EPPLEY

BULLETIN NO. 1
NOVEMBER, 1968

STANDARD CELLS

Precision voltage references for industrial and laboratory use

EPLAB

THE EPPLEY
LABORATORY, INC.

•

Scientific
Instruments

•

NEWPORT
Rhode Island

THE ABSOLUTE SYSTEM OF UNITS

In the absolute system, the units of time, length and mass are fundamental, and all others including the electrical units of the ampere, ohm and volt are derived from them. Thus, electrical measurements are in agreement with measurements in other fields of science and engineering. This principle is most important theoretically; nevertheless, the most convenient means of realizing and maintaining the standards of electrical measurement still remain the standard cell and the wire resistor.

HISTORICAL

Jaeger, in the first chapter of his "Die Normalelemente und ihre Anwendung in der elektrischen Messtechnik", an early fundamental book, says: "The following conditions must be laid down for normal elements, regarding as such in the narrower sense only hydro-elements with metal electrodes:

"(1) Their electromotive forces must remain constant under the same external conditions (of temperature) and

"(2) Their electromotive forces must not be changed either by the withdrawal of current from the system, or by the passage of current through it, when the current does not exceed a certain fixed value for each type of cell, as well as that

"(3) They must be reproducible."

VARIOUS SYSTEMS

The Daniell cell and the Fleming type of Daniell cell are among the systems that were considered. These consist of a zinc electrode in a solution of zinc sulfate, in contact with a copper sulfate solution in which is a copper electrode. Both of the salts used are very soluble, diffusion is rapid and the zinc is rapidly attacked by the copper sulfate.

The Gouy cell is not reversible. When current is passed through it, mercurous sulfate is formed, upsetting the equilibrium.

The De La Rue, Helmholz, and Hibbert cells all have a mutual disadvantage, containing, as they do, zinc chloride which is a very poorly defined substance chemically.

Finally considered were the Clark and Clark-Carhart cells, and the two Weston cells. The Clark cell consists of zinc amalgam, a saturated solution of zinc sulfate with an excess of crystals, mercurous sulfate, and mercury; the Clark-Carhart consists of the same system without an excess of zinc sulfate. The first is reproducible to a satisfactory degree and both are constant. However, the Clark cell has a high temperature coefficient, about 0.00119 volt per degree Centigrade; and that of the Clark-Carhart is about 0.00053 volt per degree Centigrade. These are not deciding disadvantages as temperatures may be controlled, but there is a tendency for the glass containing-vessels to break due to expansion of the sealed-in platinum wires because the platinum forms an alloy with the zinc, and also, gas often forms over the electrodes, open-circuiting the cell. Freedom from these troubles, together with a lower temperature coefficient, brought the cadmium cell ready acceptance. When properly made the cadmium cell has a very high degree of constancy and in addition a lower temperature coefficient than the corresponding type of zinc cell.

From the above discussion it will be seen that the last two systems described are the ones that most nearly approach the conditions laid down by Jaeger. The normal or saturated cadmium standard, also called the normal Weston

STANDARD CELLS

cell, is the one on which the Bureau of Standards has based its standard for the volt since 1911. It consists of the combination:

Hg – Hg_2SO_4 – saturated $CdSO_4$ solution with excess of solid $CdSO_4$ – Cd amalgam.

THE SATURATED CELL

The container of the saturated cell is an H-shaped glass vessel with sealed-in platinum wires at the lower ends of the vertical legs for electrical connection. In one leg there is mercury and in the other, cadmium amalgam. The mercury electrode is covered with a mixture of mercurous sulfate and finely ground cadmium sulfate crystals. A layer of larger cadmium sulfate crystals is placed upon the surface of both the amalgam and the mercurous sulfate. The cell is filled to above its crossarm with a saturated solution of cadmium sulfate after which the open ends of the H-tube are sealed by fusing in a flame to insure air-tightness. Mercurous sulfate is slightly light-sensitive and exposure of cells to light should be limited to short, infrequent periods.

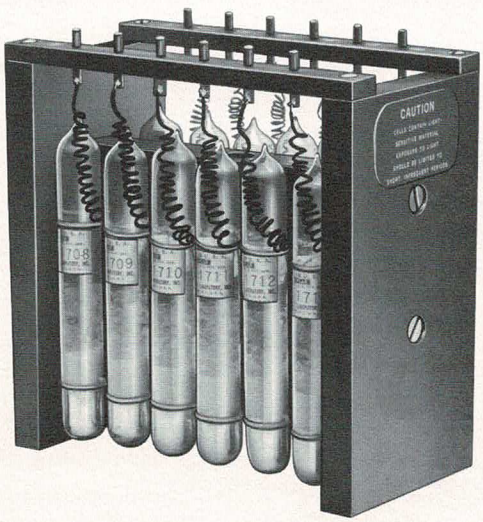


Figure 1.
Bank of six saturated cells (large)
(Cat. No. 101G6)

TYPES OF SATURATED CELLS

The Eppley Laboratory produces both the non-shippable (Cat. No. 101) and shippable (Cat. No. 114) types of saturated cells. The Cat. No. 101 is a relatively large, H-shaped cell (4 ¾″ x 2 ½″ x ⅝″) which has been employed by laboratories throughout the world in establishing a primary reference volt. Cells of this type must be hand-carried when it is desired to transport them, as damage will occur to the cells if they are not maintained in an upright position.

The Cat. No. 114 miniature shippable saturated cell (3 ¾″ x 1″ x ⅜″) provides a reliable voltage reference, accurate to 0.001%, which combines the high stability and long life of a saturated cell with the portability that is a feature of unsaturated cells. Shippability is accomplished through utilization of a patented linen covered plastic septum to retain the electrode materials in place. This type of septum has been used for over ten years in the construction of portable standard cells, permitting them to be shipped without detrimental effects.

EFFECTS OF TEMPERATURE

Temperature is by far the most important environmental condition affecting standard cells in use. Based on the work of Wolff* the international formula:

$$E_t = E_{20} - 0.0000406(t-20) - 0.00000095(t-20)^2 + 0.00000001(t-20)^3$$

has been accepted as most accurately repre-

*Wolff, Bur. Stan. Bull. 5, 326 (1908)

senting the relationship of the emf of a saturated cadmium cell to temperature between 0° and 40°C. This amounts to approximately -40 μv/°C at 20°C.

Because 28°C is extensively used as a maintenance temperature of standard cell groups, a more practical form of the international formula with coefficients calculated to apply from 28°C is:

$$\Delta e = -53.9(t-28) - 0.71(t-28)^2 + 0.01(t-28)^3$$

In this formula Δe is the difference in microvolts from the 28°C emf of the cell, and t is the temperature in °C.

As a slow transition occurs in the form of the cadmium sulfate crystal at approximately 43°C with an associated change in emf, 40°C is recommended as the safe upper limit to which saturated cells should be exposed, while -15°C is recommended as the lower limit to prevent freezing of the electrolyte.

Since saturated cells accommodate themselves rather slowly to changes of temperature, they should be maintained in an environment controlled to ± 0.01°C, or better, for from 36 hours to one week before measurements are commenced, and also during the time measurements are being made, if a constancy within ± 5 microvolts is to be secured. To attain maximum stability (1 to 2 μv), a waiting period of 4 to 6 weeks may be necessary.

Because of its large temperature coefficient, the saturated type of cadmium cell is not convenient for use as a general laboratory standard unless a primary standard comparable to the National Bureau of Standards is desired. A mounted unsaturated cell such as the Eppley Cat. No. 100, accurate to 0.005%, is recommended as a general laboratory standard. For those who do desire a primary standard, we regularly list Eppley saturated cadmium cells in groups of three to six, mounted on a bakelite rack. We do not list fewer than three because a smaller number will hardly give the results desired or attainable with saturated cells. With only one reference standard, there is no possibility of checking its constancy if it should be disturbed by either an internal or an external cause. Two standards may be used to check each other, but if a variaton should be evident, it would be impossible to determine where the variation lay. This leaves three as the smallest possible number which could be used to obtain fairly reliable results on the group. It is evident that the greater the number of standards, the greater the significance that may be attached to the results obtained.

We, as well as customers whom we have supplied with Eppley saturated cadmium cells, have found that groups of six satisfy the requirements for the maintenance of a voltage standard.

The cells of such groups may be intercompared, providing a very reliable check of the group and showing the performance of the individual cells. The method of making the intercomparison is to use each cell in turn as the standard and against it measure each of the remaining cells in the group.

CERTIFICATION

An Eppley certificate stating the value of the emf to 0.0001% is generally provided with all saturated cells. A National Bureau of Standards "Report of Calibration" can be obtained instead, if required, in which case an additional charge is involved.

CONSTANT TEMPERATURE BATHS

The Eppley Laboratory manufactures both oil and air baths suitable for maintaining satu-

STANDARD CELLS

rated standard cells at temperatures controlled to 0.01°C or better. Selection usually depends on the cell capacity desired as well as convenience in operating and handling.

The Model 105 oil bath has been designed for the maintenance of saturated cells as a primary standard, and is similar to equipment used in the various national laboratories for the establishment of the volt. It has a capacity of 36 cells in groups of 3 or 6. A smaller oil bath (Model 200) with a capacity twelve cells can also be supplied which will provide a voltage reference with a part per million stability.

Several models of constant temperature air baths are available. Model 106, described in Bulletin 12, has a capacity of six saturated cells of the 101 type, and has proven an excellent unit for maintaining a primary voltage reference. Model 121 has been developed as a standard voltage reference employing Eppley miniature saturated cells of the Cat. No. 114 type. Literature describing these and other air baths, including models designed for rack mounting, is available on request.

MEASURING INSTRUMENTS

The Eppley Standard Cell Comparator (Cat. No. 107) described in Bulletin 11 has been designed especially to provide an instrument for accurately comparing, to tenths of a microvolt, the difference between the electromotive forces of two standard cells connected in opposition. In addition, a high sensitivity galvanometer and a microammeter are necessary to obtain the measurements.

The Eppley Standard Cell Potentiometer (see Bulletin No. 7) is a precision instrument designed especially for the rapid and accurate measurement of unsaturated standard cell voltages, particularly where routine measurements must be made in quantity.

THE UNSATURATED CELL

For a high-accuracy secondary standard the Eppley Cat. No. 100 unsaturated cadmium standard cell has been generally accepted. This type of cell is similar in form to the normal cell except that the solution of cadmium sulfate is unsaturated at ordinary room temperatures, no excess of the solid cadmium sulfate being added to either the mercurous sulfate or the solution. The container of the unsaturated cell is also an H-shaped glass vessel. This laboratory uses septa to hold the electrodes and "depolarizer" in place, making the cell readily portable.

TEMPERATURE COEFFICIENT

The temperature coefficient of a cell is the algebraic sum of the temperature coefficients of the two electrodes, the electromotive forces of which are of opposite sign; that of the mercurous sulfate or positive limb being positive, and that of the cadmium amalgam limb being negative. Therefore, it is important that both electrodes be held at the same temperature.

The principal advantage of the unsaturated cell is its small net temperature coefficient which averages only $-3\ \mu v/°C$ between 4°C and 40°C. (See Figure 2.)

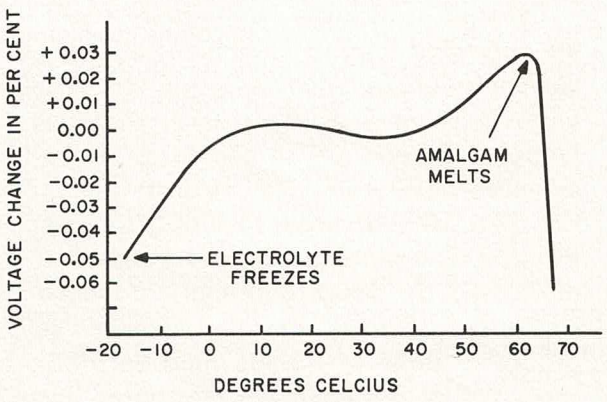


Figure 2.

HYSTERESIS IN STANDARD CELLS

Hysteresis, although definable as the erratic behavior of the voltage while the cell is coming to equilibrium following a change of temperature, is very difficult to express in figures, no satisfactory unit or standard having been devised for it. From one standpoint it may be considered as the length of time necessary for the establishment of an electromotive force of accepted value for the new temperature, following a temperature change. From another standpoint it may be considered as the magnitude of the variation from the normal value of the cell after a sufficient time has been allowed for it to come to some temperature differing from that at which it was previously maintained, or these two factors may be combined.

The extent of hysteresis is related to cell size, internal construction and age. Eppley miniature type cells have always exhibited very low hysteresis. Through an improvement several years ago in the construction of our other unsaturated cells, objectionable hysteresis frequently observed in older cells has been essentially eliminated. For several years prior to incorporating this manufacturing change in our production, cells so built underwent a rigorous test program which showed that they had greatly improved performance not only with regard to hysteresis but also with regard to the effects of aging and, to a lesser extent, temperature coefficient. Typical hysteresis for Eppley unsaturated cells following a 15°C drop in temperature is a 0.02% voltage change which returns to within 0.005% of the stable value in 2 hours. As hysteresis is smaller with an increase in temperature, an equivalent rise of 15°C produces a negligible effect. (Manufacture of the improved cells began with the following serial numbers: Cat. No. PYR, 755269; Cat. No. 100, 775880; Cat. No. 103, B5658.)

In order to secure the best performance from unsaturated cells, they should be placed where

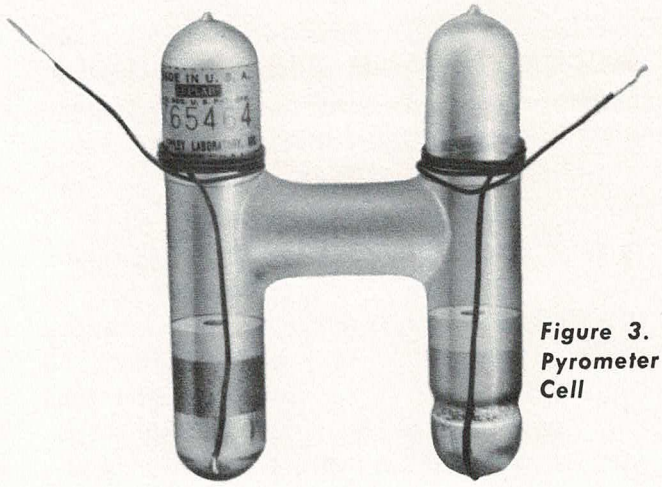


Figure 3. Pyrometer Cell

they are to be used and allowed to stand for 24 hours before measurements are made. This location should be free from drafts and localized hot or cold zones such as may be occasioned by the proximity of a radiator, steam pipes, rheostats carrying heavy currents, electric lamps, or windows allowing the rays of the sun to reach the cell case. As an aid to minimizing the harmful effects of such temperature inequalities our Catalog Numbers 100 and 103 unsaturated standard cells are contained in a molded bakelite case which is lined with an equithermal shield of metal that assists in the equal distribution of temperature around the cell.

In addition to the precautions given above, cells should not be operated at temperatures below 4°C nor above 40°C. Experiments with cells taken beyond these limits show the extreme upper limit of reliability to be in the vicinity of 50°C. It is, therefore, recommended that for precision work this limit be not too closely approached. At about 4°C the solution of an unsaturated cell is presumed to reach a state of saturation, the concentration being so calculated. Hence when this temperature is reached, the cell assumes a temperature coefficient corresponding to that of the normal or saturated cell.

When all necessary precautions are taken, the Cat. No. 100 standard cell is capable of 30 day stability of the order of ±0.001%.

STANDARD CELLS

ACCURACY AND STABILITY

In the past the accuracy of emf stated for Eppley unsaturated cells, of both the mounted and unmounted types, has indicated the limits in emf that could develop over an extended period of time and over a temperature range, usually 4-40°C (40-104°F) rather than the narrow emf limits of a new cell at a stated temperature which is the result of careful control in the manufacturing process. Although past emf specifications of accuracy included stability, future accuracy specifications will list the emf values of new cells at 25°C in terms of our primary standards.

Certificates, however, will continue to state the voltage accuracy of mounted cells over a temperature range and time limit, taking into account the temperature coefficient and aging of the cells.

Stability or constancy is that property of a cell which enables it to maintain its initial emf. Operational conditions such as temperature change and current drain affect the short term stability of standard cells, while the long term stability is primarily affected by aging, operating temperature and use.

The constancy of the electromotive force of these cells is extremely satisfactory when correctly made, only a slight decrease in emf per year of about 15 microvolts for the Cat. No. 100 and 45 microvolts for the miniature type. This is attributed to a gradual replacement of the cadmium in the amalgam by mercury because of the diffusion of mercurous-ion, the cadmium going into the solution, increasing its concentration and decreasing the electromotive force of the system.

Use, with its attendant slight current drain while balancing the circuit, hastens this action and the above figure may more than double. In consideration of this it is recommended that the cells be recertified by the maker, or a laboratory equipped to render this service, once every year or two if an accuracy of 0.01% is desirable over this period. Cat. Nos. 100 and 103 cells, which have a guaranteed accuracy of 0.005%, should be recertified at intervals not exceeding one year.

STORAGE

It is recommended that standard cells be stored upright, in a dry place, at normal room temperatures, or slightly below. High temperatures are to be avoided, as the conditions contributing to the failure of old cells appear sooner in cells which are maintained at high temperatures. Figure 4 shows the accelerated rate of decrease of emf in unsaturated cells at high temperatures.

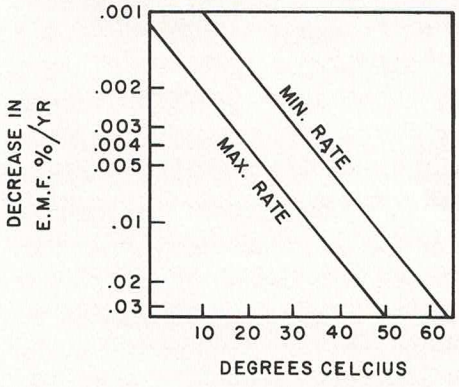


Figure 4.

ABNORMAL TEMPERATURES

During shipment and storage cells may be subjected to extreme temperatures of from several hours to several weeks duration. Time necessary for the cell emf to recover to within 0.005% of that at 25°C is given below for temperatures between −20 and +60°C.

Temperature	Recovery Time
+60°C	6 hrs
+40°	2 hrs
0	4 hrs
−10°	6 hrs
−20° (partial freezing)	4 days

At lower temperatures (below −30°C) breakage of the cell is almost inevitable. In view of the accelerated aging effect from high temperatures and the slow recovery rate from low temperatures, it is recommended that unsaturated cells be stored at temperatures between −10°C and +40°C.

CURRENT WITHDRAWAL

Extensive tests have been conducted in this laboratory regarding the amount of current that may be drawn from a standard cell without its voltage being affected. We have also investigated the magnitude of the change in voltage while undergoing a given current drain. From the results of these tests we can but emphasize that the cadmium standard cell is a standard of electromotive force for use in a potentiometer circuit and is not capable of supplying current to any marked extent without such use being detrimental to its primary purpose.

Current of the order of 100 μa may be drawn for a period of six minutes without permanently affecting cells, while time to recover to within 0.005% is less than 20 minutes for cells subjected to a current drain of 100 μa for 2 minutes. It is emphasized that to attain the best performance from any cadmium cell the current withdrawn should be as small as possible and not exceed 0.0001 ampere for more than a few minutes.

Based on results of over four years of continuous current drain tests, it may be stated that although the relationship between change in voltage and time is not a linear one, the decrease in emf per unit area of electrode produced by the withdrawal of small currents (up to 10 μa) is approximately 11 μv/coulomb cm^{-2}. Electrode areas of Eppley unsaturated cells are: Cat. No. 103, 5.5 cm^2; Cat. No. 100 and Cat. No. PYR, 1.43 cm^2; and all MIN cells 0.5 cm^2. In addition to the slow permanent change in emf of a cell resulting from current drain, the voltage will be immediately reduced by the magnitude of the IR drop upon closing the circuit.

Short-circuit tests show that a cell short-circuited for one-half hour took eleven hours to recover to within 0.07% of its original value and 36 days to come back to within 0.007%. Other cells short-circuited for one minute recovered to within 0.005% of their original values in less than four hours, while recovery from a ten second short-circuit required only ten minutes.

A voltmeter should not be used in an attempt to determine the voltage of a standard cell. The current drain caused by the ordinary voltmeter will be detrimental to the cell. For obvious additional reasons the reading will be entirely meaningless. Standard cell determinations should always be made by a null point method.

SHOCK AND VIBRATION

Eppley portable standard cells can withstand shocks of 50 g without damage to internal components or change in emf. In addition, they will pass the test for vibration as set forth in MIL-STD-202A, Method 201A. For low noise in fast response circuitry, special features (U.S. Pat. No. 2816946) have been incorporated in the MIN I cell. Because of their size and weight, type 103 cells are the most sensitive to mechanical shock. Nevertheless, they have been shipped successfully for many years.

OPERATING POSITION

Cells will remain operative when displaced up to 60° in any direction from the normal, upright position. Special miniature models (MIN I-H) can operate 90° from upright, or, as a

STANDARD CELLS

pair mounted together (MIN II), in all positions.

Although cells should not be stored in an inverted position, this condition might occur during shipment. Test cells inverted for as long as four days recovered immediately to within 0.005% after being restored to an upright position.

MINIATURE TYPE CELLS

The Eppley miniature type unsaturated standard cell is a small, light-weight cell of high accuracy and long life. Properly mounted, it is a reliable standard of emf, capable of 30 day stability of the order of ±0.001%.

Features covered by U. S. Patents and improvements in design have made the miniature cell practically hysteresis free, even at ages above five years. Because of its smaller size and weight, it responds more quickly to temperature changes than the other types of unsaturated cells. For example, after a 15°C drop in temperature, this cell recovers to within 0.005% of its initial value in less than 1 hour.

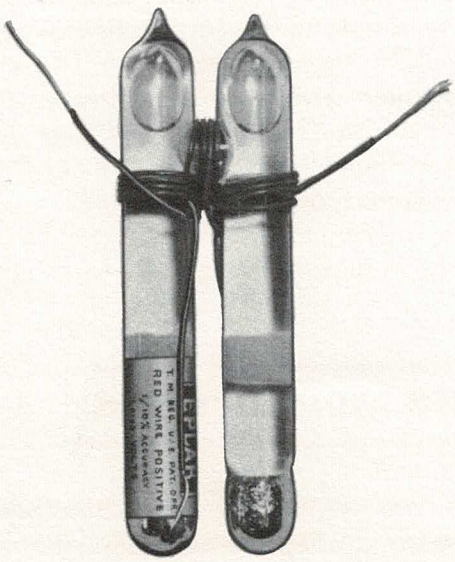


Figure 5.
Miniature Cell, Unmounted
(Cat. No. MIN. I)

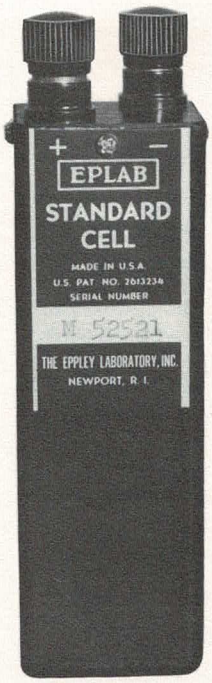


Figure 6.
Miniature Cell, Mounted
(Cat. No. MIN. III)

For smaller temperature changes (5°C) recovery time is less than 10 minutes. However, this MIN type cell has the highest internal resistance of the unsaturated cells, and, because of its small electrode area, current drains have a greater effect on it than the other types. Nevertheless, this cell exhibits excellent recovery after being subjected to small current drains of short duration. In terms of 0.005%, the recovery time is approximately 1 minute for every 5 μa minutes of electrical discharge, while cells short-circuited for 10 sec. recovered to within 0.005% in 15 minutes.

SPECIAL MODELS

Special models of the miniature cell have been developed to meet unusual operating conditions. A ruggedized model (MIN I-R) has been designed to withstand extreme mechanical shock, while another model (Cat. No. 116) consisting of a cell encapsulated in a suitable epoxy resin has been developed to provide a sealed unit in the event of breakage of the glass H-tube.

We welcome the opportunity to discuss applications of cadmium standard cells where unusual environmental conditions must be tolerated.

RECERTIFICATION SERVICE

As a laboratory engaged in cadmium standard cell manufacture and research for over fifty years, we have available a complete facility for the testing and/or recertification of both saturated and unsaturated cells. Beginning with our reference standard, our facility includes the precision measuring instruments and experienced personnel necessary to adequately perform this service.

The primary reference volt consists of some 36 saturated cells ranging in age from 3 to 30 years which are maintained at a constant temperature in oil baths at 28°C. These cells are checked periodically (six cells every six months) at the National Bureau of Standards, Washington. The precision measuring instruments used are of our own design and construction and have given many years of reliable service. In addition, the trained personnel engaged in the recertification of cells have, on the average, 25 years experience.

The recertification of saturated cells requires from four to six weeks and can be accomplished either in our oil baths at 28°C or in the customers oil or air bath. After allowing a period of time for the cells to stabilize, a minimum of ten comparisons between the standard and test cell are obtained using the difference method. Based on these readings, a certificate stating the cell value to the nearest microvolt is issued.

Mounted unsaturated cells sent to us for recertification are handled according to whether they are of Eppley manufacture or of another make. Briefly, cells of Eppley manufacture are read upon receipt and the reading checked against our record file. The cell is then removed from the mount and inspected. If in satisfactory condition, the cell is remounted, allowed to stabilize for at least 24 hours, and given a series of readings necessary for certification. If the cell is damaged or for any other reason does not qualify for recertification, a report is sent to the customer stating that a new element is required to provide a certifiable cell. Upon authorization a new cell of the same type is mounted in the customer's case, a new name plate corresponding to the serial number of the replacement cell attached, and the repaired unit recertified. For cells of other than Eppley manufacture, the inspection and repair steps in the above procedure must for obvious reasons be eliminated. Otherwise the procedure is the same. If emf readings are satisfactory, a certificate is issued; if not, a report is prepared stating the reason or reasons the cell failed to qualify for certification.

In the case of unmounted, unsaturated cells for which certificates are not issued, the cell is given a visual examination, an emf reading and is tagged with its emf. A report is made if necessary. No charge is made for this service.

Readings on all unsaturated cells are obtained using a precision potentiometer especially designed for measuring standard cell emfs. A saturated cell is employed as the standard. Approximately three weeks is required to complete the testing and recertification of unsaturated cells.

All Eppley certificates show traceability to NBS, Washington, through the NBS test number of our reference cells. Values of unsaturated cells are stated to 0.00001 v.

STANDARD CELL LIFE

When maintained at normal laboratory temperatures and operative conditions, the usable life of reliable unsaturated standard cells is from five to ten years.

SPECIFICATIONS FOR UNSATURATED CELLS

UNMOUNTED

CATALOG NUMBER	TYPE	NOMINAL SIZE H W T	WEIGHT	RESISTANCE AT 25°C (OHMS, MAX.)	ELECTROMOTIVE FORCE AT 25°C (VOLTS)	RECOMMENDED USE
PYR	Industrial	3⅛x2⅜x¾	3 oz.	500	1.0193 ±0.0002	Potentiometric Recorders
100a	Precision	3⅝x2⅜x¾	4 oz.	500	1.0193 ±0.0002	Portable Potentiometers
103b	Low Internal Resistance	3⅞x2⅝x1	8 oz.	100	1.0193 ±0.0002	Deflection Potentiometers
MIN I	Miniature	3⅛x1x⅜	1¼ oz.	1200	1.0193 ±0.0002	Recorders & Digital Voltmeters
MIN I-H	Miniature	2⅝x1x⅜	1¼ oz.	1200	1.0193 ±0.0002	Horizontal Operation

MOUNTED

100	Precision	5⅛x4⅛x4⅛	1 lb. 5 oz.	500	1.0193 ±0.0002 Accuracy Certified 0.005%	Laboratory Standard
102	Students'	5¼x3⅛x1⅜	10 oz.	500	1.0186 ±0.0005 Not certified	Demonstration Standard
102R	Students' with 10,000 Ω series resistor	5¼x3⅛x1⅜	10 oz.	11,000	1.0186 ±0.0005 Not certified	Demonstration Standard
103	Low Internal Resistance	5⅛x4⅛x4⅛	1 lb. 10 oz.	100	1.0193 ±0.0002 Accuracy Certified 0.01%	Lab. Standard of Low internal resistance
*MIN II	Miniature	4⅝x1⁵⁄₁₆x1⁵⁄₁₆	6 oz.	1200	1.0193 ±0.0002 Not certified	All position operation
*MIN III-05	Miniature	4⅝x1⁵⁄₁₆x1⁵⁄₁₆	5 oz.	1200	1.0193 ±0.0002 Not certified	Instrument Internal Standard
MIN III-01	Miniature	4⅝x1⁵⁄₁₆x1⁵⁄₁₆	5 oz.	1200	1.0193 ±0.0002 Accuracy Certified 0.01%	Instrument Internal Standard
110	Miniature (10 Cells)	5½x5x3¾	3 lb.	10,000	1.0193 to 10.193 Accuracy Certified 0.005%	1 to 10 volt Standard

*Although not certified, the emf of these cells is guaranteed within 0.05% over the temperature range 4-40°C (40-104°F) All mounted cells are stocked with binding post terminals. Other terminals available on order.

The emf of unmounted cells is guaranteed within 0.1% between 4 and 40°C (40-104°F) provided the cell has been allowed to remain for a reasonable length of time at any selected temperature within this range.

SPECIFICATIONS FOR SATURATED CELLS

UNMOUNTED

CATALOG NUMBER	TYPE	NOMINAL SIZE H W T	WEIGHT	RESISTANCE at 25°C (OHMS, MAX.)	ELECTROMOTIVE FORCE at 28°C	RECOMMENDED USE
101	Non-shippable	4¾x2½x⅝	5 oz.	1000	1.018220 ±20μv Certified to 1μv	Primary Standard
114	Miniature Shippable	3¾x1x⅜	1½ oz.	1500	1.018220 ±20μv Certified to 1μv	Travelling Standard
325	SHIPPABLE	2½x2x⅝	2 oz.	1000	1.018220 ±20μv Certified to 1μv	Travelling Standard

MOUNTED

As saturated cells are usually sold in groups of three to six, it is convenient to have them mounted on a suitable rack for ease in transporting and handling. The Eppley Laboratory provides a rack with copper pin terminals for a mounted group of cells. In this instance ordering information should include the number of cells in the group as well as the type of cell desired. For example, six mounted cells of the Cat. No. 101 type would be identified as a 101G6. Groups of Cat. No. 114 cells can be similarly mounted.

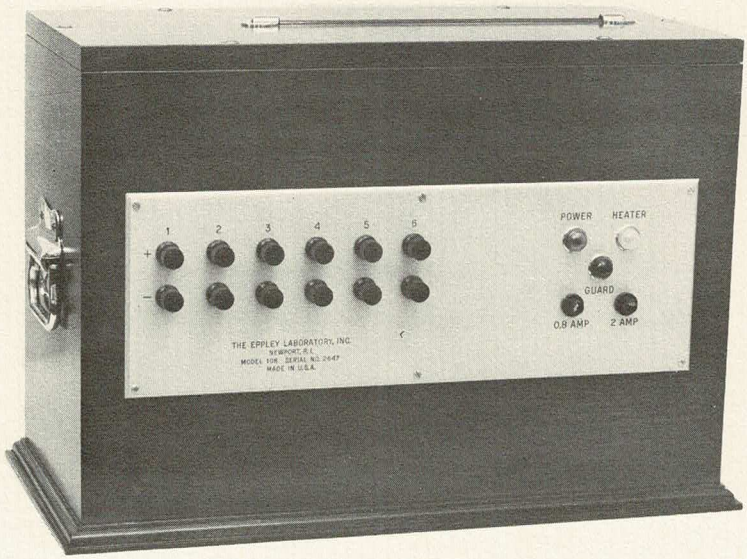
Special mercury cup racks in thermally lagged containers for use in oil baths are available, and will be quoted on request.

All Eppley saturated standard cells are obtainable with National Bureau of Standards calibration reports. This entails an additional charge plus, in the case of non-shippable cells a messenger service charge of $150.00 for transportation to Washington, D. C. The resulting total price is F.O.B. Washington D. C. where pick-up of the cells must be made by the customer.

THE EPPLEY LABORATORY, INC.
12 Sheffield Ave., Newport, R. I. 02840, U.S.A. Telephone 401 847-1020

EPLAB

Scientific Instruments
for Precision Measurements
Since 1917



Eppley Constant Temperature Enclosure

MODEL 106

The Eppley Model 106 enclosure has been satisfactorily employed for over 20 years as an air bath for maintaining saturated cells at a constant temperature to provide a primary voltage reference. Essentially, the unit consists of two rectangular cast aluminum cases, the inner one being designed to accommodate up to six saturated cells of the 101 type mounted on a bakelite rack. An electric heater is wound on all six exterior surfaces of the outer aluminum case which is separated from the inner one by one half inch of insulation. Additional insulation surrounds the outer case that is mounted in a mahogany box.

Temperature control is accomplished through a mercury-in-glass thermostat in a transistorized circuit. A safety thermo-switch set slightly higher than the thermostat is provided. Both temperature sensors are located in the walls of the outer casting. Circuit components are mounted on a panel contained in a separate compartment of the air bath. Copper binding posts as well as fuses and indicator lights are mounted on the front anodized aluminum panel. When a 12-volt D.C. source (not supplied) is connected to the terminals provided, the air bath will automatically switch to D.C. operation in the event of an A.C. power failure.

A mercury thermometer is mounted on the top of the air bath with its bulb centered in the inner cell compartment. High resoultion permits easy reading of the thermometer to 0.01°C.

Unless otherwise requested, the Model 106 will be set to regulate at a nominal 28°C, the temperature at which the National Reference is maintained. If ambient temperature exceeds 27°C, a higher operating temperature should be requested.

Although saturated cells may be certified in a suitable oil bath before placing them in an air bath, it is recommended that cells be certified under operating conditions.

The Model 106 will accommodate up to six rack-mounted Eppley saturated cells of the non-shippable Cat. No. 101 type. However, more of the shippable Cat. No. 114 or 325 cells can be conveniently maintained in it with only an increase in the number of binding posts on the front panel.

SPECIFICATIONS

Dimensions:	21⅝" L x 10¾" W x 14⅝" H
Weight:	Approximately 60 lbs.
Case:	Mahogany
Size of Inner Cell compartment:	7" L x 3¾" W x 6¼" H.
Input voltage:	115v/60 Hz A.C. with automatic changeover to 12 volt D.C. standby.
Power Consumption:	Less than 15 watts
Operating Temperature:	28°C nominal. Also available at 30°C and 32°C for higher ambient temperatures.
Regulation:	±0.01°C when ambient temperature is 1 to 8°C below operating temperature.
Thermometer:	0.02°C per division. Readable to 0.01°C.
Voltage stability:	1 ppm.

THE EPPLEY LABORATORY, INC.
12 Sheffield Ave., Newport, R. I. 02840, U.S.A. Telephone 401 847-1020

EPLAB

Scientific Instruments
for Precision Measurements
Since 1917

EPPLEY STANDARD VOLTAGE REFERENCE

MODEL 125

The Eppley Model 125 standard voltage reference consists of four Eppley saturated cells of the Cat. No. 325 (shippable) type in a compact, constant temperature air bath. As it can be readily transported by common carrier, it is recommended as a standard for inter-laboratory comparisons.

Design features include a high-resolution mercury thermometer located in the top panel and extending into the cell chamber which permits changes in cell temperature to be easily observed to 0.01°C. Portability of the Model 125, which weighs twenty-six pounds, is facilitated by the conveniently placed single drop handle.

Temperature of the reference is controlled by a mercury thermostat actuating a solid state switching network. A thermoswitch guard is provided to prevent cell damage in the event of failure of the main regulator.

Combining reliable Eppley saturated standard cells in a dependable temperature controlled air bath, the Model 125 replaces and contains all the features of the well-known and accepted Model 121 and provides a compact, shippable standard voltage reference of long life, high stability and portability. A certificate traceable to NBS standards is supplied stating the cell values to the nearest microvolt.

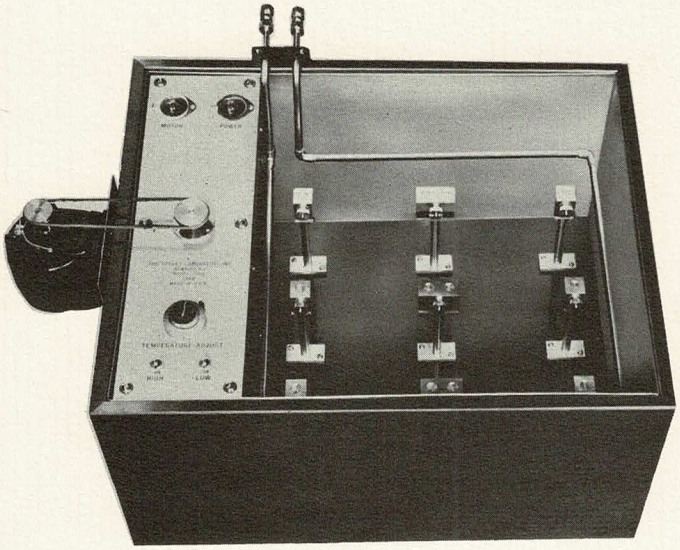
SPECIFICATIONS

Dimensions:	13" L x 9" W x 10" H (33x23x25 cm)
Weight:	26 lbs. (12 Kg)
Case:	Wood grained formica with top carrying handle.
Input voltage:	110-120 v/60 or 50 Hz AC with automatic changeover 12v DC standby. Other input voltages also available.
Power consumption:	Less than 8 watts
Operating temperature:	28°C nominal. Also available at 32°C for higher ambient temperatures.
Regulation:	±0.01°C
Thermometer range:	27.8°C to 28.2°C in 0.02° graduations. Readable to 0.01°C.
Voltage stability:	1 ppm.

THE EPPLEY LABORATORY, INC.
12 Sheffield Ave., Newport, R. I. 02840, U.S.A. Telephone 401 847-1020

EPLAB

Scientific Instruments
for Precision Measurements
Since 1917



EPPLEY OIL BATH
MODEL 200

The Eppley Model 200 Oil Bath is designed to accommodate either six (6) Standard Resistors or up to twelve (12) Standard Cells.

Outside dimensions are 31 1/8″ long x 20 1/16″ wide x 17 5/8″ deep, including stirring motor and cover while the usable interior dimensions are 18″ long x 18″ wide x 11″ deep.

The bath consists of a stainless steel inner tank mounted in a durable formica case and is thermostated to ± 0.05°C. Power requirements are 115 Volts A. C. with 400 watts maximum. A ground binding post connected to the inner tank is provided at the bottom rear of the bath.

This bath can be furnished with either a high sensitivity mercury thermo-regulator for Standard Cells or a continuously variable temperature control, 20°C to 35°C, for Standard Resistors. Suitable supports can be provided to accommodate six (6) standard resistors (Thomas type). Terminals of supports are copper 1″ wide x 3/4″ thick recessed in the top for a mercury contact

Saturated standard cells can be satisfactorily maintained in the bath to provide a voltage reference with part per million stability when they are placed in thermally lagged containers designed for the purpose. Temperature variations within the containers are less than 0.005°C.

Model 200, bath only
Model 200 A, bath with mercury contact supports but without cooling coil
Model 200 B, bath with both mercury contact supports and colling coil
Model 200 C, bath with support frame and double-wall stainless steel cell containers to accommodate 12 cells.

Supports to accommodate other types of standards can also be supplied. Those having requirement for oil baths of any configuration are requested to write stating requirements.

EPLAB THE EPPLEY LABORATORY, INC.

Telephone 401 847-1020

12 SHEFFIELD AVENUE
NEWPORT, RHODE ISLAND 02840
U. S. A.

EPPLEY STANDARD CELL VOLTAGE REFERENCE

CAT. NO. 110

A 10 Volt Reference of 0.005 % Accuracy

Designed as a reliable laboratory standard, the Eppley Cat. No. 110 voltage reference consists of ten miniature unsaturated cadmium standard cells of high stability and long life mounted in an formica case. The cells are connected in series utilizing eleven binding posts, so that through a combination of adjacent cells, voltages from one to ten in terms of the sums of the individual standard cell values can be selected.

The certificate issued with the reference states the value of each cell to 10 μv, accurate to 0.005 % for a period of one year provided the unit is maintained at temperatures between 15 and 30°C. In a temperature controlled environment, it is capable of 30 day stability of 0.001 %.

SPECIFICATIONS

Voltage:	1.01930 to 10.1930 volts, nominal
Accuracy:	0.005 % for one year from date of certificate
Temperature Range:	15 to 30°C
Case:	Mohogany grained Formica, Copper lined
Binding Posts:	Black, solid cap, with engraved indentification
Size:	5″ x 3¾″ x 5½″ high
Weight:	3 pounds

THE EPPLEY LABORATORY, INC.
12 Sheffield Ave., Newport, R. I. 02840, U.S.A. Telephone 401 847-1020

EPLAB

Scientific Instruments
for Precision Measurements
Since 1917

STANDARD CELLS AND ASSOCIATED EQUIPMENT
Price List

	1 - 4	5 - 9	10 or more	
Mounted Single Miniature Cell (Without Certificate)	$55.00	$47.00	$40.00	
With Certificate* ($45.00 extra)				
MIN II	$78.00	$68.00	$60.00	
Thermostat No. 7910D or equivalent				$50.00
Thermometer No. BA-130 or equivalent				$60.00
Thermometer No. SP-408B or equivalent				$70.00
Model 200 Oil Bath for either Standard Resistors or Saturated Standard Cells				$1,650.00
200A Mercury Contact Supports for six Resistors				$550.00 add'l
200B Cooling Coil for bath				$100.00 add'l
200C Support Frame and double wall stainless steel Cell Containers to accomodate twelve cells				$450.00 add'l
Mount new 100a in customer's container and recertify*				$65.00
Mount new 103b in customer's container and recertify*				$90.00
Recertify Cat. 110				$175.00
New Cell Box Bottom				$2.00
Brass Binding Post				$2.00
Copper Binding Post				$5.00

*Includes certification traceable to N.B.S

FOB Newport, RI
December 1979

THE EPPLEY LABORATORY, INC.
12 Sheffield Ave., Newport, R. I. 02840, U.S.A. Telephone 401 847-1020

EPLAB

Scientific Instruments
for Precision Measurements
Since 1917

UNSATURATED STANDARD CELLS
PRICE LIST

Catalog Number	Quantity 1 - 4	5 - 9	10 - 99	100 or more
		Unmounted		
PYR and MIN I, etc.	$29.00	$23.00	$18.50	$14.75
100a	34.00	28.00	24.00	20.00
103b	52.00	45.00	40.00	35.00
		Mounted		
*100		$90.00		
102		42.00		
102R		44.00		
*103		115.00		
*110		350.00		

Recertification of Mounted Unsaturated Standard Cells- $45.00

SATURATED STANDARD CELLS

	1 - 4	5 - 9	10 or more
*101	$110.00	$103.00	$95.00
*114	105.00	98.00	90.00
*325	105.00	98.00	90.00

Pin-type Rack for 3, 4, 5 or 6 Saturated Standard Cells $95.00

106 Constant Temperature Enclosure accomodating
up to 6 Saturated Standard Cells (101 or 325) $1,120.00

*125 Standard Voltage Reference
with 4 shippable Saturated Standard Cells $1,140.00

*Recertification of Saturated Standard Cells at 28°C or in
the customer's temperature controlled enclosure -per cell $ 60.00

*Includes Certification Traceable to N.B.S.

FOB Newport, RI

December 1979

MAIN SALES OFFICE
Eppley Laboratory Inc.
12 Sheffield Ave.
Newport, R.I. 02841
401 847-1020

REPRESENTED BY

W. K. Geist Co.

Arizona, California, New Mexico, Oregon, Utah, Washington

P. O. Box 5004
Glendale, Cal. 91201
213 245-9501

P. O. Box 746
Cupertino, Cal. 95014
408 968-1608

Alvin S. Mancib Co.

Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont

363 Walden St.
Cambridge, Mass. 02138
617 864-2494

Randolph & Coe Roads
Middletown, Conn.
203 347-5629

Laub Engineering

Indiana, Illinois, Iowa, Wisconsin, Minnesota

P. O. Box 8
Northfield, Ill. 60094
312 679-4172

EPLAB

THE EPPLEY LABORATORY, INC.

NEWPORT, RHODE ISLAND

PRINTED IN U.S.A.
S. Gunnar Myrbeck and Company, Inc.