage Cells. In this cell the zinc plates are placed in a horizontal position to remedy some of the defects in Reynier's cell; i. e., the differences in the density of the solution caused an unequal action on the zinc plates, which were frequently cut away from this support.

The positive plate is composed of two thick outer plates between which are held a number of very thin sheets of lead foil and the whole after being firmly riveted together are closely perforated, making a very strong and rigid element, which is not liable to disintegrate when formed and in use.

The negative is a thin perforated copper plate or dish filled with amalgam of zinc or mercury.

The elements are placed in the containing cell, one above the other alternately, retaining the proper distance apart by insulating washers, the whole held firmly by a clamping cover.

This battery is used by the River & Rail Electric Co., in Brooklyn, New York, for running their street cars, it requiring 60 cells of 250 ampere hours to each car.

Prof. G. F. Barker in his copper zinc-lead cell constructs the negative element of sheets of well amalgamated copper and zinc, held together by rivets. The positive element is built up of sheets of lead foil, covered with powdered graphite, which serves to keep the sheets a short distance apart where they are clamped together and to further increase the active surface, the clamped plate is closely perforated.

As no electromotive force is set up between the amalgamated sheets of copper and zinc little or no local action occurs.

The electrolyte used in this cell is an acid solution of sulphate of zinc.

When thoroughly formed, this type of cell is said to give a much higher current capacity per pound of plate than either a Planté or a Faure, and when at rest, neither element shows any signs of sulphating.

Kalischer's Battery, as described in a communication to the Physical Society of Berlin, consisted only of a sheet of iron and a plate of well amalgamated lead and a concentrated solution of nitrate of lead as an electrolyte.

On the immersion of the iron plate in the solution, no action followed, but the charging current being applied, the solution was electrolyzed and the iron plates became covered with an adherent deposit of peroxide of lead. The charging was continued until the greater part of the lead was abstracted from the solution, indicated by the rapid evolution of gas at the negative electrode.

If at the beginning of charging the current is passed at too high a rate, the deposited hydrated peroxide of lead assumes a scaly and non-adherent texture and tends to fall away from its support.

The tendency to form short circuits was obviated by thoroughly amalgamating the lead plate before immersion in the electrolyte.

This cell had an initial electromotive force of 2 volts falling to 1.8 to 1.7 volts after a few hours action.

This cell is slightly recuperative, if discharged until the electro motive force had fallen to 1.7 volts it would, after 24 hours rest, again nearly its initial potential.

The result of a number of tests made this accumulator shows that it compares favorably with most forms of lead or lead peroxide cells.

The Marx Liquid Accumulator.—The preceding forms of electrical storage apparatus derive their activity from the electrodes themselves, the same plates being used in the charging and discharging operation. In this accumulator the electrical energy is stored in the electrolyte itself, which owing to this peculiar property has been termed "Electroline."

Certain chemical changes induced by the passage of a current through electroline determine a number of reactions, whereby electrical energy may be stored. The electrode or conductors may be of metal or some inert semi-conducting material, such as carbon.

The formula for an electroline cell is: four hundred and fifty grammes of chloride of iron, dissolved in nine hundred grammes of water, to which has been added five hundred grammes of hydrochloric acid.

In this solution two negative plates and one positive are immersed and are correspondingly connected to the negative and positive poles of the charging source.

The passage of the current causes decomposition of the liquid, turns greenish, ultimately yellowish brown. When the chemical reactions are complete, the plates are removed, the cell is said to be charged.

When suitable conductors are immersed in the electroline and the outer circuit is completed, an energetic current is developed.

The Tatlow Battery.—This consists of a zinc and lead peroxide couple immersed in an electrolyte of dilute sulphuric acid. A cast lead grid, filled with litharge, moistened with a solution of acetate of lead; when thoroughly dry, it is placed in a concentrated solution of chloride of lime, which reacts on the lead salt, converting it into lead peroxide, forming the positive element, which, when thoroughly washed in water is ready for use.

From a plate prepared in this way in conjunction with a negative element, such as zinc, and placed in dilute sulphuric acid, an electromotive force of 2 to 2.3 volts is obtained. When the positive plate is exhausted, it may be renewed by again placing it in the hypochlorite solution. This operation may be repeated again and again.

In the regenerating bath there should be enough free lime to keep the liquid distinctly alkaline, which turns greenish, then yellow and finally yellowish brown. When all the chemical reactions are completed and the solution will not absorb further electrical energy, the conducting plates are removed and the cell is said to be charged.

In this battery a change of electrodes is essential, the best results being obtained with plates of varying conductivity, such as metal in conjunction with carbon.

A highly porous carbon block placed between two zinc plates gives excellent results, or carbon with copper or iron may be used.

When suitable conductors are used and the outer circuit is completed, an energetic current is developed and the liquid decomposes, passing through the same series of colors as in charging but in reverse order, while it gradually loses its electrical energy.

Jablochkoff's Anti-Accumulator.—This was described by him in a communication to the French Academy of Sciences, and is so termed on account of its elements being regenerated by local action. It consists of three dissimilar electrodes, first an oxidizable metal which forms the first electrode, then a plate of slightly oxidizable metal capable of being polarized, and lastly another electrode consisting of tubes of very porous carbon.

The most successful cell of this type was constructed as follows:

The first element was a flat dish of thin sheet lead in which was placed a number of fragments of an easily oxidizable metal such as sodium-amalgam, zinc, or similar material, on top of the granulated metal, a layer of cloth or sawdust.

If sodium was used it was not necessary to add water; if zinc or iron was used, the mass was moistened with a solution of common salt and the electrode of carbon tubes was placed on the damp spongy mass.

When the elements are on open circuit there are established a number of local currents between the oxidizable metal and the electrodes on which it rests, which is therefore polarized and its potential rises until its counter-motive force has reached that of the oxidizable metal; the local action is then totally arrested or reduced to a minimum.

To utilize the exterior current the lead electrode is joined to the carbon electrode, the discharge then begins, the local currents are redeveloped and tend to restore the charge to the electrode as fast as it is carried off.

With sodium-amalgam an electro-motive force of 2.2 volts with zinc, 1.6; with iron, 1.1 volts is obtained.

This battery may be worked for many months, without renewing the active material, it only being necessary to replace the liquid from time to time, which is readily effected by steeping the elements in water, allowing them to drain and then immersing in a solution of chloride of calcium.

If the current is used for lighting purposes or for running motors, the liquid must be renewed every twenty or thirty hours.

With the employment of this battery combination, electrical energy to the extent of one horse power an hour may be obtained at the expenditure of only a few cents.

Bristol's Portable Battery. Elements suitable for small storage cells are constructed by incorporating oxides of lead with binding material, such as asbestos fiber, animal hair, horn shavings or some similar fibrous material which is capable of giving the mass sufficient cohesion to retain its shape without the aid of a metallic support.

The salts of lead, when combined with from one to three per cent. by weight of the fibrous material, are found to have sufficient mechanical strength to resist all ordinary disintegrating influences, either mechanical or electrical.

The binding material having been thoroughly incorporated with the metallic oxides is moistened and made into a stiff mass, pressed in moulds to give it the desired shape, and either a flattened lead wire or a platinum strip having lateral branches inserted in a soft mass to act as conductor. When dry the masses are formed in an acid bath by the usual method.

In making up cells suitable for hand lamps, one positive and one negative only are used.

Distance pieces of wood, saturated with paraffin wax are placed between the plates to keep them apart, and covers of vulcanite are placed over the cells to keep the electrolyte from splashing over or leaking out, and having a vent plug inserted, which is removed during the operation of charging; but when the valve is fixed the cells are practically sealed and may be held in any position without the electrolyte escaping.

CHAPTER VII.

HOW TO INSTALL, WORK AND MAINTAIN A STORAGE BATTERY PLANT.

As soon as possible after the arrival, the cells should be carefully unpacked and the sawdust, etc., removed from the plates.

The glass jars for the reception of the elements should be dipped in paraffin along the edge and then stood in small wooden trays well coated with asphalt and supported on insulators.

The benches on which the cells stand should also be coated with Acme or P. & B. insulating paint to preserve the woodwork, and they must be strong and substantial. Place the plates in the jars, being careful to avoid short circuits; cover the plates well with cold electrolyte of the proper strength.

The strength of the electrolyte varies with different makes of plates but 20 per cent. Baumme will be strong enough.

Now start up your generator and having tested out the lines and found the positive pole, connect this to the positive of your battery, and the negative to the negative of the battery, and charge with a steady current until all the cells gas freely,which they should do in about twelve hours.

The generator should be either shunt-wound or under-compounded.

In no case use a series machine or an over-compounded dynamo, as you will probably reverse dynamo and spoil battery.

The electrolyte is made of sulphuric acid and water, one part acid to six parts water, by measure.

Use a new, clean butter crock, of sufficient capacity to hold the quantity of electrolyte you wish to make.

Put the water in the jar and pour the acid into the water slowly and stir with a wooden spatula or piece of broom handle. When cold, put the electrolyte into the glass jars with the plates, filling them up so as to cover the plates at least one half inch.

The plates should always be covered to this depth, as, should they get dry by being uncovered, they will be damaged and eventually destroyed.

The batteries should never be left without current in them, for while a good average battery will hold current for several months without loss of current or damage to the battery, a few in the empty state will do more to wear out a battery than a year of actual use.

Always switch battery on after starting and off before stopping dynamo.

To find the direction the current is flowing, place your back to the dynamo or source of current, and with a small pocket compass placed before you under the wire, imagine yourself swimming on the wire facing the compass.

If the north pole is deflected to the left hand, you are swimming with the current: if it deflects to your right hand, you are swimming against it.

The current flowing from the dynamo is the positive and should be placed to the positive pole of battery or dynamo.

To charge from gravity cells, it requires three gravity cells to one storage cell.

Connect the gravity cells in series, i. e. the copper pole of one cell to the zinc of the next and so on, and the terminals to the terminals of the storage battery, the copper to the positive and the zinc to the negative pole.

Short circuiting will not injure the storage cell in an appreciable degree, but as it does no good, it is best to avoid it.

Sulphating and its Removal.—One of the chief causes of loss of efficiency in lead accumulator cells is due to sulphating. Troublesome white sulphate of lead usually forms on exposed parts of the metal support, on the surface of the active material or just where it is least wanted, which is at the junction of the metal support and the peroxide.

The formation of this sulphate is probably due either to impurities in the oxide employed, deleterious substances in the lead or lead alloy, used for the frames, or chemical impurities in the sulphuric acid or water.

If a cell be allowed to remain idle and without charge, its elements frequently sulphate.

A suggested cure is to charge at a somewhat higher rate than the normal, and to continue the charging some little time after the cells freely give off gas.

This process usually either reduces the sulphate into the peroxide, or causes it to fall away from the plate.

Mr. Barker-Starkey found that by adding a small quantity of carbonated soda to the acid electrolyte, it not only reduces the tendency of the elements to sulphate, but rapidly removes this salt when already formed.

This action is probably due to the conversion of the sulphate, first into carbonated lead, and then into the peroxide, or it may be owing to the fact that sulphate of lead is sparingly soluble in a solution of sulphate of soda.

As the results of some experiments made with a view of ascertaining the effect of adding sulphate of soda to storage battery solution, it is found that the addition of sodium sulphate to the ordinary acid electrolyte has a distinctly beneficial effect upon the working of the cell.

It has been found that upon the addition of these soda salts a large proportion of the sodium sulphate is formed, in close contact with the lead sulphate on the peroxide plate, and that this formation was favorable to the reduction of the latter substance, as a paste of equal parts of minium and lead sulphate is more readily reduced in solution of sodium sulphate than in dilute sulphuric acid.

A trial of the acid soda electrolyte consisted in taking six new accumulator cells, made, as nearly as possible, identical in every respect, using in each different solutions, composed of various percentages of sulphuric acid and water, and sulphate of sodium.

The sulphate of soda and solution used was prepared by carefully adding strong sulphuric acid to a saturated solution of commercial carbonate of soda.

The addition of the acid was continued until carbonic acid gas ceased to be given off, and all the effervescence was stopped.

The following table shows the composition of the various mixtures tried.

No. of cell.	Quantity of Sulphuric acid Solution.	Quantity of Sulphate of soda Solution.	Quantity of Water.
1	5 pints.	5 pints.	15 pints.
2	5 "	4 "	16 "
3	5 "	3 "	17 "
4	5 "	2 "	18 "
5	5 "	1 "	19 "
6	5 "	0 "	20 "

The six cells were then filled respectively with these solutions. They were carefully charged and discharged continually for a period of twelve months.

On the expiration of this term the elements were thoroughly examined. The cells that contained solutions numbering from 1 to 5 were found to be in a much better condition than No. 6, which only contained the dilute acid, without the soda sulphate.

Solution No. 5 seems to have given by far the best results. In this cell the plates were found to be in perfect condition, and did not show the slightest signs of sulphating.

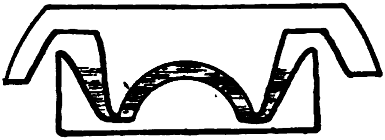
As an example of beneficial results to be derived from the use of an acid soda solution, the following may be worthy of mention.

It is said that at the Central News office in Ludgate-hill, London, England, a number of large lighting cells had been idle and dry for about two years. The plates were found to be thickly incrusted with a hard white sulphate. With the the ordinary electrolyte, and a charging current of from 10 to 15 amperes, no improvement was observed after two charges of eight hours per day; but after adding half a pint of strong carbonate of soda solution to each cell, and with the same amount of current going in as before, the plates soon improved, and in a few days all the elements presented a beautiful appearance.

When removing sulphate by this method, it is much the best way to take out the de-sulphating solution, after the plates have been brought to a healthy condition, and replace it by the ordinary dilute acid electrolyte, otherwise the negative plates are said to deteriorate.

Insulating Cells.—Wherever a number of open cells are in use unless great precautions are taken, electrical leakage between the cells invariably occurs. This leakage is in a great measure due to semi-conducting nature of the thin layer of moisture which is so frequently found to cover all parts, not only of the glass-containing cells, but the unimmersed parts of the elements, and even the shelves on which the cells rest.

To prevent this waste of energy, the outside of the cells should occasionally be well cleaned and thoroughly dried. If a little vaseline or tallow be then rubbed over them, it will have the most beneficial effect.



Oil Insulator

Fig 22

The shelves, or support for the cells, should either be well varnished or coated with paraffin wax. Electrical leakage is greatly reduced, if each cell is mounted on a glass or earthen-ware insulator.

The form of oil insulator recently introduced, constructed as shown, Fig. 22, seems to possess most of the essentials of the moisture intercepter and the electrical non-conductor.

As shown in the diagram, this insulator is in two parts and of a mushroom shape. The lower cup contains a small quantity of some non-evaporating oil, and as the conducted moisture cannot bridge across this, a nearly perfect insulating medium is obtained.

These new insulators are made of various sizes and may be obtained in earthern-ware or glass. Those made of glass are found to give the best results.

Destroying Acid Vapour in Accumulator Rooms. To neutralize and prevent the accumulation of acid vapor in battery rooms, nothing can be better than a good system of thorough and rapid ventilation; failing this the evil effect of the acid may be minimised by the fumes of a powerful alkali such as ammonia, which will readily combine with the sulphuric acid to form sulphate of ammonia, an inert and harmless salt. If the use of liquid ammonia is objectionable, the granulated carbonate of ammonia will do equally well. The ammonia fumes are best obtained by placing dilute ammonia in shallow dishes, so that an extensive evaporating surface is obtained. In the same way the corroding dew which is so frequently deposited on the lugs and connectors of storage battery elements may readily be neutralized by the application of a solution of ammonia, or even common washing soda. A good method of protecting metal-work in battery-rooms is to smear it over evenly with vaseline.

Electrical Units.—The ohm is the unit of electrical resistance. The resistance to the passage of a current offered by a uniform column of pure mercury, 104.82 centimeters long and one square millimeter in sectional area, at a temperature of 0 deg. C., is one B. A. ohm.

Commercial copies of the ohm are usually made of wire wound, on a spool and supplied with massive low-resistance terminals. The metals most commonly employed in the manufacture of these standards are platinum, platino-iridium alloy, German silver, or platinoid.

The volt is the practical unit of electromotive force or difference of potential. It may be defined as that electrical pressure or electromotive force (E. M. F.), which is required to maintain a current of one ampere through a resistance of one ohm.

A newly made-up Daniell cell gives approximately an electromotive force of one volt, or about one-half the electrical pressure developed at the poles of a storage cell of the Planté type. Standard Daniell cells are to be obtained, but the most convenient form of standard cell is the sulphate of mercury and zinc couple of Latimer Clark. The E. M. F. of this cell varies from 1.471 to 1.435 volts with a range of temperature of 0 deg. to 32 deg. C.

The ampere is taken as unity in determining the rate of flow of an electric current—that is, that amount of current flowing in a wire of a resistance of one ohm, between the two ends of which a difference of potential of one volt is maintained, is called one ampere.

One ampere in one hour will deposit 1.174 grammes of copper, 4.074 grammes of silver, and will decompose 0.3357 grammes of acidulated water. An ordinary 16 candle-power 100-volt Edison-Swan lamp requires from 0.6 to 0.8 ampere to fully incandesce it.

A *Coulomb* is the name given to that amount of electricity which is developed in a period of one second at a rate of flow of one ampere; 3,600 coulombs represents a current of one ampere hour.

This quantity unit, the coulomb, is very useful for expressing the amount of electrical energy which a primary or secondary cell is capable of yielding. It is much used in the comparison of different types of accumulators, whose relative merits may be expressed in terms of so many coulombs, or more usually ampere-hours capacity per pound of plate, of complete cell, or per unit area of exposed active surface.

The rates at which electrical energy is being consumed, or at which work is being performed, is expressed in terms of the *watt*. This measurement is obtained by taking the product of the electromotive force and the current—e. g., if a cell is being discharged at a rate of 20 amperes, and at electromotive force of two volts at its poles, then the rate at which its energy is being given out per second is 20×2=40 watts; if this discharge be maintained for a period of one hour, then the total energy is equivalent to 20×4×3,600 =144,000, or 40 watt-hours.. In an efficient glow lamp an expenditure of 3.5 watts at its terminals should produce a luminosity of one candle-power.

The term *kilowatt* is used to designate an activity of 1,000 watts. One electrical horse power hour is represented by 746 watt hours. When alluding to the energy storage capacity of an accumulator cell it is usual to express it in terms of watt-hours, or if the cell be large in electrical horse-power hours.

Ohm's Law.—In our present system of electrical measurements, based as they are on what is known as Ohm's law, if two quantities be given, the third and unknown may always be found by a simple algebraical equation.

Thus, if C stands for current.
E " " electromotive force,
R " " resistance,

then Ohm's law may be stated thus;

$$C=\frac{E}{R}$$

and $$E=CR$$

and $$R=\frac{E}{C}$$

Measuring the Internal Resistance of Voltaic Cells.—The internal resistance of a cell depends upon the total active surface area of the opposing plates, the nature of the electrolyte and its condition and temperature, and the distance between the plates.

There are many methods for determining the internal resistance of batteries. If the cells be as nearly as possible of the same dimensions, capacity, and state of charge, then two cells may be placed in opposition (poles of like polarity joined together) and their joint resistance may be measured by the ordinary Wheatstone bridge method. If the cells be exactly similar, then one-half the resistance indicated will represent the resistance of each cell.

A far more reliable and accurate means of ascertaining the internal resistance of cells is the differential method as expressed by the following formula:

$$r=\frac{D-D'}{D}R$$

where r is the resistance required, D and D′ are the values of deflections obtained on a high resistance sensitive galvanometer, and R expresses the value of a small but known resistance, used as a shunt.

When making tests by this method, a high-resistance potential galvanometer should be used, and one whose scale readings are either of uniform value, or whose tangents are strictly proportional to the angle of the deflections. To determine r we have to obtain a deflection, D, when the cell is on open circuit, and then obtain another reading D′, when the cell is shunted by R, then by the formula given the internal resistance may be ascertained. The shunt resistance, R, should be small in comparison with the galvanometer coils. Good results may be obtained if the resistance of the galvanometer is, say, 5,000 ohms, and the shunt not more than 5 ohms.

Capacity and Efficiency of Storage Cells. The total current, or energy capacity, of a storage cell is the maximum amount of current or electrical energy which it is capable of storing, without reference to any loss that may occur by it being allowed to remain idle, nor does it take into account the rate or manner of its discharge.

The working current, or energy capacity, is that amount of current, or electrical energy, which can be obtained from the cell at any specified rate of discharge. When estimating this, the discharge is always stopped as soon as the cell ceases to do useful work. The working capacity of storage cells may vary between very wide limits.

The absolute current, or energy efficiency, of an accumulator cell, is the ratio between that amount of current or energy put into it and that obtained by a total discharge, without reference either to its rate of charge or discharge, or to the time allowed to elapse between the operations.

The working current, or energy efficiency, of a storage cell is the ratio between the value of the current or energy expended in the charging operation, and that obtained when the cell is discharged at any specified rate.

In a lead storage cell, if the surface and quantity of active material be accurately proportioned and if the discharge be commenced immediately after the termination of the charge, then a current efficiency of as much as 98 per cent. may be obtained, providing the rate of discharge is low and well regulated. In practice it is found that low rates of discharge are not economical, and as the current efficiency always decreases as the discharge rate increases, it is found that the normal current efficiency seldom exceeds 90 per cent., and averages about 85 per cent.

As the normal discharging electromotive force of a lead secondary cell never exceeds 2 volts and as an electromotive force of from 2.4 to 2.5 volts is required at its poles to overcome both its opposing electromotive force and its internal resistance, there is clearly an initial loss of 20 per cent. between the energy required to charge it and that given out during its discharge. As shown, the normal, discharging potential never exceeds two volts, and as this pressure is continually being reduced as the rate of discharge increases, it follows that an energy efficiency of 80 per cent. can never be realized. As a matter of fact, a maximum of 75 and a mean of 60 per cent. is the usual energy efficiency of lead-sulphuric-acid storage cells.

TABLE FOR THE CONVERSION OF MEASURES.

One metre = 39.37 inches = 3.28 feet.
One decimetre = 3.937 inches.
One centimetre = 0.39 inches.
One millimetre = 0.039 inches.
One yard = 0.9144 metre.
One foot = 0.3048 metre.
One inch = 2.54 centimetres = 0.254 decimetres.
One kilogramme = 2.2 pounds.
One pound = 453.6 grammes.
One gramme = 0.099 ounce = 15.432 grains.
One milligramme = 0.154 grain.
One grain = 0.0648 grammes.

One hundredweight = nearly 51 kilogrammes.

One thousand kilogrammes = nearly one English ton.

One gramme = the weight of one cubic centimetre of pure water at 4 deg. C.

One litre = one cubic decimetre.

One pint = 0.761 litres.

One gallon contains approximately 4.5 litres.

One kilogrammetre = 7.233 foot-pounds.

One foot-pound = 0.138 kilogrammetre.

One cubic inch of distilled water weighs 252.5 grains.

One cubic foot of distilled water weighs 1,000 ounces or 62.5 lbs.

Sixteen cubic feet of water weigh about 1,000 lbs.

The density of distilled water, when at a temperature of 60 deg. F., is usually taken as unity for comparison with liquids heavier than water.

The density of pure concentrated sulphur acid at temperature of 0 deg. C., is 1.854. The density of pure nitric acid at the same temperature is 0.559.

Taking the density of atmospheric air at 0. deg. C., and at a barometric pressure of 76 centimetres, as unity, then the densityof dry hydrogen is 0.0693, and of oxygen 1.1056.

Thermometric Scales.—The thermometers most extensively employed for the measurement of differences of temperature are the Fahrenheit, the Centigrade, and the Reaumur. They are calibrated as follows;

	Freezing point.	Boiling point.
Fahrenheit	32 deg.	212 deg.
Centigrade	0 deg.	100 deg.
Reaumur	0 deg.	80 deg.

Calling the three scales F, C, and R, these may readily be transposed by the simple proportion method—thus:

$$F : C : R :: 180 : 100 : 80 = 9 : 5 : 4 \text{; hence}$$

(1) $F = \frac{9}{5}C, = \frac{9}{4}R.$

(2) $C = \frac{5}{4}R, = \frac{5}{9}F.$

(3) $R = \frac{4}{9}F, = \frac{4}{5}C.$

Lead and Its Impurities.—As the quality of the lead employed in the manufacture of storage cells is of some importance, especially if the active material is derived directly from the substance of the metal itself, it is very desirable to obtain some knowledge of the properties and general characteristics of this metal. A few words here as to the nature of the various native lead ores from whence we obtain our lead supply, and the method of extraction, may therefore not be out of place.

The chemical symbol for lead is Pb and its atomic weight when compared with hydrogen is 207. In this country our supply of the metal is chiefly obtained from its most abundant ores usually known as galena.

This is a sulphide of lead, having the formula PbS. Usually considerable quantities of sulphide of silver are present in galena, and in many of the specimens the sulphides of bismuth and antimony are found. Both in the United States of America and in Spain a carbonate of lead ($PbCO_3$), known as white lead ore, is frequently obtained in its native condition. The sulphate of lead ($PbO.SO_3$) is very abundant in Australia, and is largely imported into this country.

The usual method of extracting the lead from galena is effected by taking advantage of the circumstance that when a combination of a metal with oxygen is raised to a high temperature in contact with a sulphide of the same metal the oxygen and the sulphide unite, and the metal is liberated.

Some varieties of lead, particularly those obtained from Spanish ores, are known as hard-lead, their hardness being chiefly due to the presence of antimony. Impurities of this character are usually eliminated by a process of calcination, which is purposely spread over a considerable period. During this operation the metallic impurities are converted into oxides, and come away with the dross. This scum, or dross, is commercially known as antimonide of lead, and this, when reduced to a metallic state, yields an alloy of lead with sometimes as much as from 30 to 40 per cent. of the metal antimony. The hard metal obtained from this process is known as type-metal, an alloy much used by type-founders.

The following analysis gives the percentage composition of ordinary hard lead (Bloxam):

	English.	Spanish.
Pure lead	99.27	95.81
Antimony	0.57	3.66
Copper	0.10	0.32
Iron	0.06	0.21
	100.00	100.00

As previously stated, most native lead ores contain a certain percentage of silver. The method usually employed for the abstraction of this valuable metal is known as Pattinson's desilvering process. Pattinson found that when lead containing a small percentage of silver is melted and then allowed to cool, the metal in the meantime being constantly stirred, a considerable quantity of the lead separates out in the form of crystals which only contain a mere trace of silver, almost the whole of this metal being left behind in that portion which still remains liquid.

By repeated melting, stirring, allowing to cool and skimming, the whole bulk of the lead is removed, until at last a very rich alloy of silver and lead, together with copper and other metallic impurities, is left.

Simple Test for Copper and Silver in Lead. If a small quantity of lead be placed in a clean bone-ash cupel, and heated in a muffle until the whole of the lead is oxidized and absorbed within the pores of the bone-ash, any silver that may have been present in the metal will be found in the form of a small globule. Should copper be present the bone-ash will show a green stain after cooling. If the lead be free from metallic impurities only a yellow stain will be left.

In the manufacture of acids and corrosive solutions, and other operations where a metal capable of resisting the action of acids is required, leaden vessels are largely employed. Neither concentrated sulphuric, hydrochloric, nitric, or hydrofluoric acid will act upon lead at normal temperatures. One of the best solvents for this metal is nitric acid, reduced to a density of about 1,200 by the addition of water. The addition of this amount of water is found to be necessary, since nitrate of lead, which is insoluble in nitric acid of greater strength, would be liable to attach itself to the surface of the metal, and by this means protect it from further action.

If very finely-divided lead be thrown into the air, it immediately takes fire, combining with the oxygen of the atmosphere to form oxide of lead. This curious property of finely-divided lead may in a measure account for the heating effect which is usually produced when a fully charged spongy lead accumulator plate is withdrawn from the electrolyte and freely exposed to the air.

Oxide of Lead. Lead combines with oxygen to form five distinct oxides —viz.:

Sub-oxide of lead, or plumbous oxide, Pb^2O
Oxide of lead litharge or plumbic oxide, PbO
Red oxide of lead, minium, or triplumbic oxide, Pb_2O
Diplumbic oxide, Pb_2O_3
Puce, peroxide, or monoplumbic dioxide PbO_2

Sub-Oxide or Plumbous Oxide.—Sub-oxide or plumbous oxide is a black powder, usually formed by heating lead oxalate to a somewhat high temperature. It is readily decomposed when heated in dilute acid, and is converted into the monoxide when burned in air. This lead salt is but little used in storage battery work.

Oxide of Lead, Litharge, or Plumbic Oxide.—is sometimes found native as lead ochre, and may be artificially made by heating the carbonate or onglate. It is usually prepared on a larger scale by heating the lead in air. When the metal is only moderately heated, the oxide forms a yellow powder which is known as massicot, but at a higher temperature the oxide melts, and on cooling, it forms a brownish, scaly mass, which is called flake litharge. The scaly pieces are afterwards ground between stones under water, forming buff or levigated litharge.

The litharge of commerce often has a reddish yellow color, due to the presence of some of the red oxide of lead; and frequently from one to three per cent. of finely-divided metallic lead is found mixed with it. When heated to dull redness, litharge assumes a dark brown color, and becomes yellow again on cooling. At a bright red heat it fuses and readily attacks clay crucibles, forming silicate of lead. Litharge is a most powerful base, and has a strong tendency to form basic salts. Hot solution of alkalies, as potash or soda, readily dissolve it, and on cooling, it crystalizes out in form of beautiful pink crystals.

Red Lead, Minium, or Triplumbic Oxide.—Red lead, minium, or triplumbic oxide, is also occasionally found native, but it is usually prepared on a commercial scale, by heating litharge in air to about 600 deg. Fahr., at which temperature it absorbs oxygen and becomes converted into minium. The litharge or massicot used for this purpose is prepared by being heated in a reverberatory furnace to a temperature in-sufficient to fuse the oxide which is formed. During this process the first and last portions are rejected, as they contain iron and other metals more easily oxidizable than lead. The intermediate product is ground to a very fine powder, and then suspended in water to separate the coarser particles from the finer, which, when dried, are heated on iron trays placed in a reverberatory furnace, until the desired color is obtained. Minium (the name "minium" was originally applied to cinnabar, which was extensively adulterated with red lead,) is largely used in the manufacture of glass, so that it is necessary to have it free from the oxides of iron, copper, etc., which would give an unpleasant tint to the glass. On heating red lead, it temporarily darkens, becoming almost black, and at red heat it loses oxygen, and is converted into the protoxide.

When minium is treated with dilute nitric acid, nitrate of lead ($PbO.N_{2}5$) is obtained in solution and peroxide of lead (Pb_2) is left in the form of a brown powder, showing that minium is probably a compound salt composed of the oxide and peroxide of lead.

Minium obtained by heating litharge in air until no further increase in its weight is observed, has the composition $2PbO..\,Pb_2$, or Pb_{34}, which appears to represent pure minium. Commercial minium has frequently a composition corresponding to $3PbO.Pb_2$, but if it be treated with potash, PbO is disolved out, and $2PbO, Pb_2$ remains. Minium liberates some of its oxygen when raised to a red heat, becoming PbO, hence the necessity for keeping it below a temperature of 600 deg. F. during its manufacture. The tetroxide of lead is thoroughly soluble in glacial acetic acid, forming a mixture of acetates. This solution acts as an oxidizing agent, decolorizing indigo, and changing sulphurous acid into sulphuric acid.

Diplumbic Oxide, or Lead Sesquioxide, is obtained by mixing a solution of tetroxide oxide of lead dissolved in acetic acid, with dilute ammonia. It is an orange-red powder, which is decomposed on heating, and is reduced by oxalic acid. It readily dissolves in hydrochloric acid, but the solution quickly eliminates the chlorine, and lead chloride is obtained. So far this salt has scarcely entered into the construction of electric storage cells, except by the Electric Storage Battery Co., whose cells have been previously described.

Peroxide of Lead, Puce Oxide or Plumbic Dioxide, is the true active material in all forms of lead storage cells. This lead salt is found native as the mineral plattnerite. It is a heavy lead ore, forming black, lustrous, six-sided prisms. It may be prepared from the red oxide by boiling it in fine powder, with nitric acid diluted with five parts of water, or by treating the carbonate when suspended in water with a stream of chlorine gas, and then thoroughly washing and drying it. It is reduced to a lower oxide on heating or by exposure to bright sunlight. This salt readily imparts oxygen to other substances; it becomes heated to redness when thrown into sulphur dioxide, and takes fire when triturated with sulphur—hence this oxide is a common ingredient in lucifer match composition. When used in primary or secondary batteries it readily imparts its oxygen to nascent hydrogen, forming water, and thus it acts as a powerful depolariser. When robbed of its oxygen, it readily becomes reoxydised, if subjected to the action of nascent oxygen liberated by the electrolytic decomposition of water.

Plumbic Hydrates.--PbH_2O_2 and $3PbOH_2O$, are two definite white hydrates, and may be obtained by precipitating solutions such as the nitrate or acetate of lead with alkalies, such as ammonia. When moist, these compounds absorb carbon dioxide from the air, and become anhydrous on being heated to about 150 deg. centigrade.

Prevention of Lead Poisoning.—Workmen employed in the manufacture of lead or lead salts are always liable to lead poisoning, both by inhaling the dust and by contact of the materials with the hands. Various preventives for this have been employed, and of these the most simple seems to be a careful washing of the hands in petroleum. It is said that three washings a day are sufficient to prevent all serious danger of poisoning. The benzole in the petroleum appears to scour the skin and remove the loose lead dust, and the fatty substance in the oil fills up the pores of the skin and prevents the absorption of the deleterious salts.

The employment of petroleum has given such good results that it has been proposed to use this material as a guard against poisoning in other industries where the salts of copper or mercury are employed.

In a communication made by M. Melsens to the Academie des Sciences, reference was made to the excellent effect produced by iodide of potassium in all cases of lead or mercurial poisoning. He stated that this substance, by rendering soluble the metal accumulated in the system, invariably caused all the symptoms of the malady to disappear, and moreover, this salt acts as a preventive. A small daily dose of iodide of potassium is said to effectually ensure workmen against deleterious effects when working with lead or mercury salts.

Sulphuric Acid.—Sulphuric acid plays an important part in economy of lead storage cells. Some of the troubles which beset accumulators may doubtless be traced to impurities in the acid used in making up the electrolyte, or in moistening the lead salts. A brief glance at the processes involved in the production of this most potent agent, may enable us to more readily detect and eliminate such impurities as are to be met with in the commercial article.

Nordhausen Sulphuric Acid.—Nordhausen sulphuric acid, better known as Nordhausen oil of vitriol, was first made by the alchemist, Basil Valentine, some four centuries ago. Valentine subjected sulphate of iron (commonly known as green vitriol) to distillation, and by this means he obtained a heavy corrosive liquid which he termed oil of vitriol. The process of manufacture as devised by Valentine is now extensively employed at Nordhausen in Saxony, hence the name, Nordhausen acid, and consists in exposing crystals of sulphate of iron ($FeO.SO_3,.7K_2O$) to the air, so that they may absorb the oxygen of the atmosphere and become converted into the basic persulphate of iron as represented by the equation:

$$2(FeO.SO_3)+O=Fe2O_3 2SO_3$$

After the necessary exposure this salt is dried and is distilled in earthenware retorts, the oil of vitriol being condensed in suitable receivers.

On the application of heat to the basic persulphate of iron, the acid separates itself from the base and if the salts were thoroughly dry the anhydrous sulphuric acid would distil over, but there is always sufficient moisture left in the persulphate to effect combination with the anhydrous acid—thus sulphuric acid is the result. Nordhausen oil of vitriol is fairly represented by the formula $H_2O.SO_3$, or, shortly, H_2SO_4. After the distilling process is completed a residue consisting of peroxide of iron (Fe_2O_3) is found in the retorts. This material, known as colcotha, when ground into a fine powder, is much used for polishing glass and metals.

The sulphate of iron employed in the manufacture of Nordhausen acid is obtained chiefly from iron pyrites (FeS_2). The mineral found to be most suitable is a particular variety known as white or effluorescent pyrites.

The Nordhausen acid is much heavier than the English, its specific gravity being about 1.9. It is easily distinguished from the home made article by its fuming on being exposed to the air. These white fumes are due to the escape of anhydrous sulphuric acid vapor.

English Oil of Vitriol. When sulphur is burned in air, sulphur dioxide is the chief product; but when sulphuric acid acts upon hydrated nitric acid in the presence of water, sulphuric acid, in conjunction with nitric oxide, is formed according to the following equation:

$$SO_2+N_2O_3+H_2O=H_2OSO_2+2NO$$

Nitric oxide, when brought into contact with the oxygen of the atmosphere, combines with it to form nitric peroxide, NO_2. If, however, nitric peroxide meets with sulphur dioxide and water, it is again transformed into nitric oxide, with the formation of sulphuric acid, as shown by the equation:

$$NO_2+SO_2+H_2O=NO+H_2OSO_3.$$

From this it would appear that nitric oxide may be employed to absorb oxygen from the air, and then to convey it to the sulphur dioxide; therefore theory would indicate that an unlimited quantity of sulphurous acid, if supplied with air and water, would be converted into sulphuric acid by a given quantity of nitric oxide.

In commercial manufacture of sulphuric acid, sulphur is slowly burned on an iron plate which really forms the base of the furnace. Air is admitted into the chamber by means of a suitable door, which so regulates the amount of air, that when the sulphur is once ignited it may go on burning and producing sulphur dioxide with considerable regularity. Upon this iron-base plate is also placed a receptacle containing a mixture of nitrate of sodium and sulphuric acid, which generates nitric acid. The sulphur dioxide and nitric acid vapour are conveyed into a large mixing-chamber, which sometimes has a capacity of many thousands of cubic feet. Into this chamber a number of steam jets are continually beingdriven. In the reactions which now occur, the nitric acid is quickly reduced to nitrous oxide, and a succession of changes takes place, the result being that dilute sulphuric acid collects on the floor of the mixing-chamber, from whence it is drawn off into large leaden evaporating pans.

The dilute acid as it comes from the leaden mixing-chamber has a density of 1,500. By evaporation in a series of shallow lead pans it is concentrated until its density reaches 1,700. This acid is technically known as "brown acid" as it contains a number of organic impurities which imparts a dark brown color to it. Platinum or glass retorts are employed for the further concentration of this acid.

On two following pages is given table showing densities of various solutions of sulphuric acid and water, at 15 deg. C., or 59 F.

Degrees Baumé	Densities	100 parts by weight contain		
		SO_3 per cent.	H_2SO_4 per cent	Acid at 60 deg Baumé
0	1.000	0.7	0.9	1.2
1	1.007	1.5	1.9	2.4
2	1.014	2.3	2.8	3.6
3	1.022	3.1	3.8	4.9
4	1.029	3.9	4.8	6.1
5	1.037	4.7	5.8	7.4
6	1.045	5.6	6.8	8.7
7	1.052	6.4	7.8	10.0
8	1.060	7.2	8.8	11.3
9	1.067	8.0	9.8	12.6
10	1.075	8.8	10.8	13.8
11	1.083	9.7	11.9	15.2
12	1.091	10.6	13.0	16.7
13	1 100	11.5	14.1	18.1
14	1.108	12.4	15.2	19.5
15	1.116	13.2	16.2	20.7
16	1.125	14.1	17.3	22.2
17	1134	15.1	18.5	23.7
18	1.142	16.0	19.6	25.1
19	1 152	17.0	20.8	26.6
20	1.162	18.0	22.2	28.4
21	1.171	19.0	23.3	29.8
22	1 180	20.0	24.5	31.4
23	1.190	21.1	25.8	33.0
24	1.200	22.1	27.1	34.7
25	1.210	23.2	28.4	36.4
26	1.220	24.2	29.6	37.9
27	1.231	25.3	31.0	39.7
28	1.241	26.3	32.2	41.2
29	1.252	27.3	33.4	42.8
30	1.263	28.3	34.7	44.4
31	1.274	29.4	36.0	46.1
32	1.285	30.5	37.4	47.9
33	1.297	31.7	38.8	49.7

Degrees Baumé	Densities	100 parts by weight contain		
		SO_3 per Cent.	H_2SO_4 per cent	Acid at 60 deg Baumé
34	1.308	32.8	40.2	51.1
35	1.320	33.9	41.6	53.3
36	1.332	35.1	43.0	55.1
37	1.345	36.2	44.4	56.9
38	1.357	37.2	45.5	58.3
39	1.370	38.3	46.9	60.0
40	1.383	39.5	48.3	61.9
41	1.397	40.7	49.8	63.8
42	1.410	41.8	51.2	65.6
43	1.424	42.9	52.8	67.4
44	1.438	44.1	54.0	69.1
45	1.453	45.2	55.4	70.9
46	1.468	46.4	56.9	72.9
47	1.483	47.6	58.3	74.7
48	1.498	48.7	59.6	76.3
49	1.514	49.8	61.0	78.1
50	1.530	51.0	62.5	80.0
51	1.540	52.2	64.0	82.0
52	1.563	53.5	65.5	83.9
53	1.580	54.9	67.0	85.8
54	1.597	56.0	68.6	87.8
55	1.615	57.1	70.0	89.6
56	1.634	58.4	71.6	91.7
57	1.652	59.7	73.2	93.7
58	1.672	61.0	74.7	95.7
59	1.691	62.4	76.4	97.8
60	1.711	63.8	78.1	100.0
61	1.732	65.2	79.4	102.3
62	1.753	66.7	81.7	104.6
63	1.774	68.7	84.1	107.7
64	1.796	70.6	86.5	110.8
65	1.819	73.2	89.7	114.8
66	1.842	81.6	100.0	128.0

Properties of Sulphuric Acid.—The characteristic properties of concentrated sulphuric acid are very marked. Its freedom from odor, oily appearance, and great weight, distinguish it from most other liquids. The pure concentrated commercial acid has a density which usually reaches 1,842, and its boiling point is about 640 deg., F. The absolutely pure acid is perfectly colourless, but usually even that used in laboratories has a peculiar greyish colour, due to slight traces of organic matter. Sulphuric acid is exceedingly hydroscopic, and when exposed to the air it rapidly increases in bulk, owing to absorption of atmospheric moisture.

Some very masterly investigations on the nature and theory of solutions, especially those of sulphuric acid and water, have been made by Professor S.U. Pickering.

Specific Gravity of Various Metals at a Temperature of 60 deg. F. (*Fowne*).

Metal.	Specific Gravity.	Metal.	Specific Gravity.
Platinum	20.98	Iron	7.79
Gold	19.26	Molybdenum	7.40
Tungsten	17.60	Tin	7.29
Mercury	13.57	Zinc	7.10
Palladium	11.30 to 11.80	Manganese	6.85
Lead	11.35	Antimony	6.70
Silver	10.47	Tellurium	6.11
Bismuth	9.82	Arsenic	5.88
Uranium	9.00	Titanium	5.30
Copper	8.89	Aluminum	2.60
Cadmium	8.60	Magnesium	1.70
Cobalt	8.54	Sodium	0.97
Nickel	8.28	Potassium	0.87

This table is based on the specific gravity of pure water at 60 deg. F., which is taken as unity. As will be seen, the differences in the specific gravity of the various metals are exceedingly wide and pass from potassium and sodium, which are lighter than water, to platinum, which is nearly twenty-one times heavier than an equal bulk of that fluid.

The following table shows the relative conductivity, which is reciprocal of resistance, at normal temperature of some metals used in the construction of accumulators:—

Metal.	Relative Conductivity.
Silver, annealed	1.000
Copper, "	1.063
" rolled	1.068
Aluminum, annealed	1.935
Zinc, rolled	3.741
Platinum	6.022
Iron, annealed	6.460
Tin, rolled	8.784
Lead, "	13.050
Antimony, rolled	23.050
Mercury	63.730

The following table shows the approximate relative conductivity per unit surface and at normal temperatures of some insulating materials used in storage cells:—

Material.	Relative Conductivity.
Mica	1.00
Guttapercha	5.34
Flint Glass	12.14
Ebonite	333.33
Paraffin Wax	404.80

The Electrolyte.—Those accustomed to working with secondary cells can usually obtain a fair conception as to their state of charge and general condition by simple inspection. When fully charged, the positive plates are of a very dark, greyish brown tint, and the negatives of a dark slate color. During the discharge both plates gradually turn a somewhat lighter shade. When quite exhausted, the plus elements are a light chocolate hue, and the minus a light slate. Should the color of the peroxide plate change to a drab, it indicates either that the polarity of the cell has been reversed, or that the active material is becoming badly sulphated.

The usual and more accurate method of ascertaining at any time the condition of the cell as to charge, is to measure the density of the electrolyte by means of a hydrometer, or, as they are sometimes termed, an acidometer. In a newly set up cell, as soon as the acid electrolyte is added, a large percentage of the sulphuric acid is quickly absorbed by the active material, and goes to form sulphate of lead in both plates.

During the "formation" and subsequent charging, the reducible sulphate formed is reconverted into either oxide or spongy lead, and the acid is reinstated in the solution, the density therefore rising. Different makers specify different densities of solution. The usual thing for a starting electrolyte is a density of about 1,180. With such a solution the density may vary from 1,150 to 1,200 or even 1,250, when the cell changes from a condition of no charge to full charge. Some advocate acid solutions having densities as high as 1,400 to 1,500, but with solutions containing as much acid as these, although the conductivity of the liquid is greatly increased, the tendency of the active materials and metallic supports to become injuriously sulphated is greatly increased.

Hydrometers, or Acidometers.—The acidometers employed to test storage cells are usually made of glass or vulcanite, or some material which is unaffected by the corrosive action of the solution. When the density requires to be read off with great accuracy, Beaumes or Twaddell's standard instruments are used. In using Twaddell hydrometers for liquids heavier than water, to reduce the readings on these instruments to degrees of density, the number read off on the scale has to be multiplied by five and the product affixed to unity, after the decimal point. The ordinary commercial form of density indicator as now used, is either a plain cylindrical or flattened bulb tube, terminating with a thin, hollow stem. The instrument is weighted with fine lead shot or mercury, and a calibrated paper scale is made and sealed within the stem. The usual range is from 1,100 to 1,250, taking the density of pure water at 60 deg. F., as 1,000.

Hick's Glass-Bead Hydrometer.—A new form of hydrometer, very useful for testing the density of the solution in cells, has been brought out by Mr. J. Hicks. This instrument is a development of the old-fashioned glass bead arrangement used by gaugers for determining the strength of spirits. In gauging spirits a number of glass beads, having more or less weight in comparison with their volume, are taken, and by actual trial are classified and marked. To find the specific gravity of the liquid under test, these beads are tried one after another until two are found, one of which just sinks while the other just floats. The density is ascertained by taking the mean of the numbers on these two beads. Occasionally, it is found that one of the beads shows no tendency to either sink or float. The liquid then has exactly the density marked on this bead. The improved hydrometer devised by Mr. Hicks consists of a perforated flat glass tube, of such size as to easily slip between the edge of the plates and the glass containing cell. Within the tube are either three or four small flattened specific gravity beads, of different colors and placed one above the other, the lightest uppermost. These colored floats are capable of freely rising and falling in the tube, which they nearly fit. The beads may be balanced to any desired density. In the four bead the top float, which is colored green, will float when the specific gravity reaches 1,150; the next, a violet one, at 1,170; then a blue at 1,190, and a red at 1,200. The densities are plainly marked on the back of each float.

Holden's Hydrometer.—Some years ago M. LeGay of Levallois-Perret, in order to obtain greater sensibility in density indicators, employed a small weighted cylindrical glass bulb having a long thin stem, which moved up or down in front of a graduated fixed scale. A very sensitive and useful form of hydrometer working on this principle has been introduced in this country by Captain C. Holden, R. A.

The new instruments consist essentially of a light glass float, with a long narrow glass stem, which is free to move in front of a fixed scale.

The float is cylindrical, and about eight inches long; this terminates in a thin rod, between eight inches and nine inches in length. Owing to the large relative difference between the amount of displacement of the bulb and stem, these instruments may be made to have a very open range. A difference in the scale reading of seven inches may readily be obtained with an alteration of density of from 1,150 to 1,200. The densities are not marked upon the glass float, but are pointed off on a vulcanite scale. The scale may be fixed to a lug or connector of the battery elements by means of an indiarubber band, or some clamping arrangement. The lower end of the scale is V shaped, and, in adjusting, the point must be brought down to just touch the surface of the liquid. The float moves freely up and down in front of the fixed scale. The readings are taken from the top of the pointer.

Owing to the great sensibility of these instruments, the temperature of the solution should be taken into account, if very accurate measurements are required. For this purpose a thermometer should be placed in the solution, and then by reference to a table of temperature corrections, the densities may be read off to any required degree of accuracy. The scale may have a sliding arrangement affixed to it, which, by adjustment, can be made to give offhand the necessary corrections. When used as a check in a "Master" cell, if the requisite data of density, true current capacity, and internal resistance be known, then the scale may be calibrated in terms of ampere hours, and may be used as a check, either in the charging or discharging operation.

These instruments can be made either in glass or vulcanite; they are extremely accurate, easily visible, and do not stick to the sides of the cell.

Owing to its high sensibility, a most interesting experiment may be made with this form of hydrometer. If one of the most sensitive of these instruments be placed in a cell from which a very large current is being taken, the gradual subsidence of the pointer may readily be observed. For such small changes of density to become visible, it is necessary that the hydrometer employed should be of the highest sensibility.

Parker's Charge Indicator. — Some six years ago, Mr. Thomas Parker devised a form of hydrometer which indicated degrees of density on a fixed scale, and was employed to show by simple inspection the state of charge or discharge of an accumulator cell. In construction, the instrument was very simple, consisting merely of a long and thin cylindrical glass bulb, suspended in the electrolyte by means of a thin platinum wire, whose end was attached to the extremity of a delicately balanced lever. This lever was made to actuate a pointer, which traveled over a suitable graduated circular scale, pointed off in terms either of degrees of density or ampere hours.

The Volk Accumulator Indicator.—Mr. Magnus Volk is just introducing a neat little instrument for indicating the condition of a cell by simple inspection. The apparatus consists of a light glass cylindrical bulb of sufficient length to reach nearly from the top to the bottom of the electrolyte. By this arrangement the average density of the solution is obtained. The bulb is submerged at all times, so any difference in the level of it does not interfere with the readings of the instrument.

The glass bulb is suspended in the electrolyte from the end of a frictionless jointed spring arm, by means of a very fine platinum wire. A suitable pointer is fixed on the moving arm of the instrument, and travels over a scale, which may be divided either into degrees of density, or any arbitrary divisions suitable for the work of a cell. The scale is usually pointed off in terms of ampere hours, which may be used to afford an approximate indication of the number of ampere hours taken from the cell at any given period. A double reading scale may be used, which gives degrees of density, and also the corresponding current indication. The instruments may be made of any reasonable range, say, from 1,150 to 1,200 or from 1,170 to 1,250.

To prevent the acid spray or fumes from affecting the metal work of the instrument, it is wholly covered by a tightly fitting case, only a small hole being left to give free play to the suspension wire. The scale readings may be taken by means of a small mirror, placed at any desired angle if the instrument is used where the cells are in inaccessible positions.

The Grove and Garbe Density Balance.—Messrs. Grove and Garbe have devised a form of balance which is said to be extremely useful for accurate determinations of the mean density of the fluid used in storage cells. The arrangement consists of a balanced rod on which a level is permanently fixed. From both extremities of this rod similar density-indicating bulbs are suspended. One of the bulbs is immersed in a vessel containing a standard solution made up to the mean density of the accumulator electrolyte, and the other is placed within the storage cell. Any alteration of density occurring in the secondary cell due to either charge, discharge or absorption of the acid by the active material, is quickly indicated by the movement of the air bubble in the fixed level. By the employment of this device a very sensitive density balance is obtained, and one quite free from all errors due to changes of temperature in the atmosphere, a somewhat important consideration where accurate measurements are required.

The Roux Density and Charge Indicator. M. G. Roux, in a communication to "La Societe Internationale des Electriciens," on November 5, 1890, gave a most comprehensive account of the various method, employed for indicating the state of charge of an accumulator, describing at the same time his own improved density and charge indicator.

Roux demonstrated the fact that the density of the liquid in different parts of the same storage cell frequently varies to such an extent as to vitiate the measurements obtained by the ordinary form of hydrometer. He showed that it was essential, if correct measurements were sought, to make the bulb of the densiometer of sufficient length to reach nearly from the top to the bottom of the electrolyte. An instrument constructed on this principle would be found to measure as nearly as possible the mean density of the bulk of the liquid. Accordingly the Roux instrument was finally constructed as follows. A long cylindrical float made of glass is suspended, by means of a thin platinum wire, from the end of an arm which is fixed to a pivoted spindle. To the moveable spindle is attached a light pointer, which moves freely in front of a stationary horizontal scale. The moveable mechanism is balanced by a screwed counterpoise weight, which also serves as a means of adjusting the sensibility of the instrument, and for bringing the pointer to the true zero. The scale is divided into one hundred equal parts, and, as this method of calibration is found to give divisions of proportional density, the instrument is direct reading, and no additional corrections or calculations are needed. The zero mark, which in reality is the 100 point, is so arranged that it is covered by the pointer when the cell has received its full complement of charge, and, if the relative position of the pointer be noted at stated intervals during the discharging operation, the true value of the scale readings in terms of ampere-hours may be accurately obtained.

By a series of trials made with an amperemeter in circuit, Roux found that this type of instrument would accurately indicate the state of charge of a cell to within 3 per cent of its total current capacity. By a suitable arrangement of contact studs on the scale, the pointer can be made to complete an electric circuit at any determined point or points and thereby an aural or visual alarm may be obtained whenever the cell reaches any stipulated condition.

Spray Arresters.—In a storage cell, if the active materials are accurately proportioned, and the exposed surfaces so arranged that all the necessary chemical reactions may occur without hindrance, and if the electrical energy be put in and withdrawn at a proper rate, then no gases of any kind should be driven off until all the possible chemical changes are completed and the cell has absorbed its full charge. In practice, however, these conditions are rarely realized, and, consequently it is found that gas is given off at all times, not only when the cell is being charged or discharged, but also when it is at rest. As the minute bubbles of gas are liberated from the plates they rapidly ascend, and on reaching the surface of the liquid they are released from the compressing effect of the dense solution and rapidly expand, thereby causing miniature explosions. The result of this bursting of globules of gas is, that part of the electrolyte is thrown in the air and forms a troublesome and corrosive vapor or spray. Not only does this spraying action continually tend to diminish the quantity of fluid in the cell, but it also has a most injurious effect upon all connections and metallic fittings within the neighborhood of the cell. Unless an accumulator room be well ventilated, the atmosphere quickly becomes so impregnated with this acid vapor that it produces an exceedingly irritating and deleterious effect upon the lungs. To prevent its escape, or to minimise the effects of this acid spray, many spray-arresting devices have been suggested.

To arrest spray, curved glass plates placed with their concave sides downwards are sometimes used. These bent glass plates are put on the top of the cell, and act as a partial cover, and as the acid vapor condenses and collects in the form of beads it runs down to the middle of the glass, and then ultimately drops in the vessel again. Another plan is to place a layer of oil upon the liquid, which not only checks all spraying tendencies, but prevents the loss of the liquid due to surface evaporation. One great drawback to the employment of this device resides in the fact that the oil interferes considerably with the use of density testing apparatus. A plan which is free from the above objection is to spread a layer of granulated cork on the surface of the liquid. This material does not sink below the surface, it hinders surface spraying, and is not affected by the acid solution.

An excellent plan for preventing loss of fluid arising from any cause, is to completely cover the surface of the electrolyte with paraffin wax or some similar acid-proof insulating material. The covering in operation is extremely simple, and may be managed in the following way. The ordinary electrolyte is poured into the cell until it reaches to within about an inch from the top of the glass jar. The insulating wax or compound is melted in a ladle and then carefully run onto the surface of the liquid. On reaching the cold solution it immediately sets and soon solidifies. When cold and hard a small aperture of about one inch in diameter is made in any suitable position.

Part of the solution is now withdrawn by means of a syphon so as to leave some little air space between the bottom of the wax cover and the top of the liquid. When cells are sealed in this fashion the only exit for spray is through a small aperture made through the wax, and as a consequence but little escapes into the air. It is advisable to make the orifice in such a position that a hydrometer may be inserted through it and into the solution below, so that the necessary density tests may be made.

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