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Heat Balance Studies on Submarine Storage Cells

for

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by

Department of Chemistry
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ABSTRACT.

The heat balance studies on a WLH-29 Ironclad cell to determine the magnitudes and sources of all heating and cooling effects and to determine the effects of these magnitudes on cell temperature characteristics under various conditions have been continued.

By means of gassing voltage-temperature-gravity studies data have been obtained by means of which the reversible heat of water electrolysis has been accurately determined. Accurate voltage measurements on both open and closed circuit enable a more accurate computation of the irreversible heat to be made. These voltage data also give a method of computing the cell resistance change as the charge progresses. The theory of the heat of formation of molecular gas to explain the heating effects accompanying gassing has received much additional confirmation through the overcharge studies.

Data have been obtained over a wide range of conditions in connection with the heat loss due to evaporation. These data can be utilized to furnish accurate figures on water balance studies in connection with evaporation during cell charge.

The use of electrolyte of 1210 gravity gives results similar to those obtained with 1280 acid gravity.

The studies conducted in connection with the above furnish excellent data in connection with the value of temperature regulation during cell charge. Gassing can be almost entirely eliminated at low temperatures. The charging time can no doubt be much reduced. Excess cell temperatures can be prevented.

Data obtained can also be used to determine the change taking place in the potentials of the individual electrodes. With proper calculations this data will also show how polarization changes at the two electrodes and may furnish much information as to the physical changes taking place at the plates.

INTRODUCTION.

(a) Authorization.

1. This problem was authorized by Bureau of Engineering letter SS/S62(7-30-D1) of August 7, 1935.

(b) Statement of Problem.

2. The purpose of the work given in this report was to extend the studies which have been conducted by the author on the general problem of heat balance relationships in lead-acid storage cells. The complete solution of the problem should give the magnitudes of all heating and cooling effects at various stages of cell charge and discharge, and should explain all temperature phenomena associated with battery operations. The solution should also include the exact location within the cell of the heating and cooling effects. In other words it should be known just how localized the effects are.

3. In Prior Work on Problem, a discussion of the work completed to date is given. The particular phases of the problem studied in this report were concerned principally with the reversible heat connected with water electrolysis, the radiation loss to cell surroundings, and the heat of formation of the molecular gas. At the same time the data collected has added to the knowledge of the other heating and cooling effects and has added excellent information on water balance considerations, gravity-temperature-gassing voltage relationships, and the general subject of single electrode potentials both for the normal and gassing stages of cell charge. This last may prove useful in the future interpretation of electrode processes in connection with design.

(c) Explanation of Report.

4. In submitting this report it is recognized that there is considerable duplication of text and tables from NRL Report No. P-1113. It is thought that this duplication is advisable in order to make the report a complete statement on the progress of the problem to date. The duplication will be abbreviated as much as possible so as to keep the report from becoming too bulky. It is also recognized that certain repetition exists within this report, as for example in Discussion of Results and Conclusions. This was thought necessary to properly complete the report and clarify the subject matter.

5. Table 1 gives the conversion units used in the calculations and the mathematical formulas employed. These are included so that the reader may check the calculations if he so desires. Part of the intermediate data has been eliminated for the sake of brevity.

6. As far as possible the data were taken from the Chemical Engineer's Handbook.

THEORETICAL AND PRACTICAL CONSIDERATIONS.

(a) Theory of the Lead-acid Storage Cell.

7. As stated in NRL Report No. P-1113, a discussion of the cell potential relationships for the normal charging period is hardly pertinent to this problem. These relationships for the reversible reaction have been determined by Hamer and Harned (NRL Report No. P-1071). Nor is a discussion of the possible mechanism of the electrode processes pertinent at this stage of the work to a discussion of heat balance relationships. However, the energy relationships involved are most important.

8. A storage cell stores electrical energy by reason of the chemical reactions taking place within the cell. On charge electrical energy is converted to chemical energy. On discharge the chemical energy appears as electrical energy. However, even under completely reversible conditions, not all the energy supplied as electrical energy is used up in charging the cell. Part appears as heat. Hence the cell warms on charge. On the other hand, on discharge the cell cools. This means that heat is being taken away from the cell surrounding and is added to the electrical energy formed from the cell reactions taking place during the discharge. The relationship between the various magnitudes involved is given by the following equation:

$$Q = w + q \qquad (1)$$

in which Q is the change in the total energy of the cell, that is the heat of reaction, W is the available work produced, q is the heat change. If Q and w are known, q can be calculated and hence the heat gain or loss from the surroundings can be calculated for a given number of ampere-hours. This heat is spoken of as the reversible heat. The Gibbs-Helmholts equation likewise gives a relationship between these magnitudes. One form of this relationship is:

$$\frac{Q}{23{,}070n} = E - T\left(\frac{dE}{dT}\right) \qquad (2)$$

In this relationship Q is the heat of reaction in calories, E is the electromotive force of the cell, T is the absolute temperature, n = 2 for the lead-acid cell, and dE/Dt is the change in the electromotive force per degree Absolute. The last term of this expression is the reversible heat. A discussion of the use of equations (1) and (2) is given in NRL Report No. P-1113. As in that report the values of 5.595 calories is used in this work as the heat evolution obtained upon the destruction of two mols of lead sulphate. As stated in that report, the exact value is in doubt. It must be remembered that in the actual cell operations, we are not working under reversible conditions, and at the best the use of thermodynamic formulas can give results which are only approximate.

(b) Theory of the Gassing Phase of Cell Charge.

9. The theory of the gassing phase of cell charge, unlike the theory of the normal charging phase, has received scant consideration in discussions of the lead-acid cell. It can be easily computed thermodynamically that the electrolysis of water with the production of hydrogen and oxygen gas should take place at 25° C. at 1.23 volts. If this were true in practice it would be impossible ever to charge a cell as the current would go entirely into water electrolysis. As a matter of fact this does not prove to be true due to the fact that polarization effects, particularly over-voltage, increases the voltage necessary for gas production to a value greater than that necessary to destroy lead sulphate under normal conditions. This over-voltage is due to the accumulation of gas, hydrogen at the cathode and oxygen at the anode. This gas accumulation produces what is essentially a hydrogen-oxygen cell during the gassing phase of cell charge. Moreover, this gas is first formed in the monatomic condition. Later the atoms unite to form molecules and it is thought that this formation of molecular gas produces one of the major heating effects during cell charge. The reader is again referred to NRL Report No. P-1113 for a full discussion of this point. It should also be brought out that the decomposition voltage for water in the lead cell decreases with increase of temperature. Hence gassing is much more likely to take place at higher temperatures. The actual mechanism of the oxygen evolution at the peroxide plate is not understood but this is not a matter of primary importance from the standpoint of the studies given in this report. As with the normal reaction there is a reversible heat effect accompanying the water electrolysis. However, due to the sign of the dE/dT term, its effect is a cooling one. A discussion of its magnitude is given in Prior Work on Problem.

10. Very little is known of the point of origin of the gas. Nor do we know very much about the source of acid which is formed on cell charge. Whether it is formed principally within the active material or on the surface of the elements is important in the final solution of the heat balance problem.

(c) Practical Consideration Cell Operations.

11. Certain points connected with cell operation should be discussed at this time because of their connection with the present problem.

12. Temperature Effects. The examination of charging data from shipboard operation shows a large temperature increase in the cell in the early stages of the charge when the current rates are high. Another increase is found with the gassing phase of the charge. This last effect was originally attributed to the increase in the cell resistance with the formation of the gas and to the removal of concentrated electrolyte from within the active material of the plate by the gas bubbles. A new theory involving the heat of formation of molecular

gas was proposed by the author. This is discussed in Prior Work on Problem.

13. Cooling Effects from Evaporation. It has been proven by the author in his prior report that the effect of evaporation of water from the surface of the electrolyte can at the best contribute little to cell cooling. This was originally considered as one of the major cooling effects.

14. Hydrogen Evolution. Operations in warm waters result in much more pronounced gassing than when operations are carried on in colder waters. This has been discussed to some extent under the theory of the gassing phase in the Theory of the Gassing Phase of Cell Charge above. The gassing-temperature-voltage relationships have been worked out by the author. This matter will be discussed further in Prior Work on Problem.

15. Gravity Consideration. The gravity of the electrolyte will vary with its height within the cell. Also it is quite likely that the gravity within the active material is different from that in the main body of the electrolyte. Mixing of the electrolyte from any cause should therefore produce heating effects. Unfortunately, little information exists on this general subject. It is thought that its magnitude cannot be very great but until this subject is thoroughly studied a complete solution of the heat balance problem is impossible.

(d) Prior Work on Problem.

16. Prior to the work started by the author in 1934, no study seems to have been made of heat balance relationships in lead-acid cells. Theoretical discussions on the irreversible and reversible heat effects are found in all storage battery texts. Also these effects have been discussed extensively in the scientific journals. Of course these discussions are limited to the normal charging reaction. Nothing whatsoever seems to have been done with the gassing phase.

17. A series of tests were conducted by the Brooklyn Navy Yard determine the best charging voltages for Tudor submarine cells. The results of these tests were given in: Report of Tests on Charging Methods on Tudor Type 20-POR-820 Submarine Storage Cells, Test No. 2527A, July 2, 1934. These tests showed that when gassing is pronounced, cell temperatures rise rapidly. It was also brought out in these tests that the gassing voltage decreases by .05 volts per degree Fahrenheit. This data is significant in connection with the reversible heat of water electrolysis.

18. The author conducted a series of tests at the Naval Research Laboratory during the summer of 1934. The results were given in NRL Report No. P-1113. A summary of the results follows:

General Temperature Characteristics. A normal charge on a cell of the WLH-29 type results in the generation of sufficient heat to raise the cell temperature approximately 30-35° F. The rise as found varies with the surroundings of the cell, rate of ventilation, etc. A difference of 18-20° between the cell temperature and the surrounding air seems to result in a heat loss of 1° per hour. The heat capacity of the WLH-29 cell was estimated to be 52,110 calories per degree Fahrenheit. Temperatures throughout the cell during charge and discharge are fairly uniform, the highest temperatures being found in the center of the cell. A maximum variation of 8° F. was found. The greatest difference exists during the early stages of the charge. Gassing produces an equalization of temperature due no doubt to a thorough mixing of the electrolyte. The heating effects are most pronounced in the early stages of the charge where the maximum currents are employed. With the onset of the gassing phase, a marked increase in temperature is found.

Irreversible Heat. This is a major factor in cell heating during the early stages of the charge when maximum charging rates are used.

Reversible Heat. This effect will be most pronounced with the larger current values.

Heat of Formation of Molecular Gases. This effect is found, of course, when gassing takes place. It must be kept in mind that this conception was proposed to account for the large heat values connected with gas evolution. That this explanation is correct has never been proved. However, the evidence in its favor is fairly decisive. This is the major heating effect during the gassing phase of the cell charge.

Reversible Heat. Water Electrolysis. This effect produces a cooling action. Its value is one-fifth the value of the heat effect due to the formation of the molecular gases. In magnitude it is the largest single cooling effect aside from radiation from the cell jar and top.

Radiation from Cell Jar. This effect is very difficult to estimate. Its magnitude depends of course upon the temperature difference between the jar and the surroundings, and the medium surrounding the jar. In submarine practice, this medium is of course air. It is also effected by the motion of the air around or past the jar. On shipboard such an effect would not be present as there is no circulation of air.

Radiation (and Convection) to Ventilating Air. This effect is quite small in magnitude, in fact so small as to be almost insignificant.

Evaporation Losses. This cooling effect is likewise small. It cannot be considered a major cooling effect and at best has little effect on all temperatures.

19. During the Fall of 1934 and the Winter and Spring of 1935, the author conducted further tests on heat balance relationships, at the University of North Carolina. The principal points studied were concerned with the magnitude of the reversible heat of water electrolysis which could be calculated from data on open-circuit gassing voltages. In order to obtain these data complete gassing voltage-temperature-gravity studies were made. It was found that these minimum gassing voltages were unaffected by gravity and that the average dE/dT value was .0033 volts per degree Fahrenheit. It will be recalled that the value of .0025 volts was used in Report NRL P-1113, this value being obtained from the Brooklyn Navy Yard work. That value was based on closed circuit voltages which do not exactly correspond to minimum gassing voltages. This value made the cooling effect due to water electrolysis 20 percent low as calculated in Report P-1113. In addition to the determination of a more exact value of dE/dT, the studies also gave additional insight into the origin of the gas, and data were collected bearing on the individual electrode potentials and the polarization effects as affected by charge.

EXPERIMENTAL PROCEDURE.

(a) Apparatus.

20. The tests discussed in this report were made on the same WLH-29 Ironclad cell used in the tests given in NRL Report No. P-1113. The specifications for this cell are given in Table 3. In the same table is included the computation involved with the calculation of the heat capacity of the cell. The cell was submerged in a water bath, the water being contained in a copper-lined wooden tank whose inside dimensions were approximately 26" x 23" x 48". From these dimensions and the dimensions of the cell jar the quantity of water used can be calculated. The water level was maintained at approximately 3" below the top of the cell jar. This cell box was equipped with four heating units of 1000 watt rating so wired that increases in temperature in the water could be easily and rapidly realized. The water bath was also equipped with refrigerating coils operated by a Westinghouse Freon compressor. Thus changes in temperature in the water could be easily attained and with a circulating pump it was possible to obtain almost perfect temperature equalization at all points in the bath. Bath temperatures were measured by means of thermometers and thermocouples suitably placed in the water.

21. Ventilation of the cell was effected as in the work referred to above. As during tests of the previous year the duct was fitted with wet and dry bulb thermometers, tubes for removing air samples for moisture determinations, hydrogen detector tubes, and outlet tubes for the air flow gauge.

22. The moisture content of the air both at the induction and in the ventilating duct was determined by wet and dry bulb thermometers and by chemical analysis. The latter method consisted in passing liter samples of the air through U-tubes containing Anhydrone, a very powerful water-absorbing agent. The weight of water so collected was determined by weighing on an analytical balance.

23. The current values were measured by means of a Leeds and Northrup Micromax recording ammeter. Voltages were measured by a Leeds and Northrup recording voltmeter. Both were supplemented by precision meters. In addition both open and closed cell voltages were measured on a Leeds and Northrup Type K potentiometer. The open circuit values were taken at the first "arrest" in the potential fall after the breaking of the circuit. The values so read could be checked with the less exact value obtained from the voltmeters. In addition to the overall voltages the single electrode potentials were obtained by measuring the voltages of each plate against a mercury-mercurous sulphate reference electrode. Two reference electrodes were used for check purposes.

24. Gravities were measured by means of a hydrometer on samples taken from the gooseneck.

25. Hydrogen percentages in the duct air were obtained by means of an NRL Hydrogen Detector.

26. Temperature readings on the air at the induction and in the ventilating duct were made by means of mercury thermometers. In addition temperature readings in the duct air were made by means of a thermocouple located in the duct at the outlet of the gooseneck to the ventilating duct. Thermocouples made of Constantan and Copper Wire of No. 26 gauge enclosed in rubber tubes were located at proper places throughout the cell and in the free electrolyte. These couples were operated through Leeds and Northrup Rotary Selector Switches connected to a Leeds and Northrup Pyrometer Potentiometer. An ice-water cold junction was employed.

27. The charging current was furnished by a motor-generator set.

28. All instruments were properly calibrated.

(b) Methods of Test.

29. Tests were conducted by bringing the cell system (cell, bath, etc.) to the desired temperature. The charge or gassing voltage studies were then conducted with constant bath temperatures. Temperatures in the cell of course changed with the progress of the test. After most of the regular charges gassing voltage studies were conducted.

30. During the gassing voltage studies all temperatures were read at proper intervals and the readings for current, voltage, hydrogen percentage, air flow, single electrode potentials on both open and closed circuit, and all cell voltages (on potentiometer) were recorded. On charge in addition to the above the air at the intake and in the duct was analyzed for moisture content by chemical methods and at the same time wet-dry bulb thermometer readings were obtained. Gravity readings were made on the top electrolyte.

31. Certain discharge tests were made, and in these temperatures, current, closed circuit voltages, and single electrode potentials on closed circuit were made. Gravity readings were also obtained on the top electrolyte.

(c) Explanation of Calculations.

32. In the presentation of the data all heating and cooling effects are expressed in calories. The minute is used as the unit of time in most cases. In computing the estimated rise in the cell temperature various periods of time were used as best seemed to suit the particular situation. The method used is obvious in each case from an inspection of the data. Conversion units used are given in Table 1.

33. Irreversible Heat Effects. (I^2R drop). The resistance drop in the cell was determined from the open and closed circuit cell voltage values which were measured at proper intervals. The resistance values used are given with the compiled data for the various charges.

34. Reversible Heat for Normal Reaction. This magnitude was obtained in the same manner as in previous tests. The number of mols of lead sulphate destroyed is determined from the charging current which in turn is determined from the total current and the hydrogen percentage. The number of mols of lead sulphate is then multiplied by 2800 calories.

35. Heat of Formation of Molecular Gases. The mols of hydrogen gas formed per minute is obtained from the hydrogen percentage, the air flow, temperature of air in duct, and barometric pressure. This number of mols in turn is multiplied by 170,000 calories, the heat effect produced by the formation of the hydrogen molecules and the oxygen molecules which at the same time are produced at the peroxide plate.

36. Calculation of Moisture Content of Air. The formula used for this computation is given in Table 1. The moisture content per liter is multiplied by 28.32 and by the air flow to obtain the moisture content per cubic foot.

37. Calculation of Heat Loss to Ventilating Air. This magnitude is obtained by multiplying the cubic feet of ventilating air per

minute by the temperature increase and by the heat capacity of the air. The heat capacity values are given in Table 2.

38. Calculation of Heat Loss by Evaporation. The heat loss per minute by evaporation is obtained by multiplying the grams loss per minute by 577 calories, the specific heat of vaporization of water. The loss per minute is obtained from the moisture content of the air at the intake and the air in the duct with proper corrections for temperature.

39. Reversible Heat of Water Electrolysis. The mols of water electrolyzed per minute is obtained from the hydrogen percentage, the air flow, the temperature of the duct air, and the barometric pressure. This number of mols is multiplied by 40,800 calories. The latter figure is obtained from the value of dE/dT for the gassing voltage. This value is taken as .0030 volts per degree F. The value used in prior work was .0025 volts. See Table 1 for formula.

40. Gassing Voltage Data for the Computation of dE/dT for Water Electrolysis. The minimum gassing voltage for each temperature was obtained by plotting the voltage values for various charging currents against these currents at the particular temperatures. See Plate 3 for such a graph. The value used is that given by the intersection of the two curves. Table 8 gives the values obtained for various temperatures.

41. Relative Humidity Values. The wet-dry bulb thermometer data was translated into relative humidity values by means of weather bureau tables. See Psychrometric Tables, WB No. 235. For calculation of the relative humidity from the experimentally obtained moisture content a large table showing the moisture content at various temperatures and at various degrees of humidity was prepared. Table 4 is similar, but not as extensive, as the table employed. Humidity values were obtained by interpolation.

DATA OBTAINED.

42. Twenty tests in all were made. These tests were as follows:

1. Gassing voltage study. Bath at 65°.
2. Gassing voltage study. Bath at 60°.
3. Charge. Manufacturer's Procedure. Bath at 60°. Gassing voltage studies included.
4. Charge. Manufacturer's Procedure. Bath at 60°. Gassing voltage studies included.
5. Charge. Bureau Procedure. Bath at 60°. Gassing voltage studies included.
6. Charge. Manufacturer's Procedure. Bath at 80°. Gassing voltage studies included.
7. Charge. Bureau Procedure. Bath at 80°. Gassing voltage studies included.

8. Gassing voltage study. Bath at 90°.
9. Charge. Bureau Procedure. Bath at 100°. Gassing voltage studies included.
10. Bureau Procedure. Charge. Bath at 35°. Gassing voltage study included.
11. Gassing voltage study. Bath at 45°.
12. Charge. Manufacturer's Procedure. Bath at 35°. Gassing voltage study included.
13. Charge. Bureau Procedure. Bath at 60°.
14. Charge. Bureau Procedure. Bath at 60°. Gassing voltage study.
15. Gassing voltage study. Bath at 70°.
16. Charge. Manufacturer's Procedure. Bath at 60°.
17. Charge. Bureau Procedure. Bath at 80°.
18. Gassing voltage study. Bath at 80°.
19. Charge. Bureau Procedure. Bath at 95°. Gassing voltage study included.
20. Charge. Bureau Procedure. Bath at 105°. Gassing voltage study included.

Tests 1 to 13 were made with electrolyte of 1210 gravity. All others were made with 1280 electrolyte.

Discharge tests were made in connection with charges 6, 7, 9, 12 and 17. In these discharge tests temperatures and voltage readings were made.

In the regular charges moisture determinations were made both on the air at the induction and in the duct. In most cases the relative humidity was obtained both by chemical analysis and with a wet-dry bulb thermometer.

Open and closed cell potentials were made on both the regular charges and the gassing voltage studies. Only the voltage values recorded with the potentiometer are given in this report. Single electrode potentials were also measured on both open and closed circuit.

In certain tests the entire set of thermocouple readings are given. In most of the tests, however, only the group values are included. The grouping of the couples is given on Plate 1.

(a) Statement of Errors.

43. Temperatures. All temperatures whether expressed in Fahrenheit or Centigrade are accurate to 1°. All thermometers were properly checked.

44. Current and Voltage Readings. Current readings were accurate to 10 amperes. Voltage readings were made on precision meters, recording voltmeter, and a Leeds and Northrup Type K Potentiometer. Only the potential readings made with the potentiometer are included in the report. These are accurate to .005 volt. This accuracy makes the calculation of the irreversible heat by means of the cell resistance obtained from the voltage readings very accurate.

45. Moisture Loss to Ventilating Air. The moisture analysis is very accurate. However in calculating the moisture content of the air and in determining the rate of evaporation certain assumptions were made in regard to temperature corrections. In some cases as much as a three percent error is involved. However when the magnitude of this effect is considered in relation to certain of the other effects this error is vanishing small as far as final calculations of total heat change is concerned.

46. Radiation and Convection to Ventilating Air. This effect is so small that very large errors would have no effect on the calculation of the final heat effects. For its calculation the heat capacity of the air was considered constant in relation to moisture content. Table 2 shows that this assumption is justified.

47. Reversible Heat. Normal Reaction. The calculation of the total mols of lead sulphate formed is limited by the accuracy of the hydrogen calculation. This is limited by the accuracy of the hydrogen detector and the air flow gauge. The hydrogen detector was properly calibrated before the start of the experimental work and there is every reason to consider that the values read are accurate. However some trouble was experienced with the air flow gauge during charges 10-12. On the whole it is thought that the data involved with the determination of the hydrogen is accurate to at least ten percent. In most cases the accuracy is far greater.

48. Reversible Heat. Water Electrolysis. The accuracy of this magnitude is limited to the accuracy of the hydrogen determination as explained above. The calculation of the effect per mol of water is considered to be quite accurate. It is true that an average value of dE/dT was used but this effects a far smaller error than that involved with the hydrogen.

49. Heat of Formation of Gases. The statement concerning the hydrogen calculation applies likewise in this case. The value for the heat of formation of molecular hydrogen and oxygen from the atomic gases is accurate to ten percent. However, it must be kept in mind that this value is for gases existing in space and not existing on the surface of metal where the bubbles may be modified in such a way as to involve a different heat of formation.

50. Calculation of Heat Capacity of Cell. The value of 52,110 calories is probably accurate for adiabatic procedures. However, it is probably in error when used for non-adiabatic procedures as in these cases heat may be either lost to the surroundings or taken from the surroundings so that it is difficult to determine the heat necessary to effect a given temperature increase. This is more an error in application than in fact.

51. Gravity Readings. These were made with a hydrometer. They are quite accurate but of course play no part in the calculation of the heat magnitudes.

52. Calculation of Temperature Rise in Cell. The calculated rise is probably too great in all cases where an increasing hydrogen percentage is found. This is due to the fact that the calculations are made on the heating effect at the end of the given period. An average is usually used whereas the curve is probably far from linear between the beginning and end of the time period.

53. Calculation of Percent Charge. In obtaining the open circuit voltage readings it is necessary to stop the charge for two to three minutes. Part of the current so lost is accounted for when the current is again turned on as the polarization is reduced and hence a momentarily increased rate is obtained but on the whole the result is to make the percent charge value too high. The error involved depends upon the charging rates being used. Of course this calculation is likewise limited by the calculation of the hydrogen evolved.

DISCUSSION OF RESULTS.

(a) General Temperature Characteristics.

54. An inspection of the data shows that the results of the experiments follow very closely those of the prior summer. The calculated rise of approximately 30° F. is found for both the Bureau and Manufacturer's Procedure. The major heating effects are found to be the irreversible heat and reversible heat of normal reaction for the early stages of the charge and the heat of formation of molecular gases for the latter stages. Radiation and convection to air and evaporation losses are in most cases quite negligible. The cooling effect due to the reversible heat for water electrolysis is an appreciable factor in keeping cell temperatures from becoming excessive. The effect of loss to the cell surroundings by radiation and convection is brought out especially well. The greatest loss by this means is found in the charges conducted at the higher temperatures. Plates 4, 5, 6 and 7 give the charging characteristics for certain of the tests.

(b) Temperature Effects at Various Points in the Cell.

55. The experiments of the prior summer brought out the fact that temperatures varied from place to place in the cell interior although the greatest difference usually did not exceed 8° F. and this difference

was found only in the early stages of the charge. The experiments conducted in the work under discussion employed a greater number of thermocouples and hence a much better picture of this distribution was obtained. As is seen from the data the early effects were most noticeable in the center group. See Plate 1. Within the center group the most effect was obtained in the lower part of the upper third of the cell in the cell center. This central heating effect was found in the early stages of the charge with the higher charging rates indicating that the current density was larger in the upper part of the elements. The edges of the upper part did not usually show as great an effect due undoubtedly to radiation losses through the jar, and to the ventilating air and to the cell top from the upper part of the elements and the free electrolyte above the elements. The extent of these losses depends of course on the temperature gradient. Special efforts were made to study the temperature effects in the free electrolyte below the elements and in the lower portion of the elements. It was found that the temperature of the free electrolyte changed but very little, showing that conditions below the elements remain almost unchanged. In some cases the difference may be as much as 20° F. between this free electrolyte and the hotter portions of the cell. This fact has also been proven by gravity measurements (see Bibliography). The temperatures in the lowest portions of the elements change little and this change is principally associated with the latter stages of the charge. It can be concluded from the temperature measurements that charging takes place approximately in proportion to the distance below the electrical connections at the top of the elements. When the center and upper portion becomes charged, the current distributes itself to the lower portions. Then temperatures tend to equalize. Gassing of course produces a thorough mixing of the electrolyte thus further equalizing temperatures throughout the cell. The temperatures found in the free electrolyte above the elements may be a few degrees below the cell as a whole if evaporation is taking place. An inspection of these temperatures shows that the value will change from place to place over the surface depending upon the extent of the exposure to the ventilating air.

(c) Heating Effects.

56. Irreversible Heat. The taking of open and closed circuit readings accurate to .005 volt enabled this magnitude to be calculated much more accurately than in prior tests. The values obtained checked in general with those of prior tests and emphasized the fact that although cell resistance increases greatly with gassing the increase is not sufficient to produce I^2R effects sufficient to account for heating effects accompanying the gassing phase.

57. Reversible Heat. Normal Reaction. The tests discussed in this report add little to the knowledge of this magnitude. Its value and significance seem to be well established.

58. Heat of Formation of Molecular Gases. Again the rise in temperature with the gassing was demonstrated not only with normal

charging procedures but with gassing voltage studies. That the effect is inherent in the gassing and not due to heat of mixing due to gas evolution is demonstrated by the fact that major heat effects continue to be found with overcharge studies long after the electrolyte has been properly mixed. However, the magnitudes obtained are usually lower than the calculated magnitudes. This is due probably to radiation losses from the cell system to the surroundings as the cell temperature during gassing is usually well above that of the environment. However, it may be that the heat of formation of the molecular gases is not accurately known for this change when it takes place in adsorbed gases on metal surfaces. The values used are for the union of atomic gases in the gaseous states. Conditions may be quite different on the plates.

(d) Cooling Effects.

59. Reversible Heat of Water Electrolysis. This is the major cooling effect although its absolute magnitude is not large. One of the major purposes of the work of this report was to accurately determine this magnitude. Prior to the work of this summer studies had been made of the minimum gassing voltages in small cells so as to establish an accurate value of dE/dT from which the reversible heat could be calculated. The values so obtained were checked by the gassing voltage studies conducted the past summer on the WLH-29 Cell. The same general plan for determining the minimum gassing voltage was followed. The gassing currents at the various temperatures were plotted against the corresponding voltages. Two curves were obtained as shown on Plate 3. The intersection of these two curves is taken as the minimum gassing voltage and the change of this magnitude with temperature gives the dE/dT value. It was found that the values that had been used for calculations in prior tests were approximately sixteen percent low. The value of .0030 volt per degree Fahrenheit was found to hold under the conditions of the tests.

60. Radiation and Convection to Air. As discussed in Report P-1113, this effect is very small. Indeed in several tests conducted, the air was cooled in passing over the electrolyte showing that the cell was actually heated in the exchange.

61. Evaporation Losses. In Report P-1113 it was shown that only excess evaporation will serve to do more than cool the cell top two or three degrees. In the experiments of this report this fact was further demonstrated and it was shown that if the cell temperature is much below the air and if the air contains sufficient moisture, condensation takes place, thus producing heating. This occurred in a number of the tests. For example, over 1280 acid the equilibrium moisture content corresponds to about 70 percent saturation in air at the same temperature. Consequently, we may expect to never find the ventilating air saturated in terms of the value over pure water. Of course, temperature changes may produce in some cases condensation from the ventilating air. That is, temperature changes may produce saturation in the air after it has passed over a hot cell. In interpreting the moisture

data care must be taken to consider the temperatures involved. In most of the tests of this report, the cell temperature was materially different from that of the air and this fact must be kept in mind in the drawing of conclusions. Under normal conditions as regards charging temperatures, the increase in the relative humidity is about 15%. This increase of course takes place only if the air is not saturated in respect to the acid solution.

(e) Radiation and Other Heat Losses to Surroundings.

62. In all tests discussed in this report the cell was surrounded by water so that conditions were somewhat different from the other tests in which the cell was surrounded by an air jacket. Radiation and convection could of course take place much more easily into the water. In the tests with the air bath a temperature gradient of about 18° F. produced a heat loss per hour corresponding to about 1° drop in cell temperature. With water a drop of about twice this value seems to take place. It is impossible to state other than in a very rough way what the loss will be. Of course with the use of the water bath the top was still exposed to the air. When the bath and the cell are approximately at the same temperature at the start of the charge and this temperature is about 35°, a 20° rise in the cell is found during the charge. When the temperatures at the start are about 100°, a 10° rise is found.

(f) Effect of Change of Acid Gravity.

63. As can be seen from the data, the results obtained with acid of 1280 gravity are the same as those obtained with 1210 acid.

(g) Voltage Characteristics.

64. As stated above, voltage readings were made on both open and closed circuit with a potentiometer for the purpose of obtaining gassing voltage-temperature data which in turn was used to calculate dE/dT for water electrolysis. This data was also used to calculate the irreversible heat. At the time these voltages were measured the single electrode potentials were also measured against a mercury-mercurous sulphate electrode. The values obtained check in general with those obtained with the small Exide and Philco Cells but until the actual potential values for the mercury-mercurous sulphate half-cells are obtained, this data cannot be properly studied. The computation of the data for the single electrodes will no doubt give interesting information as to voltage changes at the two plates during normal charge, and will also show the effect of hydrogen and oxygen respectively on the lead, and lead peroxide plates potentials. This data may prove useful in interpreting the change taking place at the individual electrodes during charge and discharge.

(h) Computation of Cell Resistance.

65. The open and closed circuit voltage values enable one to calculate approximately the cell resistance. This is found to be of the order

too low a voltage. In other words, the hydrogen percentage could run slightly higher than the present value which modification would allow more of the charge to be made at the higher rate which in turn would shorten the charging time. Of course such a change might produce more gassing.

72. Certainly the charging period is shortened, that is, higher rates can be maintained for longer periods, when the charges are conducted at comparatively low temperatures. The data show that if a way could be found to regulate cell temperatures, a much-shortened charging procedure could be worked out and the evolution of hydrogen and oxygen greatly reduced or eliminated entirely. It would appear from the data that if the cell temperature is maintained below 80° F., the charge can be almost entirely placed in the cell at the initial rate. This is illustrated in the tests where the bath is maintained below this temperature. No doubt higher initial rates could be employed if cell temperatures were kept from going beyond a certain point.

73. If a modified procedure is used to prevent gassing, some other method of equalizing gravity would have to be found. Methods suggested include a pump for circulating the electrolyte and the bubbling of an inert gas through the electrolyte. If the latter is used, the effect of this gas on both the normal electrode potentials and the gassing potentials would have to be determined.

CONCLUSIONS.

(a) Heating Effects.

74. Irreversible Heat. By means of open and closed circuit voltage readings with a potentiometer the effect of this magnitude has been determined with a much greater accuracy than has been attained heretofore. This is one of the two main heating effects in the early stages of the charge.

75. Reversible Heat. Normal Reaction. This is the second of the two major heating effects in the early stages of the cell charge. The method of calculating the magnitude of this effect as used in prior work has been further established by the tests given in this report.

76. Heat of Formation of Molecular Gases. The heating that accompanies the gassing during cell charge has been more accurately established. The theory that this effect is due to the formation of molecular gas from the atomic gas first evolved by the electrolysis has received much additional confirmation so that there remains little doubt of its correctness. Special over-charge tests have been used to study this magnitude.

(b) Cooling Effects.

77. Radiation and Convection to Ventilating Air. That this effect is negligible in magnitude has been further demonstrated.

That it may actually produce heating when the cell temperature is below the air temperature has been demonstrated.

78. Evaporation Losses. Much additional data prove also that this effect may under certain conditions produce heating rather than cooling. In other words water may under certain conditions actually be taken up by the electrolyte. The total effect is never appreciable from the standpoint of lowering cell temperatures. However, an appreciable effect may result in the temperature of the electrolyte above the top of the elements.

79. Reversible Heat. Water Electrolysis. The major cooling effect is due to this factor. By accurate measurements of the dE/dT value for the gassing voltages the reversible heat has been recalculated and found to be larger than that calculated from prior data.

(c) Temperature Characteristics of Cell Charge.

80. The temperature characteristics found in prior tests were confirmed. The principal heating effect is found in the early stages of the charge. The effect is most pronounced in the center and upper part of the elements. The onset of the gassing phase also results in increased temperatures. These increases are found more in the outer parts and bottom of the elements rather than in the middle portion.

81. Prior conclusions as to the distribution of cell temperatures have been confirmed by the accumulation of much more extensive data. What may be termed the temperature zones can easily be established from the results. The temperature data in the early stages of the cell charge give a rough approximation of the current distribution. Prior test gave a maximum difference of 8° Fahrenheit. The tests of this report check this as far as the general temperature distribution in the elements proper is concerned. However, it was found that temperatures in the free electrolyte below the elements may be as much as 20° F. below the center cell temperature.

82. The prior conclusion that a normal charge for a WLH-29 Ironclad Cell gives an approximate calculated rise of 30° has been checked.

(d) Gassing Characteristics.

83. Gassing prior to the time when the cell charge is approximately complete can be prevented by keeping the cell temperature sufficiently low. The exact temperature to be used depends upon the magnitude of the current. For the present charging procedures about 80° F. seem to be satisfactory.

84. With high temperatures gassing sets in in the early stages of the charge and therefore produces a major heating throughout the charging period rather than just at the end.

85. Gassing is necessary to properly mix the electrolyte. This is true whether the gassing takes place throughout the cell charge or just at the end.

86. Charging currents producing approximately 100 percent gassing have been obtained.

87. To equalize gravity in the cell it is necessary to add a number of ampere-hours equal to approximately 104-108 percent of the discharge ampere-hours. The excess of course goes to gassing. Apparently the actual charge is completed while the charging current is still in the upper brackets.

88. The change of the cell resistance with the progress of the charge can be calculated from the voltage data. The cell resistance values give the effect of gassing on the voltage necessary to pass a given value of current through the cell.

(e) Voltage Characteristics.

89. The open and closed circuit values for overall cell voltage which were obtained for the purpose of calculating the irreversible heat effect and the effect due to the reversible heat of water electrolysis also can be used to calculate the minimum gassing voltages. These voltages check the minimum values obtained with the small Exide and Philco Cells.

90. The values obtained for the single electrode potentials confirm the results obtained with the small Philco and Exide Cells. However, proper conclusions cannot be drawn until the actual single potentials are calculated and plotted. For this accurate values for the mercury-mercurous sulphate half elements must be known.

91. The voltage values have been used to calculate the cell resistance as stated above.

(f) Water Balance Data.

92. The data secured in connection with the evaporation loss can be utilized to determine the evaporation factor in water loss. The data give a complete picture of this loss and also of the value of wet-dry bulb thermometer readings in connection with moisture calculations.

(g) Modification of Charging Procedure.

93. It has been further substantiated that cell temperature control can be used to modify the charging procedure. By keeping the cell temperature sufficiently low, higher rates can be used without the evolution of the undesirable hydrogen and oxygen. The elimination of the gassing would diminish the magnitude of one of the major heating effects.

94. Other methods should be found other than gassing to properly stir the electrolyte. Perhaps a circulating pump system could be used or stirring might be effected by bubbling a neutral gas through the electrolyte.

(h) Effect of Change of Acid Gravity on Heating Effects and Cell Temperature Characteristics.

95. Similar results were obtained with both 1210 and 1280 electrolyte.

RECOMMENDATIONS.

96. As the problem now stands the author feels that the gross effects due to the irreversible heat, reversible heat of the normal reaction, reversible heat due to water electrolysis, convection and radiation to air, evaporation losses, and general radiation losses to cell surroundings are satisfactorily understood. It is also felt that the effect due to the formation of molecular gas is fairly well established but a definite conclusion should not be drawn at this time. The effect of the mixing of the electrolyte due to the gassing during the gassing phase of cell charge and to the formation of water on discharge and acid on charge has not been determined. It has been assumed that the effects of these factors are negligible but its exact magnitude has not been established either by experimentation or calculation.

97. In the above statement it is the gross effect in all cases that has been established. In other words it is not known just where in the cell these various effects are most pronounced. For example it is not known how the current distributes itself; therefore it is not known in which parts of the cell the reversible and irreversible heat is most pronounced. Also it is not known whether the heat of formation of gas is centered on the surface of the plates or if it is evolved within the active material. The general distribution of temperatures can be considered as solved but the exact location of high temperatures (within active material, etc.) is not solved.

98. Since the complete solution of the problem is assumed to include not only the gross effects but the more exact locations the following recommendations are made for the continuation and completion of the work.

(a) Current distribution studies. Such studies would furnish the information necessary to locate the distribution of the reversible and irreversible heat effects with the cell. The location of the heat of formation of molecular gases and the reversible heat of water electrolysis during the gassing phase could probably be established. In addition this study would be very valuable from the standpoint of grid and plate design. Such studies are now being carried out on small cells.

(b) Temperature studies concerned primarily with the individual Plates. These studies would serve several purposes. The heating during the gassing phase of cell charge has been ascribed principally to the heat of formation of the molecular gases from the atomic gases first formed in the electrolysis. If so then this heat should divide itself in a definite ratio between the lead and lead peroxide plate. Therefore if the effects at the two electrodes are studied separately and the proper ratio found this question can be considered as definitely settled. Moreover it should be determined if the gases are generated within the plates or on their surface. If within the plate it should be further determined if the generation is at the interface between the active material and the grids or actually in the active material. The same type of study would also determine whether the acid generated on charge and the water generated on discharge is formed in the active material. This would have a bearing on the heat generated by the mixing of the electrolyte.

(c) Determination of Heat capacity of WLH-29 Cell. In all the heat balance work to date on the WLH-29 cell the heat capacity value used has been a calculated one. The calculated value appears to agree with the data obtained but the actual heat capacity should be measured experimentally. The apparatus used in the experiments given in this report is adapted to this work and by the method of mixtures the actual heat capacity should be easily obtained. Such a determination is very desirable if the study is to be made a complete one.

(d) Further studies with the adiabatic procedure. The studies made during the summer of 1934 employing the adiabatic procedure, that is the procedure in which heat is allowed neither to pass from or into the cell from the surroundings during the charge, were fairly conclusive but with the equipment now available a perfect adiabatic process could be realized. Such a study would prove very valuable in checking the total heating effect and in establishing certain of the theoretical aspects now in doubt. A perfect distribution of thermocouples with a perfect adiabatic procedure would give information on current distribution during the early stages of the charge. These studies could be made in a limited period of time, three or four charges perhaps proving sufficient.

(e) Determination of heat of mixing of electrolyte. The generation of water during discharge and the generation of acid during charge will result in a heating effect when these products pass into the general body of the electrolyte. Also the gravity equalization when gassing takes place will produce heat of mixing. These magnitudes have not been determined.

To date they have been considered as negligible in relation to other effects. Until their magnitude is known, however, this conclusion may be questionable. The calculation of these magnitudes can be made approximately from data now existing. These calculations will be made during the winter of 1935-1936 at the University of North Carolina.

(f) Shipboard tests. It is highly desirable to continue the studies as conducted to date on shipboard, particularly under normal operating conditions. Without such studies it will be impossible to calculate heat losses due to interchange with surroundings in the battery space. Temperature phenomena may prove different from those found in the laboratory. If shipboard tests cannot be made some tests conducted under conditions approximately the same as on shipboard should be made. These tests could easily be made on the equipment available with minor modifications.

(g) With the completion of the above a full report including all studies conducted and all theoretical considerations involved with heat balance relationships should be prepared.

99. If the development of a new charging procedure is desired the present equipment can be used to determine the efficiency of cell cooling from the standpoint of increased charging rates and the elimination of or decrease in the evolution of hydrogen and oxygen gas.

100. However, if hydrogen and oxygen evolution is eliminated other means must be found to equalize gravity. This would involve the study of the use of inert gases for stirring the electrolyte or the use of an electrolyte circulating system. If an inert gas is bubbled through the electrolyte the effect of this gas on the normal and gassing potentials at the plates must be determined.

101. The data collected for the study of the heat effect due to evaporation can be subjected to much more rigorous analysis than that given in this report. If water balance studies are to be made this data should be recalculated.

102. In connection with the compiling of data on potentials for the purposes of determining the heat effect due to reversible heat of water electrolysis much data was obtained which can be used for determining the single electrode potentials both during the normal charging and gassing period and on discharge. The determination of these magnitudes would be valuable in connection with the study of polarization effects and single potentials in general. The values for these magnitudes have been determined by Hamer and Harned (see bibliography) for reversible conditions. This data as given in this report could be used for calculating actual potentials under operating conditions. To make these calculations, however, it is necessary to know the potential of the mercury-mercurous sulphate electrode under various conditions. This magnitude can be calculated from existing data but the calculated values should be checked experimentally.

BIBLIOGRAPHY.

Books and Texts.

1. Storage Batteries - Vinal.

2. Storage Batteries - Arendt.

3. Storage Batteries - Morse.

4. Storage Batteries - Dolezalek.

5. Applied Electrochemistry - Allmand.

6. Thermodynamics - Lewis and Randall.

Miscellaneous.

7. Report of Test of Charging Methods, etc., on Tudor Type 20-POR-820 Submarine Storage Cells. - New York Navy Yard, 2 July 1934.

8. Collected Reports on Electrode Potentials in Lead-Acid Cells. Harned and Hamer, Yale University.

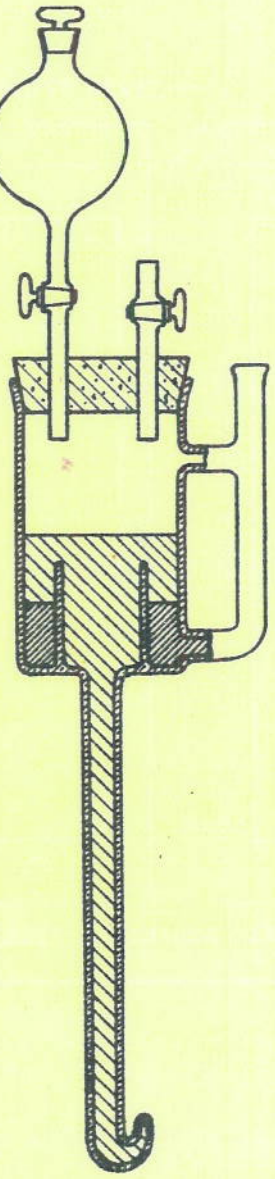
9. The Definition of Polarization, Overvoltage, and Decomposition Potential - Blum and Vinal. Preprint 66-3, The Electrochemical Society.

10. Specific Gravity of Submarine Cells - Bulletin of Engineering Information No. 90.

11. Heat Balance Studies on Submarine Storage Cells.- Crockford, NRL Report No. P-1113.

12. Heat Balance Studies on Submarine Storage Cells. The Gassing Voltage-Gravity-Temperature Relationships in Lead-Acid Cells. - Crockford and Sink. NRL Report No. P-1195.

MERCURY – MERCUROUS SULPHATE ELECTRODE VESSEL
ONE HALF ACTUAL SIZE

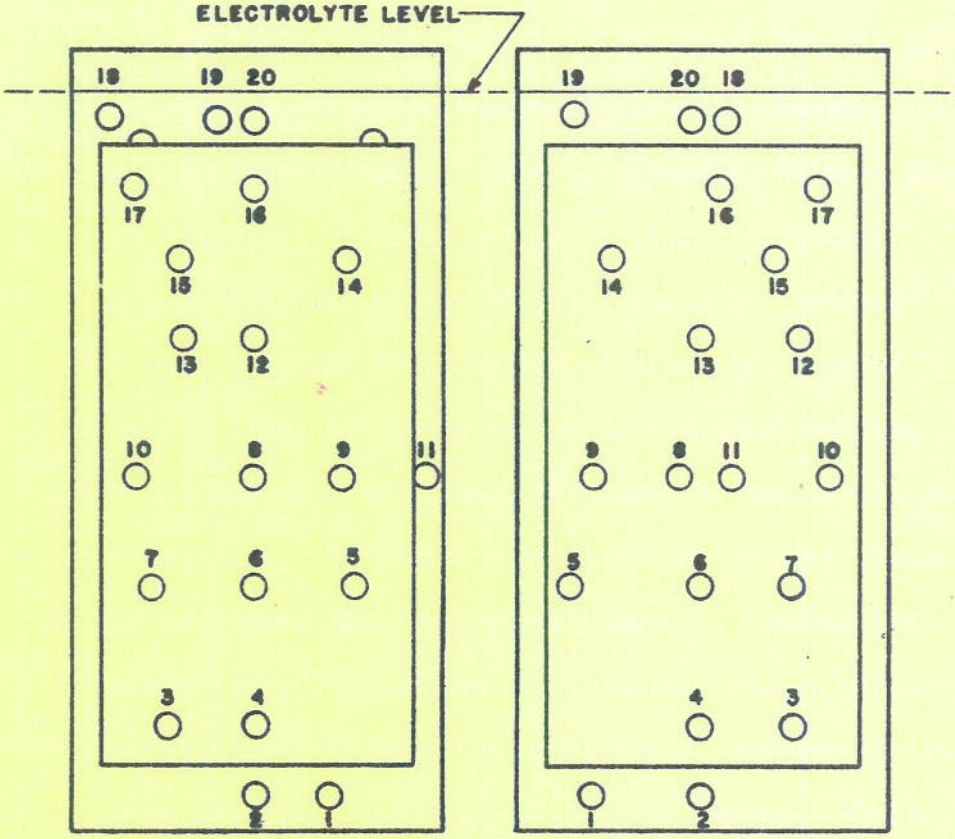


SULPHURIC ACID

MERCURY–MERCUROUS SULPHATE

PLATE I

APPROXIMATE LOCATION OF THERMOCOUPLES



FOR EXACT LOCATIONS SEE NEXT PAGE

PLATE 2

Key to Plate 2.

Location of Couples.

Couple Number.

1. 4" from negative, 2" below elements, between plates 5 and 6.
2. 8" from negative, 2" below elements, between plates 14 and 15.
3. 12" from negative, 3" above bottom of elements, between plates 25 and 26.
4. 8" from negative, 3" above bottom of elements, between plates 14 and 15.
5. 2" from negative, 9" above bottom of elements, between plates 3 and 4.
6. 8" from negative, 9" above bottom of elements, between plates 14 and 15.
7. 14" from negative, 9" above bottom of elements, between plates 22 and 23.
8. 8" from negative, 18" above bottom of elements, between plates 14 and 15.
9. 4" from negative, 18" above bottom of elements, between plates 7 and 8.
10. 14" from negative, 18" above bottom of elements, between plates 27 and 28.
11. Between jar and edge of plates, 18" above bottom of elements, between plates 16 and 17.
12. 8" from negative, 10" from top of elements, between plates 22 and 23.
13. 12" from negative, 10" from top of elements, between plates 14 and 15.
14. 4" from negative, 4" from top of elements, between plates 5 and 6.
15. 12" from negative, 4" from top of elements, between plates 20 and 21.
16. 8" from negative, 1" from top of elements, between plates 14 and 15.
17. 14" from negative, 2" from top of elements, between plates 26 and 27.
18. 14" from negative, in free electrolyte above elements, between plates 15 and 16.
19. 8" from negative, in free electrolyte above elements, between plates 3 and 4.
20. Top center of free electrolyte above elements.
21. Duct, at entrance to goosenock.

Couple Groups.

1. Electrolyte below elements, Nos. 1 and 2.
2. Electrolyte above elements, Nos. 18, 19 and 20.
3. Between elements and jar, No. 11.
4. Bottom section of elements, Nos. 3 and 4.
5. Top section of elements, Nos. 14, 15, 16 and 17.
6. Center group, Nos. 6, 12, 8 and 13.
7. Group near edges of elements, Nos. 5, 7, 9 and 10.

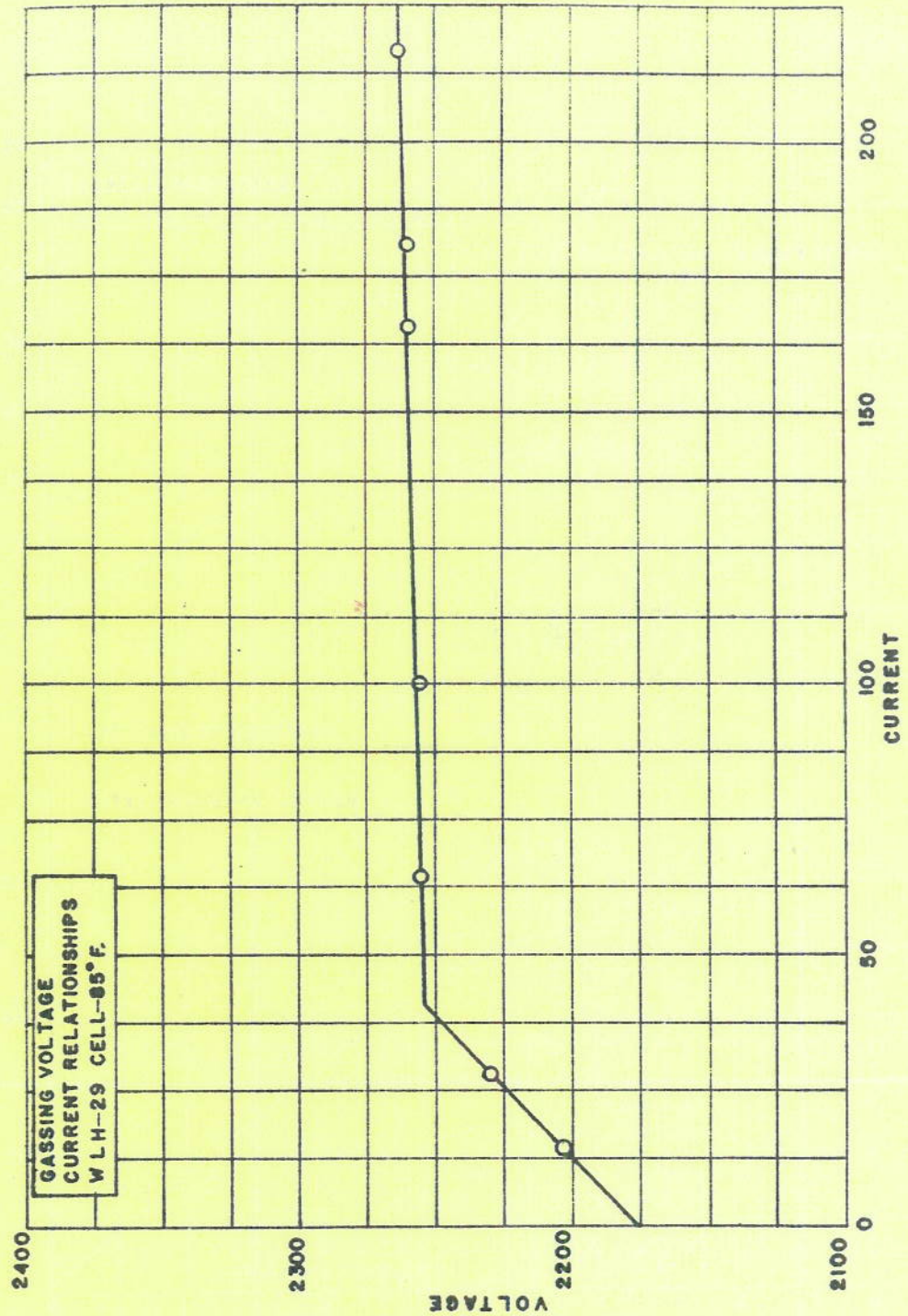

GASSING VOLTAGE
CURRENT RELATIONSHIPS
W LH-29 CELL-85° F.
VOLTAGE
2400
2300
2200
2100
0
50
100
150
200
CURRENT

PLATE 3

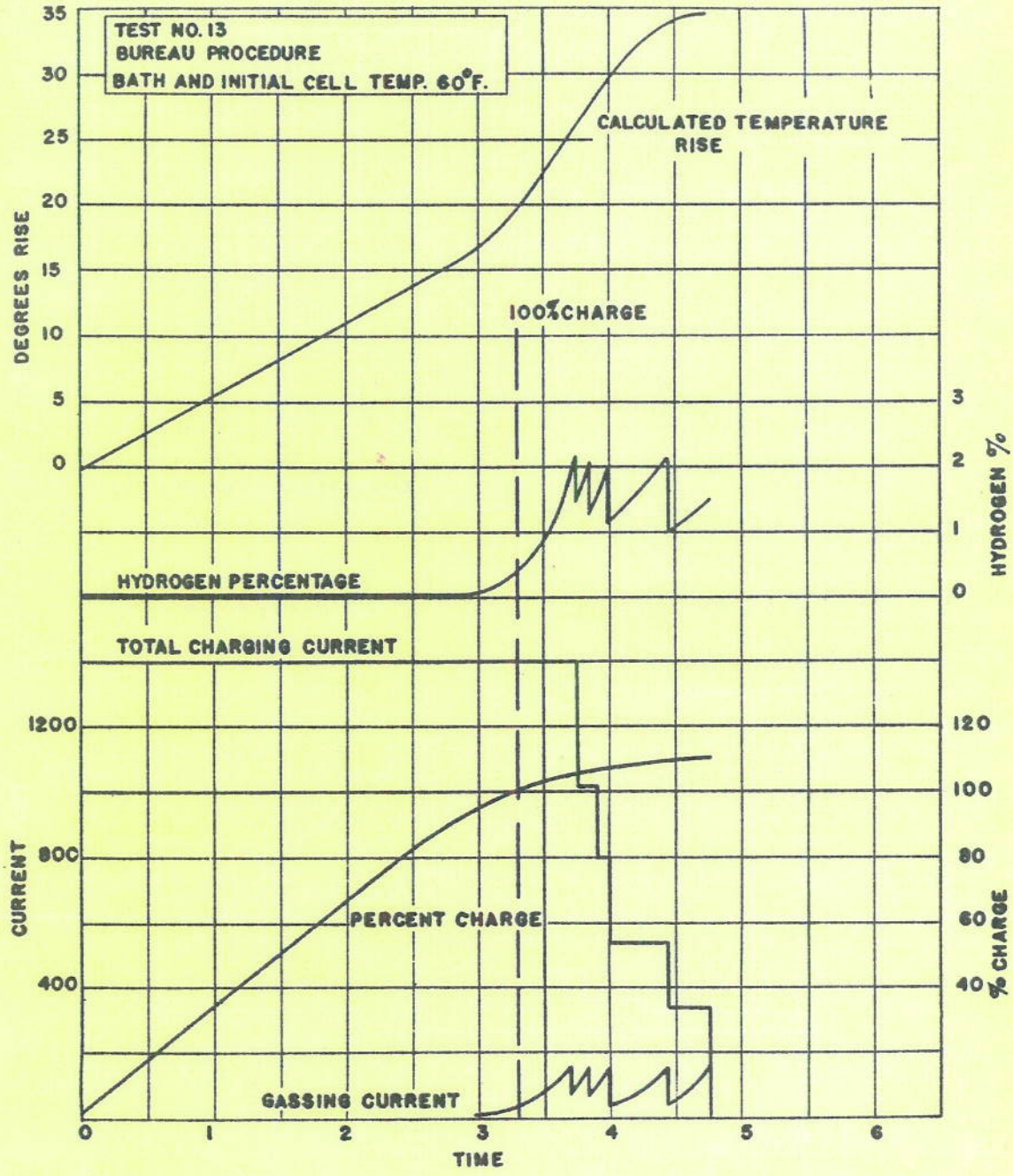
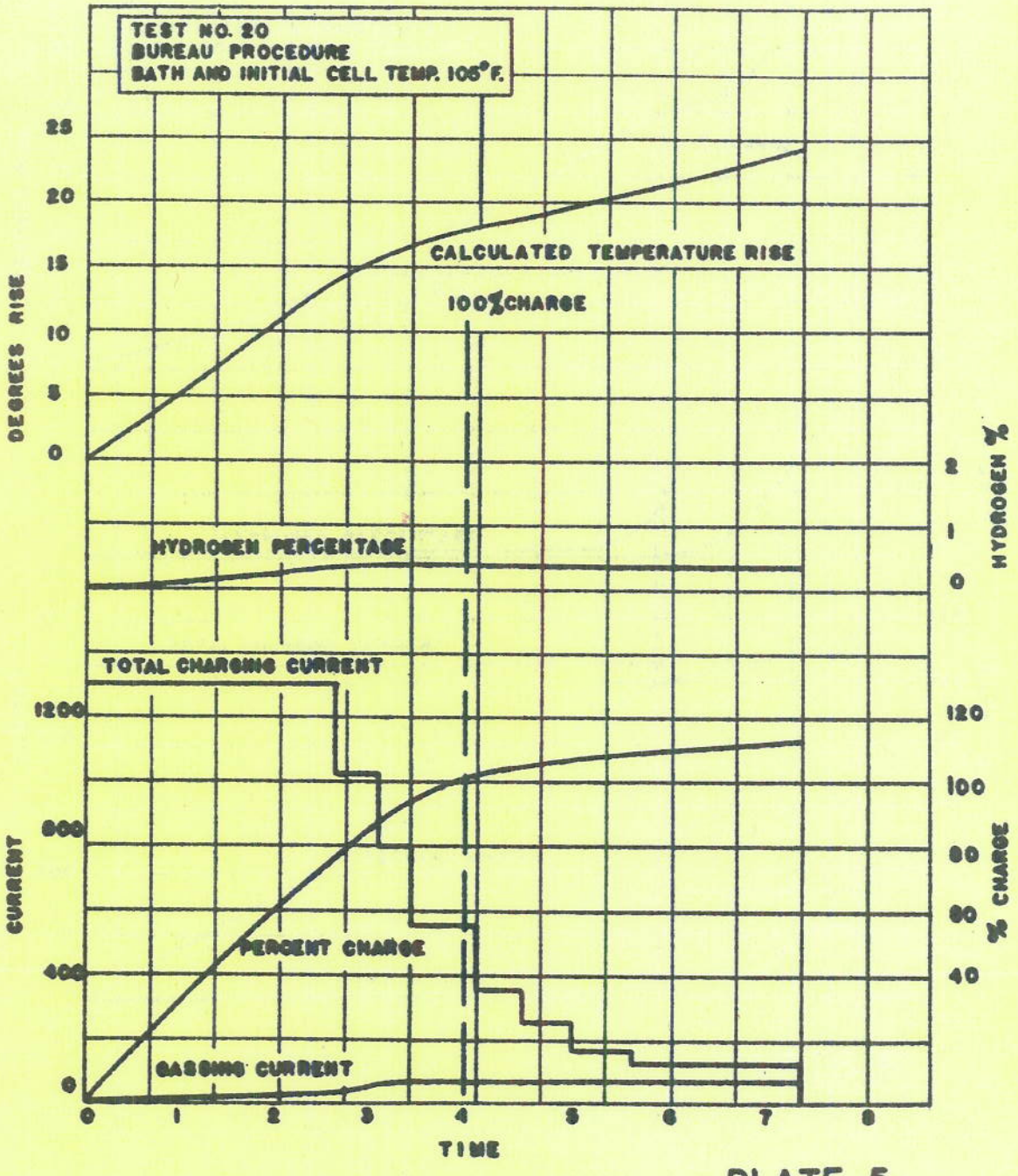

TEST NO. 13
BUREAU PROCEDURE
BATH AND INITIAL CELL TEMP. 60°F.
CALCULATED TEMPERATURE RISE
100% CHARGE
HYDROGEN PERCENTAGE
TOTAL CHARGING CURRENT
PERCENT CHARGE
GASSING CURRENT
DEGREES RISE
HYDROGEN %
CURRENT
% CHARGE
TIME
35
30
25
20
15
10
5
0
3
2
1
0
1200
800
400
120
100
80
60
40
0
1
2
3
4
5
6

PLATE 4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CALCULATED TEMPERATURE RISE
100% CHARGE
HYDROGEN PERCENTAGE
TOTAL CHARGING CURRENT
PERCENT CHARGE
GASSING CURRENT
DEGREES RISE
CURRENT
HYDROGEN %
% CHARGE
TIME
0
5
10
15
20
25
400
800
1200
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2
40
60
80
100
120
1
2
3
4
5
6
7
8

PLATE 5

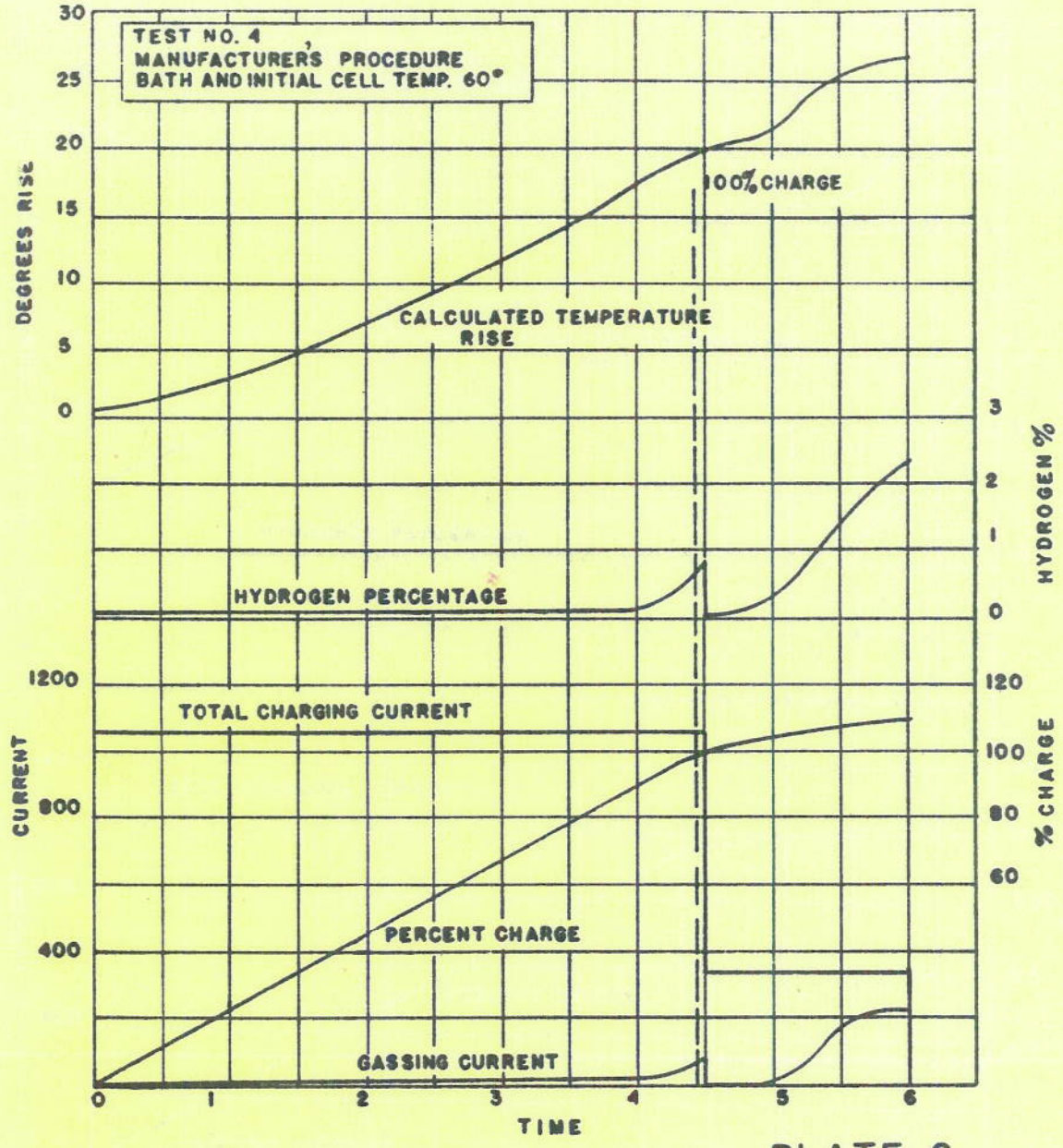
TEST NO. 4
MANUFACTURERS PROCEDURE
BATH AND INITIAL CELL TEMP. 60°
DEGREES RISE
30
25
20
15
10
5
0
100% CHARGE
CALCULATED TEMPERATURE RISE
HYDROGEN %
3
2
1
0
HYDROGEN PERCENTAGE
CURRENT
1200
800
400
TOTAL CHARGING CURRENT
% CHARGE
120
100
80
60
PERCENT CHARGE
GASSING CURRENT
0
1
2
3
4
5
6
TIME

PLATE 6

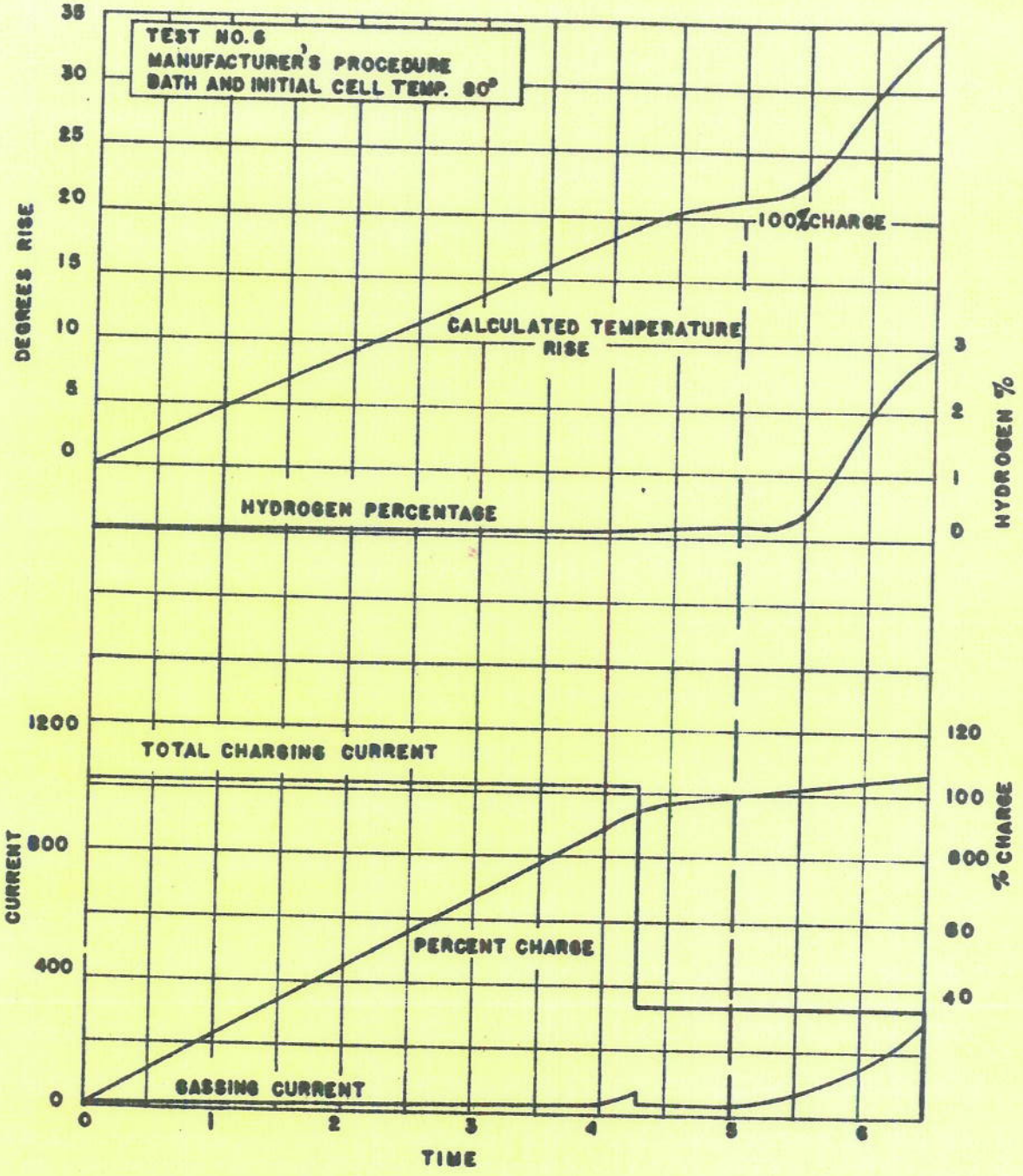
TEST NO. 6
MANUFACTURER'S PROCEDURE
BATH AND INITIAL CELL TEMP. 80°
DEGREES RISE
35
30
25
20
15
10
5
0
100% CHARGE
CALCULATED TEMPERATURE RISE
HYDROGEN PERCENTAGE
HYDROGEN %
3
2
1
0
1200
TOTAL CHARGING CURRENT
CURRENT
800
400
0
PERCENT CHARGE
GASSING CURRENT
% CHARGE
120
100
80
60
40
0
1
2
3
4
5
6
TIME

PLATE 7

Table 1.

Conversion Units and Formulas Used in Calculations.

1 Faraday = 96,500 coulombs = 96,500 ampere-seconds

4.186 joules = 4.186 watt-seconds = 1 calorie

1 BTU = 1060.4 joules at 40° F

1000 calories = 3.9685 BTU

1. cu. ft. = .02832 cu. meters = 28.32 liters

35.314 cu. ft. = 1,000 liters

1° C = 1.8° F = 1° Absolute

1 gram = 15.432 grains

1 pound = 453 grams

Calculation of Hydrogen Evolution.

air flow x percent hydrogen = no. cu. ft. of H_2 at temperature of duct air

$$\frac{\text{air flow} \times \%\ H_2 \times 28.32 \times 273/T}{22.4 \text{ liters}} = \text{no. mols } H_2 \text{ evolved at the given air flow and at one atmosphere pressure}$$

Calculation of Moisture Content of Air.

grams of water per liter of air x air flow x 28.32 liters = no. gms of water in air passing through duct in one minute

28.32 liters x grams of water per liter = grams of water per cu. ft.

Calculation of Increase of Moisture Content of Air when Passing over Electrolyte (Water loss by evaporation from electrolyte per minute)

Moisture content of cu. ft. of duct air - moisture content of cu. ft. of air before passing over electrolyte x $273 + T_1 / 273 + T_2$ = water loss by evaporation per minute per cu. ft.

T_1 = Centigrade temperature of air before passing over electrolyte.

T_2 = Centigrade temperature of air after passing over electrolyte.

Table 1 (continued)

Calculation of Reversible Heat of Water Electrolysis.

96,500 coulombs x T (Absolute) x dE/dT = q (per mol of water electrolyzed)

cooling effect per mol of water (18 gm) electrolyzed = 40,800 calories.

Calculation of Reversible Heat of Normal Reaction.

Mols of lead sulphate destroyed per minute x 2,800 calories = reversible heat effect per minute.

1 Faraday converts one half mol of lead sulphate to active material.

Heat of Formation of Molecular Gas.

1 mol of water electrolyzed (2 grams hydrogen) evolves 170,000 calories.

Evaporation Loss.

grams of water evaporated per minute x 575 calories = heat loss per minute.

Heat Capacity of Cell.

52,110 calories per degree Fahrenheit or 93,800 calories per degree Centigrade.

Radiation to Air.

Approximately 8 calories per cu. ft. per degree Centigrade.

Table 2.

Heat Capacity of Dry Air.

Temperature F	Temperature C	Volume, 1 mol gas (liters)	Grams gas per liter	Grams gas per cu.ft.	Heat Capacity per cu.ft. calories	watt-sec.	BTU
60	16	23.7	1.215	34.40	8.11	1.945	.00184
70	21	24.0	1.200	34.00	8.01	1.910	.00181
80	27	24.6	1.170	33.15	7.83	1.875	.00178
90	32	25.0	1.150	32.60	7.70	1.839	.00174
100	38	25.5	1.127	32.00	7.56	1.805	.00171
110	43	26.0	1.106	31.40	7.42	1.772	.00168
120	49	26.5	1.085	30.75	7.28	1.740	.00165

Molar Heat Capacity for Moist Air
(calories per degree C)

Relative Humidity	Temperature 60	70	80	90	100	110	120
0	6.79	6.79	6.80	6.81	6.81	6.81	6.82
50	6.78	6.78	6.79	6.79	6.80	6.80	6.81
100	6.77	6.77	6.78	6.78	6.79	6.79	6.80

The following values were used in the calculation of the above

Molal heat capacity (C_p)

Nitrogen	$6.5 + .001T$
Oxygen	$6.5 + .001T$
Water	$8.81 - .0019T + .00000222T^2$

Dry Air: 79 mol percent nitrogen, 21 mol percent oxygen

above formulas from Chemical Engineer's Handbook, Page 549

Table 3.

Specifications for WLH-29 Cell and Data for Calculation of Heat Capacity of Same.

Jar. Outside height, exclusive of poles, not to exceed 45-9/16", outside width not to exceed 17-11/16", length not to exceed 14-11/16", inside depth not less than 44", width not less than 13-3/16".

Positive Plate, Ironclad. Height not less than 35", width not less than 15-5/16", thickness not less than .52".

Negative Plate, Exide Type. Height not less than 33-7/8", width not less than 15-1/8", thickness not less than .22".

Separators, Treated Wood Veneer. Thickness not less than .05".

Sediment Space. 3-3/8" maximum, 3" minimum.

Weight complete, cell charged: 1210 electrolyte not to exceed 1205 lbs.
1250 electrolyte not to exceed 1210 lbs.
1280 electrolyte not to exceed 1215 lbs.

Weight of Electrolyte. Nominal weight for filling cell containing dry plates and wet separators, fully charged,

SG 1210 use 175 lbs. 1240 electrolyte
SG 1250 use 180 lbs. 1280 electrolyte
SG 1280 use 185 lbs. 1310 electrolyte

Weight of One Positive Plate, dry, not less than 29 lbs.

Weight of One Negative Plate, dry, not less than 24 lbs.

Permissable Temperatures. For regular service charging, 110° F. For charging as part of continuous cycle as war conditions, boat trials, etc., 130° F.

Percent by Weight, plate active material (weight of plate includes lugs), positive 48%, negative 58%.

Calculation of Heat Capacity of Cell.

Estimated weights of various materials		Total Heat Capacity
Jar, top, etc.	90 lbs.	6,523 calories
Separators	0	0
Electrolyte, 1280 gravity	225 lbs.	71,340 calories
Lead	631 lbs.	9,717 calories
Lead peroxide	214 lbs.	6,200 calories
total	1,160 lbs.	93,780 calories per degree C.

Table 3 (continued).

Heat Capacity per degree Fahrenheit = 52,110 calories

Heat capacity values used:

Lead	.034 calories per gram
Lead Peroxide	.064 calories per gram
Lead Sulphate	.084 calories per gram
Rubber	.48 calories per gram
Sulphuric Acid Solution	.70 calories per gram

Table 4.

Moisture Content of Air.

Weight of water vapor per 100 cu. ft. of air.

	percent saturation							
	10		20		30		40	
Temp. F.	Grams	lbs.	Grams	lbs.	Grams	lbs.	Grams	lbs.
60	3.745	.00828	7.46	.0164	11.16	.0246	16.64	.0367
70	5.180	.0148	10.36	.0228	15.50	.0342	21.18	.0456
80	7.080	.0156	14.16	.0313	21.28	.0469	28.34	.0626
90	9.580	.0212	19.16	.0424	28.78	.0633	38.30	.0844
100	12.80	.0286	25.60	.0572	38.85	.0849	51.10	.1130
110	16.93	.0374	33.86	.0748	51.00	.1126	67.70	.1443
	50		60		70		80	
60	18.60	.0411	22.32	.0493	26.05	.0575	29.82	.0658
70	25.80	.0572	31.04	.0685	36.23	.0800	41.40	.0914
80	35.50	.0774	42.52	.0938	49.65	.1095	56.85	.1252
90	47.90	.1057	57.50	.1270	67.10	.1484	76.60	.1690
100	64.10	.1415	76.90	.1700	89.60	.1990	102.60	.2265
110	84.60	.1867	101.50	.2240	118.50	.2613	135.30	.2938
	90		100					
60	33.50	.0740	37.52	.0828				
70	46.58	.1028	51.65	.1142				
80	64.00	.1415	70.80	.1563				
90	86.16	.1906	96.00	.2117				
100	115.30	.2548	128.20	.2828				
110	152.20	.3355	169.30	.3740				

Above values calculated from data on Page 84, Psychrometric Tables, C. F. Marvin, WB No. 235.

Table 5.

Vapor Pressures of Acid Solutions and Heat of Vaporization of Water from Same.

Weight percent acid		0	10	20	25	30
Gravity		1.000	1.0661	1.1394	1.1783	1.2185
Temperature						
C	F					
10	50	9.2mm	8.80	8.05	7.46	6.91
15	59	12.79	12.30	11.3	10.5	9.65
20	68	17.54	16.6	15.4	14.3	13.2
25	77	23.76	22.4	20.8	19.4	17.8
30	86	31.83	30.0	27.8	26.0	23.8
35	95	42.18	40.1	37.2	35.0	31.9
40	104	55.32	52.9	48.6	45.6	41.7
45	113	71.88	68.1	63.3	59.0	54.7
50	122	92.51	88.5	82.2	76.7	71.3

Heats of Vaporization (calories per gram)

percent acid	10	20	30
A	8.925	8.922	8.864
B	2259	2268	2271
Heat of vaporization	574	576	577

Vapor pressure equation $\log_{10} P_{mm} = A - \frac{B}{T}$

Table 6.

Current - Hydrogen Evolution Table.

Calculations based on assumption that entire current is producing gassing.

1. Current - amperes.
2. Cu. ft. Hydrogen, measured at 80° F. and 1 atm. pressure.
3. Hydrogen percentage, 80° F. and with air flow of 1.92 cu.ft. per minute.
4. Hydrogen percentage, 100° F. and with air flow of 1.92 cu.ft. per minute.

1.	2.	3.	4.
10	.00269	.14	.14
20	.00539	.28	.29
30	.00807	.42	.43
50	.01345	.70	.72
70	.01883	.98	1.01
90	.0242	1.26	1.30
100	.0269	1.40	1.44
200	.0538	2.80	2.88
300	.0807	4.20	4.32
400	.1076	5.60	5.76

Table 7.

Barometric Pressures for Various Tests.

Test No.	Barometric Pressure	Test No.	Barometric Pressure
1	29.96	11	29.86
2	30.02	12	29.94
3	29.96	13	30.00
4	30.14	14	29.66
5	30.02	15	29.84
6	30.14	16	29.98
7	30.14	17	30.14
8	30.04	18	30.10
9	30.02	19	30.08
10	29.92	20	30.00

Barometric Pressures expressed in inches of mercury.

Table 8.

Minimum Gassing Voltages.

Temperature F	Exide Cells	Philco Cells	WLH-29 Cell
35	2.455	2.450	-
55	-	-	2.365
60	2.365	2.360	-
70	-	-	2.320
80	2.305	2.270	2.290
100	2.255	2.225	2.240
115	-	-	2.200
120	2.210	2.150	-

Test No. 1

Overcharge data.

Time	Temperatures Couple Groups									
	1	2	3	4	5	6	7.	Bath	Air	Duct at Gooseneck
0950	68	75	69	68	75	72	69	67	86	94
1030	68	75	68	68	75	71	69	67	86	92
1100	68	75	68	68	75	71	68	67	85	92
1130	67	75	68	67	74	70	68	65	86	88
1145	67	72	72	71	72	71	71	66	85	82
1230	67	72	71	69	72	72	70	65	86	84
1315	67	74	74	74	74	74	73	65	88	81
1345	68	76	76	78	77	78	77	65	88	84
1415	68	76	76	79	77	79	77	65	88	86
1430	68	77	77	77	79	79	77	65	89	88
1500	68	77	77	73	78	78	75	63	88	88
1515	68	79	77	73	79	79	75	63	88	88

Time	Current	Gassing Current	Charging Current	Gravity	Hydrogen Percent	Voltage Open	Voltage Closed
0930	0	0	0	-	-	-	-
1030	0	0	0	-	-	-	-
1100	0	0	0	-	-	-	-
1130	0-500	-	-	1210	-	-	-
1145	500-0	-	-	1210	-	-	-
1230	0-500	296	204	1210	3.20	-	-
1315	500	280	220	1210	3.00	2.302	2.612
1345	500-300	324-148	176-162	1210	3.50-1.60	2.300	2.614
1415	300	176	124	1210	1.90	2.285	2.550
1430	300	185	115	1210	2.00	2.264	2.555
1500	300	231	69	1210	2.50	2.314	2.559
1515	300-0	231	69	1210	2.50	2.285	2.567

Time	Heating Effects 1	2	3	Cooling Effects 4.	5.	6	Net Effect	Rise Cal.	Rise Found
1230	3153	355	15,640	-22	n	3128	16,048	-	-
1315	2220	383	14,780	-77	e	2956	14,332	12°	4°
1345	2248	306-282	17,120-7811	-44	g	3424-	16,296-	9	3
					l	1562	8823		
1415	1139	216	9315	-22	i	1863	8830	4	0
1430	1251	200	9780	-11	g	1956	9286	2	0
1500	1053	120	12,200	0	i	2440	10,923	6	0
1515	1341	120	12,200	0	b	2440	10,623	3	-1
					l				
					e				
						Total effect		36°	6°

1. Irreversible Heat
2. Reversible Heat, Normal Reaction
3. Heat of Formation of Gases
4. Radiation and Convection to Air
5. Evaporation Loss
6. Reversible, Water Electrolysis

Air Flow Constant at 2.53 cu.ft.

Test No. 2

Overcharge Data

Time	Air	Bath	Duct	Temperatures Couple Groups 1	2	3	4	5	6	7
0845	90	60	88	63	74	66	65	73	67	65
0915	88	60	85	64	69	67	68	73	68	65
0945	89	60	83	64	68	68	71	68	68	69
1015	89	60	84	64	68	68	71	69	70	69
1045	89	60	85	63	68	69	72	69	70	71
1115	89	60	85	63	69	69	71	70	71	71
1145	86	60	84	63	70	70	69	69	70	69
1230	86	60	84	63	69	68	67	68	70	67
1330	88	60	88	66	73	74	71	73	73	72
1430	89	60	91	68	77	79	77	77	77	77

Time	Current	H_2	Gassing Current	Charging Current	Gravity	Voltage Open	Closed
0845	0-300	1.95	181	119	1210	2.085-	2.588
0915	300	2.70	250	50	1210	2.299	2.590
0945	300-150	2.7-1.1	250	50	1210	2.298	2.588
1015	150	.95	88	62	1210	2.288	2.490
1045	150-75	1.0- .4	92	58	1210	2.301	2.502
1115	75	.40	37	38	1210	2.288	2.423
1145	75-25	.4-.1	37	38	1210	2.283	2.430
1230	25-0	.1	9	16	1210	2.265	2.297
1330	discharge	-	-	-	-	-	-
1430	discharge	-	-	-	-	1.920	1.655

Air Flow constant at 2.53 cu.ft.

Couple groups
1 Electrolyte below elements
2 Electrolyte above elements
3 Between jar and elements
4 Bottom section of elements
5 Top section of elements
6 Center group
7 Group near edges

Test No. 2 (continued)

Overcharge data.

Time	Voltages 1	2	3	4	Cell Resistance (estimated)
0815	-	-	-	-	-
0830	.970	-	1.115	-	-
0845	-	-	-	-	.000967
0915	1.015	1.232	1.284	1.358	.000970
0945	1.014	1.232	1.284	1.358	.001346
1015	.990	1.161	1.298	1.298	.001246
1045	.994	1.173	1.330	1.307	.001340
1115	.988	1.115	1.283	1.308	.001801
1145	.986	1.118	1.282	1.310	.001960
1230	.984	1.128	1.266	1.273	.001280
1330	-	-	-	-	-
1430	.708	.916	.947	1.009	-

Time	Heating Effects 1	2	3	Cooling Effects 4	5	6	Net Effect	Temp. Rise est.	Found
0845	1247	207	9563	-22	n	1913	9128		
0915	1251	87	13210	-44	e	2642	11950	3°	-
0945	1247	87	13210-	-55	g	2642-	11947-	6°	4°
			5390		l	1078	5698		
1015	434	108	4650	-55	i	930	4317	2	1
1045	432	101-66	4861-	-44	g	972-	4466-	2	1
			1955		i	391	2106		
1115	145	66	1955	-44	b	391	1819	1	.5
1145	158	66-28	1955-	-22	l	391-	1810-	1	.5
			476		e	95	589		
1230	12	28	476	-22		95	433	.4	-1
				total				15.4°	6°

1. Irreversible heat
2. Reversible heat, normal reaction
3. Heat of formation, molecular gas
4. Radiation and convection to air
5. Evaporation loss
6. Reversible heat, water electrolysis

Test No. 3

Manufacturers Procedure
Discharged at 4000 ampere-hours

Time	Temperatures Couple Numbers										
	1	2	18	19	20	6	8	3	4	14	15
0615	60	60	71	68	71	62	65	60	60	68	68
0630	60	60	72	68	71	63	65	60	62	68	68
0645	61	61	71	68	71	63	63	61	62	70	71
0700	61	62	72	68	72	65	67	61	62	70	71
0715	61	61	72	71	72	66	67	63	62	71	69
0730	61	61	72	71	74	66	68	63	63	71	69
0800	61	61	74	71	74	67	71	66	65	72	70
0830	61	61	74	71	74	69	74	67	67	72	70
0900	63	62	74	71	75	71	76	68	70	71	71
0930	66	65	76	72	76	74	79	70	72	71	72
1000	70	70	77	72	77	78	81	72	75	75	76
1015	72	72	76	72	76	77	81	72	75	75	75
1030	71	71	74	74	75	77	81	72	76	75	75
1100	70	70	74	74	74	78	79	74	76	75	75
1130	68	68	74	72	74	78	79	74	76	75	75
1200	68	68	72	72	74	78	79	72	76	74	74
1230	68	68	72	72	74	78	79	71	76	72	74
1300	67	67	72	72	72	76	77	71	74	72	73
1400	65	65	70	71	71	74	75	70	72	70	70
1415	63	63	-	-	-	-	-	-	-	-	-
1430	-	-	-	-	-	-	-	-	-	-	-
1500	-	-	-	-	-	-	-	-	-	-	-
1515	63	63	70	70	70	73	74	68	72	70	70
1530	63	63	69	69	69	73	74	67	69	70	70
1600	62	62	69	69	69	72	73	67	69	70	70

Time	Temperatures Couple Numbers										Duct at
	16	17	11	12	13	7	9	10	Air	Bath	Gooseneck
0615	70	70	63	67	67	62	63	61	75	63	77
0630	70	70	63	67	67	62	63	61	80	-	77
0645	70	71	64	68	68	62	63	62	79	61	77
0700	72	71	64	69	68	63	64	64	79	-	81
0715	74	71	64	71	71	64	67	64	80	61	81
0730	75	71	66	72	71	65	67	65	81	61	82
0800	75	71	66	70	75	67	70	67	82	60	82
0830	75	71	67	74	75	68	74	67	86	60	84
0900	75	71	65	75	75	69	74	67	82	60	84
0930	77	74	70	77	74	71	74	68	80	60	83
1000	77	76	70	81	77	74	76	71	82	-	84
1015	77	74	70	78	77	75	76	70	84	60	84
1030	76	74	71	78	76	74	76	70	84	56	83
1100	76	74	71	78	76	75	77	71	82	56	83
1130	76	74	72	78	76	75	76	72	80	57	82
1200	75	71	71	76	76	75	75	70	80	-	81
1230	75	71	71	76	74	74	74	70	80	60	81
1300	75	72	70	75	74	74	74	68	79	60	81
1400	73	70	68	74	71	71	72	67	80	-	81
1415	-	-	-	-	-	-	-	-	-	-	-
1430	-	-	-	-	-	-	-	-	-	-	-
1500	-	-	-	-	-	-	-	-	81	-	-
1515	72	70	67	74	71	70	70	67	-	-	81
1530	72	70	66	72	71	70	68	66	79	-	81
1600	72	70	66	72	71	70	67	66	79	-	80

Test No. 3 (continued)

Time	Air at intake		Air in duct			Evaporation
	1.	3.	1.	2.	3.	Grams per minute
0615	40.75	-	-	-	-	-
0630	-	.55	-	.80	-	-
0645	45.00	-	41.33	-	-	-.0931
0700	-	.65	43.85	.71	.60	-
0715	-	-	-	-	.60	-
0730	39.90	-	40.30	.74	-	.0071
0800	40.50	.60	44.15	.63	.60	.0931
0830	41.05	.60	43.30	.60	.60	.0573
0900	41.35	.60	47.00	.64	.60	.1433
0930	44.70	.60	44.70	.64	.65	.0000
1000	-	.60	-	.64	.60	-
1015	42.45	-	46.45	.68	-	.1003
1030	43.85	.53	44.70	.64	.60	.0215
1100	40.80	.60	-	.64	.55	-
1130	42.45	.55	-	.64	-	-
1200	-	.60	-	.60	-	-
1230	41.05	-	42.45	.68	-	.0429
1300	42.45	.58	-	.64	.60	-
1400	-	.60	-	.74	-	-

1. Grams water per 100 cu.ft. air
2. Humidity, relative, wet-dry bulb thermometer
3. Ditto, calculated

Air Flow: 2.53 cu.ft. per minute

Time	Current	Gassing Current	Charging Current	Percent charge	Hydrogen percent
0615	0	0	0	-	0
0630	0-1050	0	1050	-	0
0645	1050	0	1050	-	0
0700	1050	0	1050	-	0
0715	1050	0	1050	-	0
0730	1050	0	1050	-	0
0800	1050	5	1045	-	.05
0830	1050	7	1043	52	.08
0900	1050	7	1043	78	.08
0930	1050	11	1039	97	.12
1000	1050-330	131-9	919-321	105	1.4-1.10
1015	330	56	374	107	.60
1030	330	206	124	108	2.2
1100	330-100	300	30	109	3.2
1130	100	52	48	109	.55
1200	100	76	24	-	.80
1230	100	-	-	110	-
1300	100	85	15	-	.90
1400	100-50	85	15	-	.90
1415	50	37	13	-	.38
1430	50	37	13	-	.38
1500	50-25	37	13	-	.38
1515	25	9	16	-	.10
1530	25-0	9	16	111	.18
1600	0	-	-	-	-

Test No. 3 (continued)

Time	Voltages						Cell Resistance (calculated)	Gravity
	1.	2.	3.	4.	5.	6.		
0615	1.980	-	.940	-	1.040	-	-	-
0630	-	-	-	-	-	-	-	1123
0645	-	-	-	-	-	-	-	-
0700	2.065	2.203	.953	1.053	1.104	1.152	.000131	-
0715	-	-	-	-	-	-	-	-
0730	2.084	2.227	.963	1.070	1.110	1.159	.000136	1125
0800	2.103	2.245	.970	1.077	1.117	1.169	-	-
0830	2.124	2.278	.972	1.079	1.119	1.142	.000147	1126
0900	2.129	2.304	.964	1.074	1.161	1.232	.000166	-
0930	2.147	2.387	.958	1.116	1.186	1.280	.000133	1135
1000	2.121	2.542	.954	-	1.209	1.359	.000118	-
1015	-	-	-	-	-	-	-	-
1030	2.246	2.410	.963	1.119	1.260	1.300	.000472	1170
1100	2.278	2.533	.981	-	1.285	1.350	.000772	1205
1130	2.274	2.380	.982	1.082	1.278	1.297	.001060	-
1200	2.288	2.419	.987	1.115	1.285	1.308	.001310	1215
1230	2.292	2.414	.991	1.108	1.287	1.306	.001220	-
1300	2.300	2.438	.994	1.125	1.292	1.315	.001380	1215
1400	2.292	2.437	.992	1.123	1.290	1.315	.001450	1215
1415	-	-	-	-	-	-	-	-
1430	2.280	2.346	.988	1.065	1.275	1.286	.001800	1215
1500	2.278	2.359	.989	1.075	1.276	1.288	.001650	1215
1515	2.256	2.287	.982	1.027	1.260	1.262	.001240	-
1530	2.258	2.287	.982	1.027	1.260	1.265	.001200	-
1600	-	-	-	-	-	-	-	-

Voltages

1. Voltage - open
2. Voltage - closed
3. Lead-mercurous sulphate, open
4. Lead-mercurous sulphate, closed
5. Lead peroxide-mercurous sulphate, open
6. Lead peroxide-mercurous sulphate, closed

Test No. 3 (continued)

Time	Heating Effects			Cooling Effects				Temp. rise	
	1.	2.	3.	4.	5.	6.	Net Effect	est.	found
0615	-	-	0	22	-	0	-		
0630	-	1820	0	-33	50	0	-		
0700	2080	1820	0	22	57	0	3821		
0730	2160	1820	0	11	50	0	3920	4°	3°
0800	2000	1810	264	0	4	53	4017		
0830	2320	1810	370	-22	57	74	4145	4.5	3
0900	2630	1810	370	22	81	74	4633		
0930	2110	1810	581	33	0	116	4352	4.5	3
1000	1870	1600-558	6920-475	22	50	1384-95	8934-1704	4	3
1030	738	216	1088-7	-11	58	2177	9617	2.5	0
1100	1210	52	1585-5	11	12	3171	13934	6	1
1130	152	84	2750	22	10	550	2404		
1200	188	42	4020	11	10	804	3425	2	0
1230	175	-	-	11	23	-	3400		
1300	198	26	4490	22	23	898	3771	4	0
1400	208	26	4490	11	23	898	3791	4	-2
1430	47	21	1960	11	23	392	1602		
1500	58	21	1960	11	23	392	1613	1.5	0
1515	11	28	475	11	23	95	385		
1530	11	28	475	22	23	95	385	2	-1
					total		39°	10°	

1. Irreversible Heat
2. Reversible Heat, Normal Reaction
3. Heat of Formation of Gases
4. Radiation and Convection to Air
5. Evaporation Loss
6. Reversible Heat, Water Electrolysis

Test No. 4.

Manufacturer's procedure.

Time	Temperatures									
	Couple Groups									Duct at
	1.	2.	3.	4.	5.	6.	7.	Air	Bath	Gooseneck
0600	60	67	61	60	66	62	61	77	61	75
0630	60	67	61	60	66	63	61	79	61	75
0645	60	68	61	61	67	64	61	79	61	76
0700	60	68	62	61	68	67	62	79	61	77
0715	60	70	62	61	69	68	62	81	61	78
0730	60	70	63	62	69	69	63	82	61	79
0800	60	73	65	63	70	72	67	83	61	81
0830	61	73	67	67	72	72	68	86	61	82
0900	61	74	67	68	73	73	68	87	61	84
0930	61	74	68	69	72	76	69	87	61	88
1000	63	74	68	72	73	77	72	88	61	89
1030	63	75	68	73	74	77	72	88	61	89
1040	-	-	-	-	-	-	-	-	61	-
1050	-	-	-	-	-	-	-	-	61	-
1100	65	77	71	76	76	81	74	88	61	88
1115	-	-	-	-	-	-	-	-	61	-
1130	70	76	72	77	78	82	73	87	60	87
1145	-	-	-	-	-	-	-	-	60	-
1200	72	75	73	77	76	81	75	87	60	85
1215	-	-	-	-	-	-	-	-	59	-
1230	70	75	74	78	76	81	75	86	56	85
1300	68	74	72	76	75	80	74	85	58	85
1330	67	74	70	75	75	79	73	85	58	85
1400	66	72	70	73	74	78	71	85	58	84
1430	65	72	69	73	72	78	70	85	61	84
1500	65	71	68	72	71	76	69	85	61	84
1530	65	71	67	71	70	76	68	83	61	84

1. Electrolyte below elements.
2. Electrolyte above elements.
3. Between elements and cell jar.
4. Bottom of elements.
5. Top of elements.
6. Center group.
7. Group near edge.

Test No. 4 (Continued)

Time	Air at Intake		Air in Duct			Evaporation - grams per minute.
	1.	3.	1.	2.	3.	
0630	40.80	.65	45.35	.74	.73	.1145
0645	35.75	.50	39.20	.74	.65	-
0700	-	-	-	.70	-	-
0715	-	-	-	.70	-	-
0730	40.80	.65	-	.71	-	.0430
0800	38.55	.55	42.55	.64	.65	-
0830	39.65	.55	41.20	.63	.60	.1000
0900	39.20	.55	44.60	.60	.63	.0358
0930	38.55	.45	42.50	.53	.50	.1295
1000	39.20	.55	45.65	.54	.55	.1075
1030	-	-	-	.59	-	.1647
1040	-	-	-	-	-	-
1050	-	-	-	-	-	-
1100	34.60	.45	-	-	-	-
1115	-	-	-	-	-	-
1130	-	-	39.40	.59	.47	-
1145	-	-	-	-	-	-
1200	-	-	-	-	-	-
1215	32.60	.35	-	-	-	.2865
1230	-	-	43.90	.59	.53	-
1300	34.55	.40	-	.55	-	.2508
1330	31.75	.37	36.80	.55	.53	.1290
1400	28.32	.35	31.75	.55	.45	.0858

1. Grams water per 100 cu.ft. air.
2. Relative humidity, wet-dry bulb thermometer.
3. Relative humidity, calculated.

Test No. 4 (Continued)

Time	Current	Charging Current	Gassing Current	Per Cent Hydrogen	Per Cent Charge	Gravity	Cell Resistance
0630	0-1050	1050	0	0	-	1087	.000209
0645	1050	1050	0	0	-	-	-
0700	1050	1050	0	0	-	-	.000119
0715	1050	1050	0	0	-	-	-
0730	1050	1050	0	0	-	1086	.000118
0800	1050	1050	0	0	-	-	.000123
0830	1050	1050	0	0	45	1087	.000121
0900	1050	1045	5	.05	-	-	.000133
0930	1050	1044	6	.07	-	1091	.000139
1000	1050	1043	7	.08	-	-	.000152
1030	1050	1041	9	.10	89	1102	.000174
1040	1050	1036	14	.15	-	-	-
1050	1050	1022	28	.30	96	-	-
1100	1050-330	980-321	70-9	.75-.10	100	1139	.000286
1115	330	321	9	.10	101	-	-
1130	330	312	18	.19	-	1149	.000309
1145	330	283	47	.50	104	-	-
1200	330	204	126	1.35	-	1185	.000546
1215	330	134	196	2.10	106	-	-
1230	330-100	124	206	2.20	107	1205	.000697
1300	100-50	30	70	.75	-	1212	.001120
1330	50	17	33	.35	-	-	.001420
1400	50	22	28	.30	-	-	.001380
1430	50-25	9	16	.17	-	1213	.000620
1500	25-0	4	21	.22	-	1213	.002360
1530	0	-	-	-	-	-	-

Air flow 2.53 cu.ft. per minute.

Test No. 4 (Continued)

Time	Voltages					
	1.	2.	3.	4.	5.	6.
0600	1.944	-	.928	-	1.020	-
0630	-	-	-	-	-	-
0645	-	-	-	-	-	-
0700	2.038	2.163	.937	1.031	1.094	1.130
0715	-	-	-	-	-	-
0730	2.053	2.177	.950	1.050	1.093	1.130
0800	2.068	2.197	.961	1.060	1.100	1.138
0830	2.091	2.218	.972	1.073	1.112	1.153
0900	2.096	2.236	.970	1.068	1.118	1.169
0930	2.113	2.259	.967	1.065	1.139	1.197
1000	2.134	2.294	.958	1.059	1.168	1.237
1030	2.160	2.343	.951	1.083	1.190	1.267
1040	-	-	-	-	-	-
1050	-	-	-	-	-	-
1100	2.200	2.500	.956	1.215	1.220	1.285
1115	-	-	-	-	-	-
1130	2.234	2.336	.968	1.087	1.130	1.255
1145	-	-	-	-	-	-
1200	2.279	2.459	.989	1.171	1.269	1.297
1215	-	-	-	-	-	-
1230	2.282	2.512	.983	1.226	1.272	1.321
1300	2.281	2.393	.984	1.115	1.276	1.292
1330	2.259	2.330	.983	1.068	1.268	1.268
1400	2.263	2.332	.984	1.060	1.271	1.280
1430	2.235	2.266	.977	1.012	1.246	1.248
1500	2.248	2.307	.981	1.046	1.254	1.260
1530	-	-	-	-	-	-

1. Voltage, open.
2. Voltage, closed.
3. Lead - mercurous sulphate, open.
4. Lead - mercurous sulphate, closed.
5. Lead peroxide - mercurous sulphate, open.
6. Lead peroxide - mercurous sulphate, closed.

Test No. 4 (Continued)

Time	Heating Effects			Cooling Effects			Net Effect	Temp.Rise	
	1.	2.	3.	4.	5.	6.		Calc.	Found
0600	-	1827	0	-22	-57	0	-	-	-
0630	3311	1827	0	-33	-	0	4171	-	-
0645	-	1827	0	-22	-	0	4160	-	-
0700	1882	1827	0	-11	-	0	3777	1	1
0715	-	1827	0	-33	-	0	3800	-	-
0730	1866	1827	0	-11	-19	0	3723	-	-
0800	1941	1827	0	-11	-	0	3798	4	4
0830	1912	1827	0	-11	-57	0	3807	-	-
0900	2107	1818	264	-22	-14	63	4163	4.5	3
0930	2198	1817	317	11	-57	76	4302	-	-
1000	2408	1815	370	22	-57	89	4543	5	-
1030	2754	1811	476	11	-97	114	4013	-	2
1040	-	1803	750	-	-	138	5162	4	-
1050	-	1778	1480	-	-	355	-	-	-
1100	4515	1705-559	3699-476	0	-	888-114	9030-2425	3	3
1115	-	559	476	-	-70	114	1475	-	-
1130	483	543	951	0	-	228	1750	1	-
1145	-	493	2483	-	-	596	-	-	-
1200	852	355	6660	-22	-	1598	5291	3	0
1215	-	233	1036	99	-160	249	-	-	-
1230	1088	216	1088	0	-	261	2282	1	-
1300	161	52	3699	0	-140	888	3170	1.5	-1
1330	51	29	1744	0	-75	419	1424	-	-
1400	49	38	1480	-11	-50	355	1274	1.5	-2
1430	22	16	845	-11	-	203	691	-	0
1500	21	7	1110	-11	-	266	628	.6	-2
1530	-	-	-	-11	-	-	-	-	-
						Total Effect		30°	8°

1. Irreversible heat.
2. Reversible heat, normal reaction.
3. Heat of formation of gases.
4. Convection and radiation to air.
5. Evaporation loss.
6. Reversible heat, water electrolysis.

Test No. 5.

Bureau Procedure.
Discharged at 4675 ampere-hours.

Time	Temperatures Couple Numbers												
	1	2	18	19	20	11	3	4	14	15	16	17	6
0600	60	60	71	69	68	61	61	61	67	68	71	69	61
0630	60	60	73	69	72	63	61	61	72	70	74	70	63
0700	60	60	75	71	75	65	63	63	73	70	76	71	67
0730	60	60	77	74	76	67	66	66	74	70	78	74	70
0800	61	60	79	76	81	70	67	69	76	75	82	77	72
0830	60	60	82	78	82	71	68	72	78	75	84	78	76
0900	60	60	83	78	83	71	70	75	78	76	84	78	77
0915	61	60	84	81	84	74	73	78	80	78	86	80	81
0930	61	61	82	80	83	73	74	79	79	78	85	80	82
0945	63	61	82	80	82	74	73	80	80	80	85	79	83
1000	64	62	81	79	82	74	74	81	81	80	84	78	84
1030	67	68	80	80	81	75	75	82	80	81	83	80	86
1100	68	71	78	78	80	75	75	81	80	80	82	78	85
1115	-	-	-	-	-	-	-	-	-	-	-	-	-
1130	68	70	78	77	78	75	75	81	78	79	81	76	84
1200	68	70	76	77	76	75	74	80	78	78	80	76	84
1230	67	68	75	76	76	74	73	79	77	77	78	75	83
1300	67	67	75	74	75	73	72	77	75	76	76	75	82
1330	67	67	74	75	75	71	71	76	74	74	76	74	81
1400	66	66	74	73	75	69	71	76	72	75	75	74	80
1430	64	63	74	72	74	67	68	75	72	73	75	74	77
1530	61	61	72	71	74	65	67	72	72	70	72	74	76

Time	Couples Temperatures								
	12	13	5	7	9	10	air	Bath	Duct at gooseneck
0600	67	66	61	61	62	60	85	61	78
0630	69	68	61	65	65	63	85	59	52
0700	74	72	64	67	69	65	86	59	85
0730	78	75	67	68	72	67	87	60	85
0800	81	77	68	70	75	69	90	58	87
0830	84	80	70	74	78	70	92	59	89
0900	84	80	71	75	79	70	91	60	89
0915	84	82	73	76	80	73	93	60	89
0930	85	82	73	76	80	72	94	58	88
0945	85	81	74	76	80	72	94	58	89
1000	85	82	74	76	80	72	92	59	88
1030	85	82	75	77	81	72	92	60	88
1100	83	82	75	77	80	73	91	60	85
1115	-	-	-	-	-	-	-	60	85
1130	83	81	75	77	78	73	93	60	85
1200	82	80	74	77	77	72	91	59	82
1230	80	79	72	76	75	72	91	59	82
1300	80	77	70	75	73	70	91	60	84
1330	80	77	70	73	73	69	92	60	82
1400	77	77	69	73	70	68	92	60	82
1430	75	75	67	71	68	65	92	56	82
1530	67	76	67	69	67	65	92	70	86

Test No. 5 (continued)

Time	Air at Induction			Air in Duct			Evaporation,
	1.	2.	3.	1.	2.	3.	gram per minute
0600	51.00	n	61	49.10	68	70	none
0630	49.10	o	60	48.80	72	70	-.0072
0700	54.40	t	65	51.00	69	61	-.8040
0730	52.20		55	53.60	66	65	.0288
0800	55.60	r	58	56.75	64	68	.0288
0830	57.00	e	55	57.00	58	60	none
0900	54.40	c	58	59.60	58	62	.1289
0915	54.75	o	52	-	61	-	-
0930	-	r	-	59.80	61	62	-
0945	56.75	d	50	-	58	-	-
1000	-	e	-	56.75	61	60	-
1030	52.75	d	56	56.75	61	60	.1002
1100	52.75		56	57.00	67	60	.1074
1115	-		-	-	64	-	-
1130	50.22		47	52.20	64	55	.0501
1200	50.22		52	52.20	61	55	.0430
1230	-		-	-	-	-	-
1300	-		-	-	-	-	-
1330	-		-	-	-	-	-
1400	-		-	-	-	-	-
1430	-		-	-	-	-	-
1530	-		-	-	-	-	-

1. Grams water per 100 cu. ft. air
2. Relative Humidity, wet-dry bulb thermometer
3. Ditto, calculated

Air flow: 2.53 cu.ft. per minute

Time	Current	Gassing Current	Charging Current	percent charge	Hydrogen percentage	Cell Resistance
0600	0-1300	0	1300	-	0	.000208
0630	1300	0	1300	-	0	.000118
0700	1300	0	1300	-	0	-
0730	1300	0	1300	-	0	.000122
0800	1300	3	1297	-	.03	-
0830	1300	7	1293	-	.08	.000060
0900	1300	9	1291	-	.10	-
0915	1300-1050	19-9	1281-1041	90	.21-.10	.000191
0930	1050-800	27-9	1023-791	95	.30-.10	.000208
0945	800-550	32-9	768-541	99.6	.35-.10	.000221
1000	550-330	54-9	446-321	100	.60-.10	.000292
1030	330-250	64-9	266-241	104	.70-.10	.000394
1100	250-190	102	148	106	1.10	.000644
1115	190-165	102	88	106	1.10	.000784
1130	165-100	101	64	107	1.10	.000891
1200	100	65	35	108	.70	.000190
1230	100-50	76	24	108	.82	.001250
1300	50	28	22	108	.30	.001140
1330	50-25	28	22	108	.30	.001540
1400	25	19	6	108	.20	.001679
1430	25-0	17	8	109	.18	.001039
1530	0	0	0	-	0	-

Test No. 5 (continued)

Voltages

Time	1	2	3	4	5	6	gravity
0600	1.945	-	.926	-	1.020	-	1083
0630	2.047	2.200	.953	1.067	1.083	1.133	-
0700	-	-	-	-	-	-	1079
0730	2.084	2.243	.973	1.092	1.100	1.155	-
0800	-	-	-	-	-	-	1083
0830	2.232	2.310	.965	1.085	1.146	1.232	-
0900	-	-	-	-	-	-	1096
0915	2.177	2.425	.960	1.126	1.187	1.285	-
0930	2.213	2.421	.961	1.144	1.206	1.283	-
0945	2.227	2.404	.966	1.130	1.217	1.279	-
1000	2.266	2.427	.990	1.145	1.249	1.286	1143
1030	2.261	2.391	.990	1.117	1.247	1.276	-
1100	2.274	2.435	.998	1.147	1.254	1.290	1198
1115	2.276	2.425	.998	1.137	1.263	1.290	-
1130	2.218	2.425	.998	1.136	1.262	1.290	-
1200	2.273	2.292	.998	1.114	1.260	1.281	1207
1230	2.275	2.400	.998	1.120	1.261	1.286	-
1300	2.258	2.315	.990	1.056	1.248	1.257	-
1330	2.263	2.340	.992	1.076	1.256	1.262	1212
1400	2.240	2.282	.988	1.036	1.242	1.249	-
1430	2.242	2.268	.988	1.033	1.240	1.246	-
1530	-	-	-	-	-	-	-

Voltages

1. Voltage - open
2. Voltage - closed
3. Lead-mercurous sulphate, open
4. Lead-mercurous sulphate, closed
5. Lead peroxide-mercurous sulphate, open
6. Lead peroxide-mercurous sulphate, closed

Test No. 5 (continued)

Time	Heating Effects				Cooling Effects		Net effect	Temp. rise cal.	Temp. rise found
	1.	2.	3.	4.	5.	6.			
0600	5030	2262	0	140	0	0	7152	-	-
0630	2851	2262	0	60	-4	0	5057	-	-
0700	-	2262	0	19	46	0	5195	5°	5°
0730	2964	2262	0	40	16	0	5170	-	-
0800	-	2258	158	60	16	38	5266	3	4
0830	2453	2250	370	60	0	89	3924	2.2	2
0900	-	2248	476	40	75	114	5533	3	-
0915	4622	2229-1812	1004-476	120	60	241-114	7434-6616	2	3
0930	3281	1780-1386	1427-476	120	60	343-114	5965-4849	2	-
0945	2030	1337-941	1692-476	80	60	406-114	4513-3193	1	1
1000	1268	776-559	2854-476	80	60	685-114	4073-2049	1	-
1030	615	463-419	3383-476	80	57	812-114	3512-1259	1.5	1
1100	577	258	5392	120	57	1296	4756	-	-
1115	406	153	5392	120	50	1294	4487	-	-
1130	348	111	5340	160	28	1282	4329	4	-1
1200	27	61	3436	180	24	825	2495	1.5	-
1230	179	42	4017	180	24	964	3070	1.5	-1
1300	41	38	1480	140	24	355	1040	-	-
1330	56	38	1480	200	24	355	994	1	2
1400	15	10	1004	200	24	241	564	-	-
1430	9	14	898	200	24	216	491	.6	-1
1500	-	0	0	120	24	-	-	-	-
				total effect				29.3°	11°

1. Irreversible Heat
2. Reversible Heat, Normal Reaction
3. Heat of Formation of Gases
4. Radiation and convection to air
5. Evaporation loss
6. Reversible Heat, Water Electrolysis

Test No. 6.

Manufacturer's procedure.
Discharge data.

Time	Temperatures									
	Couple Groups									Duct at
	1.	2.	3.	4.	5.	6.	7.	Bath	Air	Gooseneck
0930	67	75	67	70	75	73	69	56	86	89
1000	66	75	68	69	74	72	67	58	86	88
1030	65	74	68	67	74	71	67	59	86	88
1100	64	76	69	67	75	72	67	58	86	87
1130	63	76	68	66	75	71	67	56	86	87
1200	61	76	68	65	75	70	66	56	88	86
1230	61	76	68	64	74	70	64	58	89	87
1300	61	76	68	63	74	69	65	59	89	87
1330	60	75	68	64	74	69	65	54	92	87
1400	58	75	67	63	73	69	64	55	90	87
1430	58	74	67	62	73	68	64	56	90	86
1500	58	74	68	61	72	68	64	58	90	86
1530	-	-	-	-	-	-	-	58	90	86

Couple Groups.
1. Electrolyte below elements.
2. Electrolyte above elements.
3. Between jar and elements.
4. Bottom of elements.
5. Top part of elements.
6. Center group.
7. Group near edge.

Time	Voltages			
	1.	2.	3.	Current
0930	2.071-1.943	1.030-1.105	.915-.971	0-850
1000	1.939	1.032	.907	850
1030	1.929	1.027	.902	850
1100	1.918	1.021	.898	850
1130	1.904	1.013	.891	850
1200	1.886	1.004	.882	850
1230	1.872	.996	.874	850
1300	1.856	.988	.866	850
1330	1.836	.980	.855	850
1400	1.814	.972	.840	850
1430	1.775	.960	.814	850
1500	1.729	-	-	850-0
1530	1.912	.997	.916	0

1. Cell voltage.
2. Lead peroxide - mercury mercurous sulphate.
3. Lead - mercury mercurous sulphate.

Test No. 6 (Continued)

Temperatures

Time	Couple Groups									Duct at Gooseneck
	1.	2.	3.	4.	5.	6.	7.	Air	Bath	
0600	64	74	66	64	72	71	65	82	69	77
0615	65	75	68	65	75	73	67	84	75	79
0630	66	75	68	66	76	75	68	85	79	80
0645	67	77	71	67	78	75	70	86	79	82
0700	68	78	72	68	81	79	71	87	79	82
0730	68	80	74	70	82	81	73	84	79	83
0800	71	82	75	73	84	83	77	86	80	84
0830	71	85	78	74	85	83	78	88	80	86
0900	73	86	79	77	87	85	80	89	79	88
0930	74	88	81	80	88	87	83	88	79	88
1000	75	89	82	82	88	87	84	89	79	89
1015	-	-	-	-	-	-	-	89	79	89
1030	75	89	83	83	89	90	85	89	79	89
1100	78	88	85	84	88	89	85	89	80	89
1130	82	88	86	85	88	89	86	90	78	88
1200	82	87	86	87	88	90	87	91	79	87
1230	82	88	87	90	89	91	89	90	79	87
1300	82	89	88	90	89	91	88	91	79	88
1330	83	88	88	89	89	90	88	90	79	88
1400	83	88	87	88	88	90	87	91	78	88
1415	83	88	86	88	89	89	87	91	79	88
1500	82	87	86	87	89	89	85	90	79	88

Time	Air at Intake		Air in Duct			Evaporation - grams per minute.
	1.	3.	1.	2.	3.	
0600	54.40	.70	53.22	.79	.75	-.0349
0615	-	-	42.80	.79	-	-
0630	53.22	-	-	.79	.65	-
0645	-	-	52.18	.76	.65	-
0700	51.80	.53	44.50	.76	.55	-.1862
0730	46.80	.55	-	.76	-	-
0800	51.80	.62	53.80	.80	.65	.0450
0830	51.78	.53	58.65	.80	.70	.1619
0900	56.04	.57	55.86	.74	.58	-.0101
0930	51.85	.57	48.45	.73	.58	-.0860
1000	50.20	.53	55.25	.73	.58	.1250
1015	-	-	56.90	.74	.60	-
1030	54.78	.57	-	.68	-	-
1100	55.25	.57	57.80	.68	.60	.0676
1130	52.18	.55	55.80	.68	.58	.0944
1200	39.65	.43	53.80	.71	.57	.3523
1230	41.88	.43	55.60	.68	.55	.3471
1300	30.60	.33	55.62	.68	.58	.6275
1330	41.40	.43	47.95	.68	.50	.1664
1400	-	-	-	-	-	-
1415	-	-	-	-	-	-
1500	-	-	-	-	-	-

1. Grams water per 100 cu.ft. air.
2. Relative humidity, wet-dry bulb thermometer.
3. Relative humidity, calculated.

Air flow constant at 2.53 cu.ft.

Test No. 6 (Continued)

Time	Current	Gassing Current	Charging Current	Per Cent Charge	Per Cent Hydrogen	Gravity	Cell Resistance
0600	0-1050	0	1050	-	0	1081	.000200
0615	1050	0	1050	-	0	-	-
0630	1050	0	1050	-	0	-	.000121
0645	1050	0	1050	-	0	-	-
0700	1050	0	1050	-	0	1081	.000116
0730	1050	5	1045	-	.05	-	.000115
0800	1050	5	1045	48	.05	1082	.000116
0830	1050	7	1043	-	.07	-	.000119
0900	1050	8	1042	67	.08	1091	.000120
0930	1050	8	1042	-	.08	-	.000137
1000	1050	11	1039	-	.12	1109	.000163
1015	1050-330	18	1032	95	.20	-	.000179
1030	330	14	316	96	.15	-	-
1100	330	14	316	99	.15	1131	.000221
1130	330	28	302	103	.30	-	.000324
1200	330	185	145	104	2.00	1191	.000515
1230	330-200	278	52	105	3.00	1210	.000615
1300	200-100	166	34	105	1.30	1210	.000790
1330	100-50	101	0	105	1.10	-	.001030
1400	50	37	13	106	.40	-	.000800
1415	50-25	28	22	106	.30	-	.000920
1500	25-0	17	8	106	.18	-	.000400

Time	Voltages					
	1.	2.	3.	4.	5.	6.
0600	1.942	-	.928	-	1.018	-
0630	2.033	2.160	.948	1.043	1.076	1.117
0700	2.045	2.167	.955	1.048	1.078	1.119
0730	2.063	2.184	.966	1.060	1.086	1.126
0800	2.074	2.196	.970	1.064	1.093	1.135
0830	2.091	2.216	.971	1.063	1.108	1.155
0900	2.114	2.240	.962	1.053	1.129	1.190
0930	2.132	2.276	.948	1.043	1.153	1.235
1000	2.163	2.334	.948	1.082	1.153	1.153
1015	2.190	2.378	.953	1.120	1.195	1.267
1100	2.200	2.273	.963	1.042	1.210	1.232
1130	2.230	2.337	.979	1.092	1.230	1.251
1200	2.260	2.430	.996	1.151	1.246	1.282
1230	2.271	2.474	1.000	1.176	1.254	1.297
1300	2.268	2.426	1.000	1.141	1.252	1.284
1330	2.261	2.364	.997	1.096	1.250	1.264
1400	2.250	2.290	.990	1.044	1.235	1.245
1415	2.236	2.282	.990	1.041	1.234	1.242
1500	2.206	2.216	.987	.993	1.218	1.222

1. Voltage, open.
2. Voltage, closed.
3. Lead - mercurous sulphate, open.
4. Lead - mercurous sulphate, closed.
5. Lead peroxide - mercurous sulphate, open.
6. Lead peroxide - mercurous sulphate, closed.

Test No. 6 (Continued)

Time	Heating Effects			Cooling Effects			Net Effect	Temperature Rise Calculated/Found	
	1.	2.	3.	4.	5.	6.			
0600	3160	1827	0	-55	20	0	5020	-	-
0615	-	1827	0	-55	-	0	3850	-	-
0630	1911	1827	0	-55	-	0	3750	-	-
0645	-	1827	0	-44	-	0	3700	-	-
0700	1836	1827	0	-55	-108	0	3820	-	-
0730	1821	1818	264	-11	-	53	3850	-	-
0800	1836	1818	264	-22	26	53	3860	10°	6°
0830	1881	1815	370	-22	93	74	3920	-	-
0900	1896	1813	423	-11	-5	85	4070	4	4
0930	2167	1813	423	0	-45	85	4360	2	2
1000	2574	1808	582	0	69	116	4780	2.5	1
1015	2829	1795	952	0	-	190	5340	1.5	-
1030	-	550	740	0	-	148	4090	1.5	.5
1100	345	550	740	0	49	148	1440	.5	-
1130	506	526	1480	-22	54	296	2180	1	.5
1200	804	252	9780	-44	201	1956	8820	5	.5
1230	960	91	14690	-33	196	2938	12640	7	1
1300	453	59	8775	-33	353	1755	7210	4	.5
1330	148	0	5320	-22	90	1064	4340	2	-
1400	29	23	1955	-33	-	391	1560	1	-1
1415	33	38	1480	-33	-	296	1200	.25	-
1500	4	14	898	-22	-	180	670	.50	-1
							Total Effect	42.75°	14°

1. Irreversible heat.
2. Reversible heat, normal reaction.
3. Heat of formation of gases.
4. Radiation and convection to air.
5. Evaporation loss.
6. Reversible heat, water electrolysis.

Test No. 7

Bureau Procedure.
Discharge data.

Time	Temperatures Couple Numbers										
	1.	2.	18.	19.	20.	11.	4.	14.	15.	16.	17.
1030	82	81	85	83	86	84	85	84	84	85	83
1100	82	80	86	86	86	85	83	86	86	87	86
1130	81	80	87	86	86	84	82	86	86	87	86
1200	81	80	87	86	87	84	82	86	86	88	86
1230	79	79	88	86	87	84	82	86	86	88	86
1300	79	79	88	86	88	84	82	85	86	88	86
1330	79	79	88	87	88	84	82	86	86	88	86
1400	79	80	89	88	88	85	82	86	86	87	86
1430	80	80	88	88	88	86	82	87	87	88	86
1500	81	80	89	88	89	86	82	87	87	88	88
1530	81	81	89	88	89	86	82	88	88	88	88
1600	81	81	89	89	89	86	84	87	88	89	88

End of discharge

Time	Temperatures Couple Numbers									
	6.	12.	13.	5.	7.	9.	10.	Bath	Air	Duct at Gooseneck
1030	85	84	84	84	84	84	84	77	89	86
1100	84	85	86	83	83	85	82	75	88	88
1130	83	86	86	82	82	84	82	76	88	88
1200	82	86	86	82	82	84	82	72	91	89
1230	82	86	86	82	82	84	82	72	89	89
1300	82	85	85	82	82	84	81	83	89	89
1330	82	84	85	82	82	84	82	81	88	89
1400	82	85	86	82	82	84	82	82	88	89
1430	82	86	86	82	82	84	82	82	87	89
1500	83	86	86	83	83	86	83	81	87	89
1530	84	86	86	84	84	86	86	81	86	89
1600	84	86	86	84	84	86	84	80	86	89

Time	Voltages		
	1.	2.	3.
1030	1.934	1.023	.903
1100	1.940	1.029	.911
1130	1.928	1.025	.903
1200	1.917	1.020	.897
1230	1.894	1.010	.885
1300	-	-	-
1330	1.876	1.000	.875
1400	1.858	.992	.866
1430	1.837	.982	.854
1500	1.811	.973	.841
1530	1.785	.962	.822
1600	1.756	.952	.803
-	-	-	-
1605	1.903	.993	.913

Voltages

1. Cell Voltage
2. Lead - mercurous sulphate
3. Lead peroxide - mercurous sulphate

All voltages on closed circuit with exception of 1605 data

Current constant at 850 amperes

Test No. 7 (continued)

Time	Temperatures Couple Groups									
	1.	2.	3.	4.	5.	6.	7.	Air Bath		Duct at Gooseneck
0600	74	79	76	75	79	77	76	80	76	81
0615	74	81	77	75	82	79	76	83	80	82
0630	75	82	79	75	82	82	78	83	80	83
0645	75	84	79	77	83	83	80	84	80	85
0700	75	85	81	77	85	86	81	85	80	86
0730	75	88	82	79	87	83	83	85	80	87
0800	76	90	86	82	89	90	86	86	81	89
0830	78	92	86	86	91	92	89	87	81	89
0900	79	94	89	89	95	95	90	83	82	89
0910	-	-	-	-	-	-	-	-	82	89
0930	81	94	90	93	94	97	92	82	82	89
0945	-	-	-	-	-	-	-	-	82	89
1000	84	94	92	94	95	98	94	82	82	89
1030	86	93	93	92	94	98	93	83	79	89
1040	-	-	-	-	-	-	-	-	79	89
1100	88	92	91	96	93	97	93	82	78	88
1130	88	91	91	96	93	96	93	82	79	88
1200	86	91	89	96	93	95	92	82	79	88
1230	86	91	90	95	92	95	91	82	80	88
1300	86	92	90	93	92	94	91	82	81	88
1330	86	91	91	91	92	93	90	83	86	88
1400	85	90	90	89	91	93	89	83	81	87
1430	85	91	89	89	91	93	89	83	82	87
1500	85	89	89	89	90	91	89	84	79	88
1530	85	89	88	87	89	90	88	83	79	86

1. Electrolyte below elements
2. Electrolyte above elements
3. Between cell jar and elements
4. Bottom of elements
5. Top part of elements
6. Center group
7. Edge of elements

Test No. 7 (continued)

Time	Air at Intake		Air in Duct			Evaporation
	1.	3.	1.	2.	3.	gm. per minute
0600	-	-	51.55	.80	.72	-
0615	47.30	.60	-	.76	-	-
0630	-	-	54.35	.72	.75	-
0645	54.90	.65	-	.76	-	-
0700	-	-	57.20	.73	.70	-
0730	50.10	.60	45.85	.74	.55	-.0922
0800	52.95	.63	56.65	.66	.67	.0803
0830	54.65	.65	53.80	.73	.65	-.0184
0900	55.20	.65	56.05	.80	.67	.0184
0910	47.55	-	-	-	-	-
0930	46.15	.60	43.60	.88	.55	-.0553
0945	42.48	-	-	.92	-	-
1000	46.15	.60	61.25	.88	.73	.3278
1030	-	-	60.90	.88	.73	-
1040	43.90	-	-	-	-	-
1100	50.95	.60	62.85	.84	.75	.2583
1130	41.05	.55	59.45	.84	.72	.3993
1200	50.95	.60	59.20	.84	.72	.1790
1230	48.13	.60	61.70	.84	.73	.2945
1300	35.40	.50	59.45	.84	.72	.5220
1330	-	-	37.65	.88	.45	-
1400	43.30	.55	53.80	.88	.63	.2278
1430	49.55	.60	33.98	.88	.42	-.3420
1500	-	-	-	-	-	-
1530	-	-	-	-	-	-

1. Grams water per 100 cu. ft. air
2. Relative Humidity, Wet-dry Bulb Thermometer
3. Relative Humidity, Calculated

Air Flow constant at 2.53 cu.ft.

Test No. 7 (continued)

Time	Current	Charging Current	Gassing Current	Hydrogen Percentage	Percent Charge	Gravity	Cell Resistance
0600	0-1300	1300	0	0	-	1086	.000184
0615	1300	1300	0	0	-	-	-
0630	1300	1300	0	0	-	-	-
0645	1300	1300	0	0	-	-	-
0700	1300	1300	0	0	-	1083	.000112
0730	1300	1297	3	.03	-	-	-
0800	1300	1292	8	.08	.56	1088	.000115
0830	1300	1291	9	.10	-	-	.000120
0900	1300	1289	11	.12	.83	-	.000140
0910	1300-1050	1286	14	.15	.88	1105	-
0930	1050-800	1031-786	19-14	.20-.15	.95	-	.000172
0945	800-550	767	33	.35	.99	-	.000206
1000	550-330	503-316	47-14	.50-.15	1.01	1139	.000238
1030	330-250	259-231	71-19	.75-.20	1.04	-	.000409
1040	250-190	156	94	1.00	1.05	-	.000508
1100	190-165	98	92	.99	1.06	1182	.000626
1130	165	44	121	1.30	1.06	-	.000794
1200	165	27	138	1.48	-	1205	.000855
1230	165	16	149	1.60	-	-	.000867
1300	165-100	25	140	1.50	1.07	1214	.000788
1330	100-50	11	89	.95	-	-	.00106
1400	50	8	42	.45	-	-	.00120
1430	50-25	12	38	.40	-	-	.00116
1500	25	8	17	.18	-	-	.000720
1530	25-0	8-0	17	.18	-	-	.000760

Test No. 7 (continued)

Time	Voltages					
	1.	2.	3.	4.	5.	6.
0600	1.942	2.181	.927	1.060	1.016	1.138
0615	-	-	-	-	-	-
0630	-	-	-	-	-	-
0645	-	-	-	-	-	-
0700	2.055	2.200	.927	.960	1.082	1.130
0730	-	-	-	-	-	-
0800	2.096	2.245	.976	1.090	1.106	1.160
0830	2.126	2.282	.967	1.080	1.130	1.204
0900	2.148	2.330	.960	1.185	1.165	1.248
0910	-	-	-	-	-	-
0930	2.174	2.355	.955	1.100	1.191	1.260
0945	2.205	2.370	.965	1.112	1.212	1.263
1000	2.227	2.358	.976	1.115	1.224	1.260
1030	2.242	2.377	.993	1.117	1.240	1.270
1040	2.253	2.380	.997	1.118	1.247	1.270
1100	2.248	2.367	.997	1.105	1.241	1.262
1130	2.254	2.385	1.000	1.120	1.252	1.271
1200	2.255	2.396	.998	1.130	1.250	1.275
1230	2.257	2.400	.998	1.124	1.250	1.280
1300	2.276	2.406	.998	1.126	1.255	1.280
1330	2.258	2.364	.995	1.097	1.252	1.270
1400	2.238	2.298	.990	1.055	1.247	1.236
1430	2.242	2.300	.990	1.050	1.238	1.250
1500	2.214	2.232	.984	1.005	1.220	1.225
1530	2.209	2.228	.982	1.005	1.220	1.224

1. Voltage - open
2. Voltage - closed
3. Lead-mercurous sulphate, open
4. Lead-mercurous sulphate, closed
5. Lead peroxide - mercurous sulphate, open
6. Lead peroxide - mercurous sulphate, closed

Test No. 7 (continued).

Time	Heating Effects			Cooling Effects			Net	Temp. Rise	
	1.	2.	3.	4.	5.	6.	Effect	Cal.	Found
0600	4454	2262	0	9	-	0	6600	-	-
0615	-	2262	0	-9	-	0	4970	-	-
0630	-	2262	0	0	-	0	4960	-	-
0645	-	2262	0	9	-	0	4950	-	-
0700	2701	2262	0	9	-	0	4950	-	-
0730	-	2257	159	18	-53	32	5100	-	-
0800	2778	2248	423	27	46	85	5290	11°	10°
0830	2908	2247	476	18	-11	95	5530	-	-
0900	3393	2244	581	36	11	116	6050	6	4
0910	-	2239	740	-	-	148	4750	-	-
0930	2724-2075	1794-1368	1040-740	63	-33	208-148	5320-4000	3	-
0945	1892-1300	1335	1744	-	-	349	4480	-	-
1000	1033-620	876-550	2484-740	63	189	497-148	3640-1510	1	2
1030	638-484	451-402	3751-1040	54	-	750-208	3870-1500	2	-
1045	455-346	272	4966	-	-	993	4480-4370	2	-
1100	324-282	171	4860	54	150	972	4180-4130	1	0
1130	310	77	6395	54	230	1279	5220	-	-
1200	334	47	7290	54	104	1458	6040	6	-1
1230	338	28	7885	54	169	1575	6440	-	-
1300	308-186	44	7399	54	302	1480	5920-5790	6	0
1330	152-76	19	4701	45	-	940	3670-3600	4	-
1400	43	14	2220	36	132	440	1660	-	-2
1430	42-21	21	2008	36	-195	402	1820	2	-
1500	6	14	898	36	-	180	900	-	-
1530	7	14	898	45	-	180	900	1	-2
						total effect		45°	11°

1. Irreversible Heat
2. Reversible Heat Normal Reaction
3. Heat of Formation of Gases
4. Radiation and Convection to Air
5. Evaporation Loss
6. Reversible Heat, Water Formation

Test No. 8.

Overcharge data.

Time	Temperatures									
	Couple Groups									Duct at
	1.	2.	3.	4.	5.	6.	7.	Air	Bath	Gooseneck
0830	85	85	85	86	85	85	85	80	84	82
0900	86	86	86	86	86	86	86	81	90	84
0915	86	87	87	87	87	87	87	82	90	86
0930	86	89	88	88	89	89	89	82	90	86
0945	86	89	89	89	89	89	89	82	90	86
1000	87	89	89	89	89	89	89	82	89	87
1015	87	90	89	89	90	89	89	84	89	89
1030	-	-	-	-	-	-	-	-	-	-
1045	87	92	90	91	92	91	91	84	89	89
1100	88	93	92	92	93	93	92	84	89	89
1130	89	94	94	94	94	94	93	83	89	89
1145	-	-	-	-	-	-	-	-	-	-
1200	89	94	93	94	94	94	94	84	89	89
1215	-	-	-	-	-	-	-	-	-	-
1230	90	94	94	94	94	95	94	84	89	89
1300	91	94	94	94	95	95	94	83	90	90
1330	91	94	94	94	94	95	94	82	90	89
1345	-	-	-	-	-	-	-	-	-	-
1400	91	94	94	94	95	95	94	83	90	89
1415	-	-	-	-	-	-	-	-	-	-
1445	92	94	94	94	94	95	94	82	90	89
1530	91	93	93	93	94	94	93	82	90	89

1. Electrolyte below elements.
2. Electrolyte above elements.
3. Between jar and elements.
4. Bottom of elements.
5. Top of elements.
6. Center group.
7. Group near edge.

Air flow, 2.53 cu.ft. per minute.

Test No. 8 (Continued)

Time	Current	Charging Current	Gassing Current	Hydrogen Percentage	Cell Resistance
0830	0	0	0	0	-
0900	0-300	84	216	2.30	.000707
0915	300	84	216	2.30	.000713
0930	300-250	28	272	2.90	.000660
0945	250	11	239	2.55	.000712
1000	250	11	239	2.55	.000704
1015	250	0	251	2.70	.000776
1030	250	0	251	2.70	.000680
1045	250	0	256	2.75	-
1100	250	0	260	2.80	.000696
1130	250-150	0	258	2.75	.000680
1145	150	28	122	1.30	.000840
1200	150	11	139	1.50	.000840
1215	150	9	141	1.55	.000840
1230	150-100	20-7	130-93	1.40-1.00	.000827
1300	100	25	75	.80	.000720
1330	100	16	84	.90	.000980
1345	100-50	6	94	1.00	.001030
1400	50	-	-	-	-
1415	50	9	41	.45	.000920
1445	50-25	10	40	.43	.001180
1530	25-0	6	19	.20	.000560

Time	Voltages					
	1.	2.	3.	4.	5.	6.
0900	2.072	2.284	1.106	1.195	.966	1.140
0915	2.258	2.472	1.258	1.304	1.000	1.175
0930	2.288	2.486	1.265	1.300	1.000	1.180
0945	2.292	2.470	1.266	1.302	1.000	1.170
1000	2.287	2.463	1.265	1.300	1.000	1.165
1015	2.278	2.472	1.261	1.300	.996	1.170
1030	2.298	2.468	1.251	1.300	.987	1.168
1045	-	-	-	-	-	-
1100	2.295	2.469	1.254	1.301	.995	1.169
1130	2.290	2.460	1.262	1.298	1.000	1.162
1145	2.274	2.400	1.252	1.278	.996	1.120
1200	2.280	2.406	1.256	1.280	.997	1.126
1215	2.280	2.406	1.256	1.280	.996	1.127
1230	2.280	2.404	1.256	1.279	.996	1.122
1300	2.281	2.353	1.251	1.265	.997	1.090
1330	2.265	2.363	1.247	1.268	.991	1.090
1345	2.270	2.373	1.248	1.272	.993	1.104
1400	-	-	-	-	-	-
1415	2.253	2.299	1.237	1.250	.990	1.052
1445	2.246	2.305	1.237	1.247	.989	1.050
1530	2.221	2.235	1.234	1.228	.977	1.013

1. Voltage, open.
2. Voltage, closed.
3. Lead - mercurous sulphate, open.
4. Lead - mercurous sulphate, closed.
5. Lead peroxide - mercurous sulphate, open.
6. Lead peroxide - mercurous sulphate, closed.

Test No. 8 (Continued)

Time	Heating Effects			Cooling Effects			Net Effect	Temp. Rise Calc./Found	
	1.	2.	3.	4.	5.	6.			
0900	912	146	11410	50*	150*	2738	9530	-	-
0915	920	146	11410	50	150	2738	9540	-	-
0930	852	49	14370	50	150	3449	11620	5°	4°
0945	638	19	12625	50	150	3030	10030	-	-
1000	631	19	12625	50	150	3030	10050	5	1
1015	695	0	13210	50	150	3170	10530	-	-
1030	609	0	13210	50	150	3170	10450	5	-
1045	-	0	13525	50	150	3246	10700	-	-
1100	624	0	13735	50	150	3296	10860	5	-
1130	609	0	13630	50	150	3271	10770	5	5
1145	271	49	6445	50	150	1547	5020	-	-
1200	271	19	7342	50	150	1762	5700	-	-
1215	271	16	7449	50	150	1788	5750	-	-
1230	267	35-12	6870-4912	50	150	1649-1178	5320-3810	6	1
1300	103	44	3962	50	150	950	2860	-	-
1330	140	28	4438	50	150	1065	3340	-	-
1345	148	10	4965	50	150	1192	3730	5	0
1400	-	-	-	50	150	-	-	-	-
1415	33	14	2219	50	150	533	1530	-	-
1445	42	17	2113	50	150	507	1470	1.5	0
1530	5	10	1103	50	150	241	580	0	-.5
	* Est.						Total Effect	37°	10.5°

1. Irreversible heat.
2. Reversible heat, normal reaction.
3. Heat of formation of gases.
4. Radiation and convection to air.
5. Evaporation loss.
6. Reversible heat, water formation.

Test No. 9.

Bureau Procedure.
Discharge Data.

Time	Temperatures Couple Groups									Duct at
	1.	2.	3.	4.	5.	6.	7.	Bath	Air	Gooseneck
0830	94	96	94	94	96	95	94	94	84	95
0900	94	97	95	94	96	95	94	94	84	89
0930	93	96	94	94	95	94	94	93	87	89
1000	93	94	94	93	94	94	93	93	85	90
1100	93	96	95	93	96	94	93	93	85	90
1130	93	96	95	94	96	95	94	93	85	90
1215	93	96	95	94	96	95	94	93	85	90
1300	93	96	96	94	96	95	94	93	87	92
1330	93	97	96	94	96	95	94	93	87	91
1400	93	97	96	94	96	96	95	93	86	91

Couple Groups.
1. Electrolyte below elements.
2. Electrolyte above elements.
3. Between jar and elements.
4. Bottom of elements.
5. Top part of elements.
6. Center group.
7. Group near edge.

Time	Voltages			Current
	1.	2.	3.	
0830	2.060-1.994	1.094-1.030	.966-.918	0-850
0900	1.946	1.034	.911	850
0930	1.937	1.035	.910	850
1000	1.925	1.022	.904	850
1100	1.894	1.013	.890	850
1130	1.890	1.006	.884	850
1215	1.866	.995	.870	850
1300	1.831	.988	.851	850
1330	1.803	.970	.835	850
1400	1.772	.966	.812	850-0

1. Cell Voltage
2. Lead peroxide-mercury mercurous sulphate
3. Lead-mercury-mercurous sulphate

Test No. 9 (Continued).

Time	Temperatures Couple Groups 1.	2.	3.	4.	5.	6.	7.	Air	Bath	Duct at Gooseneck
0600	101	97	99	103	99	101	100	78	100	75
0615	101	100	101	103	100	103	101	80	100	86
0630	101	100	103	104	102	104	101	81	100	86
0645	101	101	104	105	103	106	103	81	100	87
0700	100	102	105	105	104	106	104	82	100	87
0730	101	104	106	106	105	108	106	83	100	89
0800	101	106	107	109	107	110	108	85	100	92
0830	101	110	110	112	111	113	110	87	101	96
0900	102	110	110	113	110	114	110	88	101	96
0930	104	110	111	115	110	116	111	88	101	96
0945	-	-	-	-	-	-	-	-	-	-
1000	108	109	110	117	110	115	111	87	100	96
1030	110	109	110	116	110	115	110	86	100	96
1050	-	-	-	-	-	-	-	-	-	-
1100	108	109	108	115	110	114	109	86	100	94
1130	106	110	108	113	110	113	107	86	100	94
1200	106	110	109	110	111	112	107	86	100	94
1230	105	110	109	109	111	111	108	86	100	94
1300	103	110	108	108	110	110	107	85	100	93
1345	103	108	106	106	109	109	105	86	100	93
1430	102	106	106	105	106	106	106	85	100	92
1510	101	107	107	106	107	108	106	85	100	90

1. Electrolyte below elements.
2. Electrolyte above elements.
3. Between elements and cell jar.
4. Bottom of elements.
5. Top of elements.
6. Center group.
7. Group near edge.

Test No. 9 (continued)

Time	Current	Charging Current	Gassing Current	Hydrogen Percentage	Percent Charge	Gravity	Cell Resistance
0600	0-1300	1300	0	0	-	1090	.000167
0615	-	-	0	0	-	-	-
0630	1300	1300	0	0	-	-	-
0645	-	-	0	0	-	-	-
0700	1300	1294	6	.08	28	1093	.000106
0730	-	1294	6	.08	41	-	-
0800	1300	-	-	-	-	1100	.000107
0830	1300	1291	9	.11	67	-	-
0900	1300-1050	1285	15	.19	-	1124	.000128
0930	1050-800	1018	32	.20	-	-	.000160
0945	800-550	776	24	.30	99	-	.000168
1000	550-330	526	24	.30	102	-	.000200
1030	330-250	290	40	.50	106	-	.000291
1050	250-190	195	55	.70	107	-	.000436
1100	190-165	143	47	.60	107	1200	.000484
1130	165	98	67	.85	108	-	.000631
1200	165	94	71	.90	109	1216	.000661
1230	165-100	86	79	1.00	110	-	.000643
1300	100-50	53	47	.60	111	-	.000780
1345	50-25	26-13	24-12	.30-.15	-	-	.000700
1430	25-350	13	12	.15	-	-	.000160
1510	350-0	-	-	-	-	-	.000491

Time	Air at Intake		Air in Duct			Evaporation
	1.	3.	1.	2.	3.	grams per minute
0600	-	-	40.78	.83	.57	.3070
0615	26.60	.38	-	.75	-	-
0630	-	-	40.80	.66	.57	-
0645	30.80	.47	-	.66	-	.3070
0700	32.00	.40	35.70	.63	.43	.8015
0730	-	-	34.85	.63	.43	-
0800	26.30	.33	44.75	.62	.40	.3990
0830	-	-	39.20	.57	.35	-
0900	32.00	.35	50.50	.57	.45	.4015
0930	29.70	.35	-	.57	-	-
0945	-	-	-	-	-	-
1000	32.55	.35	54.00	.63	.47	.4660
1030	29.70	.35	55.80	.75	.50	.5660
1050	-	-	62.60	-	-	-
1100	34.00	.40	48.25	.79	.43	.3090
1130	31.70	.37	56.65	.79	.47	.5400
1200	34.55	.43	66.80	.82	.60	.7000
1230	33.40	.40	-	.85	-	-
1300	31.15	.37	64.50	.82	.58	.7260
1345	-	-	-	-	-	-

1. Grams water per 100 cu. ft. air
2. Relative humidity, Wet-dry bulb thermometer
3. Relative Humidity, calculated

Test No. 10.

Bureau Procedure.
Discharged at 4675 ampere-hours.

Time	Temperatures Couple Groups									
	1.	2.	3.	4.	5.	6.	7.	Air	Bath	Duct at Gooseneck
0600	37	47	37	38	44	41	37	79	34	67
0615	38	49	40	41	47	42	40	80	34	69
0630	38	51	41	41	48	45	41	80	34	71
0645	38	52	42	42	48	47	42	80	34	72
0700	38	55	44	43	51	50	44	81	35	72
0730	38	57	47	47	55	54	47	82	37	75
0800	38	59	48	48	56	57	50	83	34	75
0830	38	61	52	53	57	60	52	81	34	75
0900	39	63	53	58	62	65	57	80	34	75
0908	-	-	-	-	-	-	-	80	34	75
0915	-	-	56	-	-	-	-	80	34	75
0935	41	64	55	62	62	67	56	81	36	75
1000	43	64	55	64	62	67	60	82	34	74
1030	44	61	55	64	61	67	59	81	34	73
1045	-	-	55	-	-	-	-	81	34	73
1100	45	60	55	62	61	65	59	80	34	73
1107	-	-	54	-	-	-	-	80	34	73
1130	46	58	54	61	60	65	57	80	34	72
1200	44	57	55	61	58	63	57	81	34	72
1230	44	56	54	61	57	62	56	83	34	72
1300	44	56	54	58	56	60	56	81	34	72
1330	43	56	54	56	56	59	54	81	34	72
1415	43	56	54	52	56	56	52	83	34	72
1500	42	56	48	50	55	55	48	83	34	73
1545	42	51	51	54	52	55	52	83	34	70

1. Electrolyte below elements.
2. Electrolyte above elements.
3. Between jar and elements.
4. Bottom of elements.
5. Top part of elements.
6. Center group.
7. Group near edge.

Time	Air at Intake		Air in Duct			Evaporation - gm. per minute.
	1.	3.	1.	2.	3.	
0600	34.55	.50	-	.65	-	-
0615	-	-	31.72	.63	.53	-
0630	33.98	.50	-	.63	-	-
0645	-	-	29.45	.63	.50	.0308
0700	33.13	.48	34.55	.60	.60	-.0065
0730	35.70	.57	35.40	.58	.60	.0738
0800	28.32	.43	31.72	.58	.53	-.0184
0830	33.13	.50	32.28	.57	.55	.0738
0900	32.28	.45	35.68	.57	.57	-
0908	-	-	-	-	-	-
0915	-	-	-	.58	-	-.1107
0935	34.55	.47	29.45	.58	.50	-.0493
1000	33.42	.45	31.15	.58	.53	-
1030	31.15	.45	-	.58	-	-
1045	-	-	33.98	.58	.55	0
1100	35.68	.50	35.68	.58	.58	-

Test No. 10 (Continued)

Time	Air at Intake		Air in Duct			Evaporation
	1.	3.	1.	2.	3.	gm. per minute
1107	-	-	-	-	-	-.0616
1130	37.67	.53	34.83	.58	.58	-.1167
1200	35.68	.50	30.30	.61	.50	-.0369
1230	34.83	.50	33.13	.61	.55	-.0247
1300	35.97	.50	34.83	.61	.58	-
1330	32.57	.47	-	.61	-	-

1. Grams water per 100 cu.ft. air.
2. Relative humidity, wet-dry bulb thermometer.
3. Relative humidity, calculated.

Time	Current	Charging Current	Gassing Current	Per cent Charge	Percent Hydrogen	Gravity	Cell Resistance
0600	0-1300	1300	0	-	0	1080	.000227
0615	1300	1300	0	-	0	-	-
0630	1300	1300	0	-	0	-	-
0645	1300	1300	0	-	0	1080	-
0700	1300	1300	0	-	0	-	.000150
0730	1300	1300	0	-	0	1081	-
0800	1300	1300	0	56	0	-	.000167
0830	1300	1296	4	69	.05	-	-
0900	1300	-	-	80	-	1104	.000228
0908	1300-1050	1288	12	87	.15	-	-
0915	1050-800	1038	12	90	.15	-	-
0935	800-550	784	16	95	.20	-	.000271
1000	550-330	526	24	101	.30	1144	.000346
1030	330-250	290	40	104	.50	-	.000533
1045	250-190	214	36	105	.45	-	-
1100	-	-	-	-	-	-	.000784
1107	190-165	153	37	108	.45	1185	-
1130	165-	125	40	108	.50	-	.000994
1200	165	112	53	108	.65	1205	.001024
1230	165	100	65	109	.80	1210	.001091
1300	165-100	100	65	110	.80	1214	.001115
1330	100-50	55	45	-	.55	-	.001540
1415	50-25	33	17	-	.21	-	.001800
1500	25-250	18	7	-	.09	-	.000880
1545	250-0	120	130	-	1.60	-	.000948

Time	Voltages					
	1.	2.	3.	4.	5.	6.
0600	1.940	2.235	.928	1.074	1.013	1.168
0700	2.092	2.287	.971	1.117	1.114	1.176
0800	2.131	2.348	.972	1.126	1.145	1.224
0900	2.200	2.496	.960	1.283	1.224	1.317
0935	2.258	2.475	.973	1.180	1.255	1.310
1000	2.280	2.470	.988	1.168	1.270	1.307
1030	2.300	2.476	.996	1.172	1.282	1.307
1100	2.296	2.445	.995	1.150	1.280	1.300
1130	2.300	2.464	1.003	1.160	1.290	1.308
1200	2.310	2.479	1.002	1.167	1.293	1.310

Test No. 10 (Continued)

Time	Voltages					
	1.	2.	3.	4.	5.	6.
1230	2.310	2.490	1.005	1.174	1.295	1.310
1300	2.316	2.500	1.005	1.182	1.298	1.325
1330	2.326	2.480	1.014	1.157	1.302	1.320
1415	2.327	2.417	1.017	1.122	1.293	1.304
1500	2.290	2.312	1.010	1.040	1.274	1.277
1545	2.365	2.102	1.050	1.250	1.318	1.340

1. Voltage - open.
2. Voltage - closed.
3. Lead - mercurous sulphate, open.
4. Lead - mercurous sulphate, closed.
5. Lead peroxide - mercurous sulphate, open.
6. Lead peroxide - mercurous sulphate, closed.

Time	Heating Effects			Cooling Effects			Net Effect	Temperature Rise	
	1.	2.	3.	4.	5.	6.		Calc.	Found
0600	5495	2262	0	-120	-	0	7637	-	-
0615	-	2262	0	-110	-	0	6152	-	-
0630	-	2262	0	-90	-	0	6172	-	-
0645	-	2262	0	-80	-	0	6182	-	-
0700	3634	2262	0	-90	18	0	5788	-	-
0730	-	2262	0	-70	-4	0	6000	-	-
0800	4043	2262	0	-80	43	0	6182	12°	13°
0830	-	2255	211	-60	-11	42	7075	-	-
0900	5515	-	-	-50	43	-	8067	-	-
0908	-	2242	634	-	-	127	7200	9	9
0915	-	1807	634	-	-	127	5500	-	-
0935	2488-1711	1364	845	-60	-64	169	4532-3755	3	2
1000	1498-898	915	1268	-80	28	254	3375-2775	1.5	0
1030	832-631	504	2113	-80	-	423	2949-2748	1.5	-.5
1045	-	372	1902	-	-	380	2374	-	-
1100	406	-	-	-20	0	-	2374	-	-
1107	-	266	1955	-	-	391	2168	-	-
1130	388	218	2113	-60	-36	423	2272	2.5	-2
1200	400	195	2800	-90	-67	560	2812	-	-
1230	426	174	3435	-110	-21	687	3259	-	-
1300	435-264	174	3435	-90	-14	686	381-3110	5	-2
1330	221-110	96	2378	-90	-	476	2135-2024	1.5	0
1415	64-32	57	898	-110	-	180	739-707	.25	-1
1500	8-79	31	370	-100	-	74	240-310	1	-1
1545	850	209	6870	-130	-	1574	6230	5	2
						Total effect		42.25°	19.5°

1. Irreversible heat.
2. Reversible heat, normal reaction.
3. Heat of formation of gases.
4. Radiation and convection to air.
5. Evaporation loss.
6. Reversible heat water electrolysis.

Air flow 2.17 cu.ft. per minute.

Test No. 11.

Overcharge data.

Time	Temperatures Couple Groups									
	1.	2.	3.	4.	5.	6.	7.	Air	Bath	Duct at Gooseneck
0830	38	47	36	37	44	40	37	77	35	72
0900	37	44	35	37	44	40	36	79	34	68
0930	36	41	41	41	41	41	41	79	34	65
1000	36	42	42	42	42	42	42	80	35	65
1030	36	43	42	44	42	44	43	84	34	67
1100	39	46	44	47	45	47	45	82	35	69
1130	39	47	45	46	46	47	46	82	35	69
1200	40	47	42	47	47	47	46	82	37	69
1230	39	47	45	44	46	47	45	86	34	17
1300	39	47	45	43	47	47	45	84	34	17
1330	39	47	45	42	47	46	44	84	35	72
1400	38	48	44	41	47	47	43	84	36	72
1415	-	-	-	-	-	-	-	-	-	-
1500	39	47	47	47	47	48	47	86	34	70
1545	40	51	50	51	51	51	50	86	35	71

Time	Current	Gassing Current	Hydrogen Percentage	Cell Resistance (calculated)
0830	0	0	-	-
0900	0-250	10	0-1.20	.00154
0930	250	135	1.65	.00100
1000	250-200	138	1.70	.00100
1030	200-150	94	1.15	.00110
1100	150-100	73	0.90	.00135
1130	100	42	0.52	.00179
1200	100-50	44	0.54	.00171
1230	50	23	0.28	.00256
1300	50-25	20	0.25	.00266
1330	25	10	0.12	.00324
1400	25	-	-	-
1415	25-250	10	0.12	.00052
1500	250-330	114	1.40	.00097
1545	330-0	161	2.00	.00083

Couple Groups

1. Irreversible heat.
2. Reversible heat, normal reaction.
3. Heat of formation of gases.
4. Radiation and convection to air.
5. Evaporation losses.
6. Reversible heat, water electrolysis.

Air flow, 2.17 cuft. per minute.

Test No. 11 (Continued)

Time	Voltages					
	1.	2.	3.	4.	5.	6.
0830	-	-	-	-	-	-
0900	2.124	2.508	.968	1.227	1.155	1.322
0930	2.378	2.627	1.013	1.263	1.334	1.367
1000	2.382	2.632	1.024	1.265	1.327	1.368
1030	2.368	2.587	1.022	1.237	1.323	1.354
1100	2.371	2.573	1.025	1.224	1.323	1.350
1130	2.351	2.530	1.017	1.197	1.314	1.336
1200	2.361	2.532	1.022	1.199	1.317	1.337
1230	2.335	2.463	1.009	1.148	1.308	1.317
1300	2.332	2.465	1.012	1.146	1.303	1.316
1330	2.308	2.329	1.008	1.097	1.287	1.293
1400	-	-	-	-	-	-
1415	2.303	2.316	1.009	1.102	1.290	1.297
1500	2.383	2.625	1.020	1.261	1.321	1.365
1545	2.380	2.654	1.026	1.280	1.325	1.373

Voltages.

1. Voltage - open.
2. Voltage - closed.
3. Lead - mercurous sulphate, open.
4. Lead - mercurous sulphate, closed.
5. Lead peroxide - mercurous sulphate, open.
6. Lead peroxide - mercurous sulphate, closed.

Time	Heating Effects						Net	Temperature Rise	
	1.	2.	3.	4.	5.	6.	Effect	Calculated	Found
0830	-	-	-	n	n	-	-	-	-
0900	1375	418	529	e	e	110	2572	-	-
0930	893	200	7118	g	g	1424	6787	5.5°	0
1000	893	195	7290	l	l	1458	6920	4	1
1030	628	184	4968	i	i	994	4786	2.5	1
1100	434	134	3858	g	g	772	3654	2	3
1130	256	101	2219	i	i	444	2132	1.2	-
1200	245	97	2325	b	b	465	2200	1.2	.5
1230	92	47	1215	l	l	243	1110	-	-
1300	95	52	1057	e	e	211	1000	1	-.5
1330	29	26	529			110	474	-	-
1400	-	26	-			-	-	-	-
1415	5	26	529			110	450	-	-.5
1500	852	237	6025			1205	5950	5	3
1545	1168	294	8504			1701	8268	7	3
							Total effect	30°	10.5°

1. Irreversible heat.
2. Reversible heat, normal reaction.
3. Heat of formation of gases.
4. Radiation and convection to air.
5. Evaporation loss.
6. Reversible heat, water electrolysis.

Test No. 12.

Manufacturer's Procedure.
Discharged at 4675 ampere-hours.

Discharge data.

Time	Temperatures Couple Numbers												
	1.	2.	18.	20.	11.	4.	14.	15.	16.	17.	6.	12.	13.
1000	38	38	44	44	43	41	43	43	44	44	42	43	43
1030	38	37	45	45	43	41	44	44	44	44	42	43	43
1100	38	37	47	47	44	41	44	44	46	46	41	44	44
1130	38	37	47	47	44	41	45	46	47	47	41	44	44
1200	38	37	48	48	44	41	46	47	47	47	41	44	45
1230	38	37	49	49	44	41	46	47	48	47	42	45	45
1300	38	37	50	50	44	41	47	47	49	47	42	45	47
1330	38	38	51	50	45	42	47	48	49	48	42	45	47
1400	38	37	51	51	45	42	47	48	50	49	42	46	47
1430	37	37	51	51	45	42	47	49	50	49	42	47	47
1515	37	37	52	51	47	42	47	50	51	50	43	47	47
1530	37	37	52	52	47	42	48	51	51	50	44	47	48

Time	Temperatures Couple Numbers					Duct at	Voltages	
	5.	7.	9.	Bath	Air	Gooseneck	1.	2.
1000	42	42	43	35	75	65	2.252-1.931	.980-.896
1030	41	41	43	35	76	68	1.923	.900
1100	41	41	43	37	75	73	1.911	.890
1130	41	41	43	35	76	75	1.901	.884
1200	41	41	43	36	76	75	1.887	.875
1230	41	42	43	37	76	75	1.873	.868
1300	41	42	44	35	76	75	1.855	.858
1330	41	42	44	37	76	75	1.836	.848
1400	42	42	44	37	79	75	1.816	.838
1430	42	42	44	35	78	75	1.783	.818
1515	42	43	45	37	78	75	1.725	.781
1530	42	43	45	36	78	75	1.689	.752

Time	Voltages 3.
1000	1.270-1.031
1030	1.027
1100	1.021
1130	1.017
1200	1.010
1230	1.005
1300	.998
1330	.988
1400	.978
1430	.963
1515	.944
1530	.935

Voltages.
1. Lead-lead peroxide, closed.
2. Lead - mercurous sulphate, closed.
3. Lead peroxide - mercurous sulphate, closed.

Current constant at 850 amperes.
Cell overcharged for 50 minutes at 250 amperes, before start of discharge.

Test No. 12 (Continued)

Charge data.

Time	Temperatures Couple Groups									Duct at Gooseneck
	1.	2.	3.	4.	5.	6.	7.	Air	Bath	
0600	40	47	39	40	44	41	39	76	37	65
0615	40	48	40	40	47	42	40	71	35	66
0630	40	49	40	40	48	44	41	72	36	67
0645	39	50	41	41	48	45	42	70	36	66
0700	39	48	42	42	49	46	42	71	37	67
0730	39	54	44	43	51	50	45	73	36	68
0800	39	44	47	45	52	51	46	71	37	68
0830	39	56	47	47	55	54	49	72	37	68
0900	39	58	48	50	55	55	50	71	36	68
0930	40	59	50	52	57	59	52	71	37	68
1000	41	61	52	58	58	62	56	72	37	68
1015	-	-	-	-	-	-	-	-	-	-
1030	44	60	52	58	59	62	56	72	38	68
1100	45	57	53	58	58	62	56	72	36	68
1130	47	56	54	61	58	62	51	72	37	67
1200	47	56	55	61	58	62	58	73	36	67
1230	47	57	56	61	59	62	58	74	38	68
1300	47	58	56	59	59	62	58	76	35	68
1330	47	57	55	59	58	60	58	75	35	68
1345	-	-	-	-	-	-	-	78	35	69
1400	46	57	54	57	57	60	56	76	35	69
1430	45	56	53	55	56	58	54	76	35	69
1500	44	56	51	53	56	57	51	76	35	70

Couple Groups.

1. Electrolyte below elements.
2. Electrolyte above elements.
3. Between jar and elements.
4. Bottom of elements.
5. Top part of elements.
6. Center group.
7. Group near edges.

Test No. 12 (Continued)

Time	Air at Intake 1.	2.	3.	Air in Duct 1.	2.	3.	Evaporation - grams per minute
0600	28.32	n	.47	-	.53	-	.0130
0615	-	o	-	28.90	.53	.55	-
0630	31.70	t	.62	-	.53	-	-.0119
0645	-		-	31.15	.53	.60	-
0700	30.17	t	.70	30.60	.53	.58	-.0141
0730	31.70	a	.53	31.70	.55	.62	.0000
0800	34.85	k	.67	32.00	.55	.62	-.0619
0830	32.00	e	.55	32.30	.55	.62	.0065
0900	33.40	n	.65	32.00	.55	.62	-.0304
0930	-		-	27.19	.55	.54	-
1000	31.70		.62	33.15	.55	.65	.0315
1015	-		-	-	.55	-	-
1030	31.15		.62	33.40	.55	.65	.0488
1100	29.75		.57	31.70	.55	.62	.0423
1130	32.55		.63	31.45	.55	.62	-.0239
1200	32.30		.63	28.90	.55	.57	-.0738
1230	28.32		.47	30.02	.55	.58	.0369

Air flow 2.17 cu.ft. per minute.

1. Grams water per 100 cu.ft. of air.
2. Per cent humidity, wet-dry bulb thermometer.
3. Per cent humidity, wet-dry bulb thermometer, calculated.

Time	Current	Gassing Current	Charging Current	Per Cent Charge	Hydrogen Percentage	Gravity
0600	0-1050	0	1050	-	0	1081
0615	1050	0	1050	-	0	-
0630	1050	0	1050	-	0	-
0645	1050	0	1050	-	0	-
0700	1050	0	1050	-	0	1078
0730	1050	0	1050	-	0	-
0800	1050	0	1050	50	0	1080
0830	1050	0	1050	-	0	-
0900	1050	2	1048	67	.03	1089
0930	1050	4	1046	-	.05	-
1000	1050	12	1038	90	.15	1108
1015	1050-330	42-16	1008-314	95	.51-.20	-
1030	330	7	323	97	.08	-
1100	330	16	314	100	.20	1144
1130	330	82	248	102	1.00	1173
1200	330	152	178	104	1.85	1197
1230	330-200	177-99	153-101	107	1.15-1.20	1211
1300	200-100	58	142	-	.70	1214
1330	100	-	-	-	-	-
1345	100-50	53	47	-	.65	-
1400	50	-	-	-	-	-
1430	50-25	21	29	-	.25	-
1500	25-0	12	13	-	.15	-

Test No. 12 (Continued)

Time	Voltages						Cell
	1.	2.	3.	4.	5.	6.	Resistance
0600	1.948	-	.930	-	1.022	-	.000248
0615	-	-	-	-	-	-	-
0630	-	-	-	-	-	-	-
0645	-	-	-	-	-	-	-
0700	2.087	2.234	.963	1.084	1.105	1.152	.000140
0730	-	-	-	-	-	-	-
0800	2.114	2.267	.974	1.094	1.124	1.176	.000146
0830	-	-	-	-	-	-	-
0900	2.149	2.321	.967	1.086	1.171	1.238	.000164
0930	-	-	-	-	-	-	-
1000	2.235	2.499	.954	1.186	1.248	1.315	.000251
1015	-	-	-	-	-	-	-
1030	-	-	-	-	-	-	-
1100	2.291	2.436	.987	1.147	1.278	1.294	.000439
1130	-	-	-	-	-	-	-
1200	2.326	2.577	.995	1.235	1.306	1.342	.000761
1230	2.328	2.592	.997	1.244	1.308	1.349	.000800
1300	2.343	2.536	1.003	1.205	1.307	1.333	.000965
1330	-	-	-	-	-	-	-
1345	2.334	2.481	1.003	1.165	1.303	1.318	.001470
1400	-	-	-	-	-	-	-
1430	2.305	2.403	.998	1.107	1.288	1.295	.001960
1500	2.286	2,343	.993	1.067	1.274	1.280	.002280

Voltages.

1. Voltage of cell, open.
2. Voltage of cell, closed.
3. Lead - mercurous sulphate, open.
4. Lead - mercurous sulphate, closed.
5. Lead peroxide - mercurous sulphate, open.
6. Lead peroxide - mercurous sulphate, closed.

Test No. 12 (Continued)

Time	Heating Effects			Cooling Effects			Net	Temp. Rise	
	1.	2.	3.	4.	5.	6.	Effect	Est.	Found
0600	3915	1827	0	110	8	0	5620	-	-
0615	-	1827	0	-50	-	0	-	-	-
0630	-	1827	0	-50	-7	0	4075	-	-
0645	-	1827	0	-40	-	0	-	-	-
0700	2213	1827	0	-40	-8	0	4090	4°	4°
0730	-	1827	0	-50	0	0	-	-	-
0800	2305	1827	0	-30	-36	0	4198	4°	4°
0830	-	1827	0	-40	4	0	-	-	-
0900	2509	1824	106	-30	-18	25	4500	-	-
0930	-	1820	211	-30	-	50	5200	5°	5°
1000	3975	1807	634	-40	18	152	6290	-	-
1015	-	1755-546	2219-846	-	-	533-203	7400-5100	.6°	-
1030	-	562	370	-40	28	89	1300	-	-
1100	686	546	846	-40	24	203	1890	1.5°	2°
1130	-	432	4342	-50	-14	1039	4670	2	0
1200	1187	310	8016	-60	-43	1924	7692	-	-
1230	1248	266-176	9355-5230	-60	21	2244-1255	8663-5438	4°	.5°
1300	553	247	3064	-80	-	735	3190	1.5°	0
1330	-	-	-	-70	-	-	-	-	-
1345	211	82	2799	-90	-	672	2490	2°	-2°
1400	-	-	-	-70	-	-	-	-	-
1430	70	50	1109	-70	-	266	1010	.6°	-
1500	20	23	634	-60	-	152	570	.3°	-2°
							Net effect	25.2°	11.5°

1. Irreversible heat.
2. Reversible heat, normal reaction.
3. Heat of formation of gases.
4. Radiation (and convection) to air.
5. Evaporation loss.
6. Reversible heat, water electrolysis.

Test No. 13.

Bureau Procedure Charge.
Cell discharged at 4675 ampere-hours.
Air Flow, 2.17 cu.ft. per minute.

Time	Temperatures									
	Couple Groups									Duct at
	1	2	3	4	5	6	7	Air	Bath	gooseneck
0800	60	67	61	61	65	63	61	73	61	72
0830	61	69	64	62	69	67	64	78	60	75
0900	61	74	67	64	72	70	67	79	61	78
0930	61	75	68	67	74	73	70	77	61	77
1000	61	77	70	68	75	76	72	77	60	79
1030	61	79	71	72	77	79	74	78	61	79
1100	62	80	73	76	79	82	76	80	61	80
1130	64	82	76	81	82	86	76	80	61	80
1145	-	-	-	-	-	-	-	-	61	-
1150	-	-	-	-	-	-	-	-	61	-
1200	67	85	83	88	85	89	84	82	60	81
1215	-	-	-	-	-	-	-	-	61	-
1225	-	-	-	-	-	-	-	-	61	-
1230	67	86	86	88	87	89	86	79	61	81
1245	69	87	85	85	87	89	86	78	61	81

Couple Groups
1. Electrolyte below elements
2. Electrolyte above elements
3. Between jar and elements
4. Top part of elements
5. Center group
6. Group near edge

Time	Air at intake		Air in Duct			
	1	3	1	2	3	Evaporation g per minute
0800	49.80	.90	52.90	.81	1.00	.0676
0830	41.50	.60	50.50	.85	.90	.1966
0900	50.20	.70	52.90	.85	.75	.0553
0930	52.10	.80	53.80	.85	.80	.0369
1000	53.20	.80	53.80	.85	.80	.0123
1030	52.25	.80	53.20	.85	.80	.0185
1100	50.20	.70	56.80	.85	.80	.0246
1130	46.40	.65	46.70	.85	.65	.0061
1145	46.70	-	-	.81	-	.0000
1150	-	-	56.00	.81	.80	.0123
1200	56.80	.80	-	.81	-	.0123
1215	-	-	-	.81	-	-
1225	-	-	50.60	.81	.80	.0430
1230	-	-	-	.81	-	-
1245	-	-	-	.81	-	-

1. Grams water per 100 cu. ft. air
2. Relative humidity, wet-dry bulb
3. Relative humidity, calculated

Test No. 13 (continued)

Time	Current	Gassing Current	Charging Current	Percent charge	Hydrogen Percentage	Gravity
0800	0-1300	0	1300	-	0	1084
0830	1300	0	1300	-	0	-
0900	1300	0	1300	-	0	1083
0930	1300	0	1300	-	0	-
1000	1300	0	1300	.69	0	1087
1030	1300	4	1296	.83	.05	-
1100	1300	6	1294	.97	.07	1099
1130	1300	32	1268	102	.40	-
1145	1300-1050	178-122	1122-928	1.04	2.20-1.50	1183
1150	1050-800	170-105	880-695	1.05	2.10-1.30	-
1200	800-550	177-96	623-454	1.08	2.20-1.20	1202
1215	550	157	393	1.10	1.95	1207
1225	550-330	169-88	381-242	1.11	2.10-1.10	-
1230	330	96	234	1.11	1.20	1212
1245	330-0	104	226	1.12	1.30	-

Time	Voltages					
	1.	2.	3.	4.	5.	6.
0800	1.943	2.202	.927	1.060	1.017	1.145
0830	-	-	-	-	-	-
0900	2.067	2.221	.966	1.090	1.090	1.136
0930	-	-	-	-	-	-
1000	2.109	2.272	.980	1.106	1.115	1.168
1030	-	-	-	-	-	-
1100	2.171	2.370	.960	1.110	1.195	1.266
1130	-	-	-	-	-	-
1145	-	-	-	-	-	-
1150	-	-	-	-	-	-
1200	-	-	-	-	-	-
1215	-	-	-	-	-	-
1225	-	-	-	-	-	-
1230	-	-	-	-	-	-
1245	2.305	2.505	1.017	1.157	1.287	1.347

1. Voltage, open
2. Voltage, closed
3. Lead-mercurous sulphate, open
4. Lead-mercurous sulphate, closed
5. Lead Peroxide-mercurous sulphate, open
6. Lead Peroxide-mercurous sulphate, closed

Test No. 13 (continued)

Time	Heating Effects		Cooling Effects				Net Effect	Temp. Rise	
	1	2	3	4	5	6		Cal.	found
0800	2260	4850	0	9	38	0	7062	-	-
0830	2260	4800	0	27	113	0	5044	3.4	3.2
0900	2260	2870	0	-9	32	0	5107	3.0	3.2
0930	2260	2870	0	0	21	0	4489	2.6	2.3
1000	2260	1630	0	18	7	0	3865	2.2	2.0
1030	2235	1630	211	9	10	42	5085	3.0	2.0
1100	2255	3730	316	0	14	63	6222	3.5	2.5
1130	2205	3700	1690	0	4	338	7283	4.2	3.2
1145	1950-1615	3730-3015	9400-6440	0	0	1880-1290	13200-9780	3.5	-
1150	1530-1210	3015-2290	9000-5540	0	7	1800-1110	11738-7923	-	-
1200	1080-790	2290-1580	9340-5060	-9	7	1870-1210	10840-6220	3.0	4.0
1215	681	1580	8330	9	0	1600	8982	-	-
1225	662-420	1580-948	8940-4650	9	25	1790-930	9358	5.0	-
1230	407	948	5060	18	0	1010	5387	-	1.40
1245	393	948	5500	27	0	1100	5714	1.5	-.4
						total effect		34.9°	23.4°

1. Reversible Heat, Normal Reaction
2. Irreversible Heat
3. Heat of Formation of Gases
4. Loss to Air
5. Evaporation Loss
6. Water Electrolysis, Reversible Heat

Test No. 14.

Bureau Procedure Charge.
Discharged at 4675 ampere-hours.

Time	Temperatures Couple Numbers										
	1	2	18	20	11	4	14	15	16	17	6
0800	60	60	67	67	62	60	66	66	66	66	61
0830	61	61	69	68	63	62	69	68	70	68	63
0900	60	61	72	72	66	63	72	70	74	71	67
0930	61	61	75	75	68	65	74	72	76	73	68
1000	61	61	76	76	69	68	75	74	79	75	72
1030	61	61	78	78	70	71	77	75	80	75	75
1045	-	-	-	-	-	-	-	-	-	-	-
1100	61	61	79	79	72	75	78	76	81	76	79
1130	63	62	79	79	74	78	79	78	81	77	81
1200	64	63	78	78	74	79	79	79	80	76	82
1230	65	64	76	76	73	79	76	78	79	75	83
1245	-	-	-	-	-	-	-	-	-	-	-
1300	65	65	75	75	74	80	76	77	78	75	83
1330	-	-	-	-	-	-	-	-	-	-	-
1400	65	66	75	75	74	80	75	76	77	75	83
1430	66	66	74	74	72	83	75	75	76	74	82
1445	-	-	-	-	-	-	-	-	-	-	-
1500	65	65	74	74	72	79	75	75	76	73	81
1515	65	65	75	75	73	76	75	75	78	74	80

Time	Couple Numbers				Temperatures			Duct at
	12	13	5	7	9	Air	Bath	Gooseneck
0800	63	63	60	61	63	72	60	70
0830	68	68	62	64	65	74	61	73
0900	74	72	65	67	68	76	61	75
0930	76	75	67	68	72	76	61	75
1000	80	76	68	72	75	80	58	78
1030	82	79	71	74	77	79	58	78
1045	-	-	-	-	-	-	-	-
1100	84	81	73	75	79	79	60	79
1130	84	81	73	77	80	80	61	79
1200	83	82	74	77	80	80	56	79
1230	81	80	73	76	80	79	58	79
1245	-	-	-	-	-	-	-	-
1300	81	80	73	76	79	79	59	78
1330	-	-	-	-	-	-	-	-
1400	80	79	73	77	79	81	56	79
1430	79	77	72	76	76	79	56	77
1445	-	-	-	-	-	-	-	-
1500	79	76	71	75	75	80	58	78
1515	78	77	72	75	75	78	59	78

Couple Groups.
1. 1, 2. Electrolyte below elements.
2. 18,20. Electrolyte above elements.
3. 11. Between jar and elements.
4. 4. Bottom of elements.
5. 14,15,16,17. Top part of elements.
6. 6,12,13. Center group.
7. 5,7,9. Group near edge.

Test No. 14 (continued).

Time	Air at intake			Air in Duct			Evaporation grams per minute
	1	2	3	1	2	3	
0800	39.10	.70	.70	36.85	.79	.70	.0492
0830	41.40	.70	.67	36.85	.80	.65	.0984
0900	42.50	.74	.70	-	.72	-	.0246
0930	40.50	.70	-	41.40	.72	.67	.0246
1000	43.70	.62	.55	39.70	.67	.55	-.0184
1030	45.00	.70	.60	49.80	.67	.60	.0184
1045	-	-	.65	-	-	-	.0492
1100	40.50	.72	-	38.80	.69	.55	.0246
1130	44.25	.72	.57	40.50	.68	.57	.0000
1200	39.10	.63	.63	44.25	.64	.62	.0000
1230	-	.62	.55	38.80	.68	.55	.0061
1245	32.30	-	-	-	-	-	-
1300	31.20	.63	.45	39.40	.64	.55	-.1538
1330	31.75	.63	.45	40.20	.64	.57	-.1968
1400	31.75	.58	.45	45.10	.58	.63	-.2888
1430	-	.60	.45	35.70	.59	.50	-.0769
1445	-	-	-	-	-	-	-
1500	-	-	-	-	-	-	-
1515	-	-	-	-	-	-	-

1. Grams H_2O per 100 cu. ft. air
2. Humidity-percent, wet-dry bulb thermometer
3. Humidity-percent, calculated

Air flow 2.17 cu. ft. per minute

Time	Current	Gassing Current	Charging Current	Percent charge
0800	0-1300	0	1300	-
0830	1300	0	1300	-
0900	1300	0	1300	-
0930	1300	4	1296	-
1000	1300	8	1292	53
1030	1300	8	1292	67
1045	1300-1050	8	1292-1042	74
1100	1050-800	12	1038-788	81
1130	800-550	16	784-534	88
1200	550-330	16	534-314	93
1230	330	16	314	96
1245	330-250	36	294-214	98
1300	250-190	40	210-150	100
1330	190-165	40	150-125	100.5
1400	165	48	117	102
1430	165	60	105	103
1445	165	64	101	104
1500	165-250	64	101-186	104
1515	250-0	144	106-0	105

Test No. 12 (continued)

Time	Hydrogen percentage	Gravity Hydrometer	Cell Resistance (calculated)
0800	0	1156	-
0830	0	-	-
0900	0	1157	.000113
0930	.05	-	-
1000	.10	1167	.000123
1030	.10	-	-
1045	.10	-	-
1100	.15	1193	.000156
1130	.20	-	.000240
1200	.20	-	.000210
1230	.20	-	-
1245	.45	1243	.000370
1300	.50	-	-
1330	.50	1258	-
1400	.60	1267	.000730
1430	.75	1277	-
1445	.80	1275	-
1500	.80	1279	.000850
1515	1.80	-	.000624

Time	Voltages					
	1	2	3	4	5	6
0800	2.015	2.247	.955	1.058	1.063	1.187
0830	-	-	-	-	-	-
0900	2.139	2.285	.987	1.196	1.143	1.190
0930	-	-	-	-	-	-
1000	2.184	2.343	.993	1.106	1.181	1.240
1030	-	-	-	-	-	-
1045	-	-	-	-	-	-
1100	2.249	2.413	.980	1.110	1.246	1.305
1130	-	-	-	-	-	-
1200	2.292	2.407	.990	1.110	1.274	1.300
1230	-	-	-	-	-	-
1245	2.315	2.436	1.005	1.135	1.287	1.304
1300	-	2.428-2.398	-	1.130-1.100	-	1.305-1.296
1330	-	-	-	-	-	-
1400	2.320	2.440	1.010	1.130	1.295	1.310
1430	-	-	-	-	-	-
1445	-	-	-	-	-	-
1500	2.329	2.469	1.015	1.148	1.296	1.322
1515	2.349	2.505	1.023	1.176	1.300	1.336

Voltages
1. Voltage-Open
2. Voltage-Closed
3. Lead-mercurous sulphate, open
4. Lead-mercurous sulphate, closed
5. Lead peroxide-mercurous sulphate, open
6. Lead peroxide-mercurous sulphate, closed

Test No. 14 (continued)

Time	Heating Effects			Cooling Effects			Total effect	Temp. est.	Change found
	1	2	3	4	5	6			
0800	4285	2263	0	-18	29	0	-	-	-
0830	-	2263	0	-9	57	0	-	-	-
0900	2720	2263	0	-9	14	0	5760	6.6	5.0
0930	-	2255	212	-9	14	42	5220	3.0	2.0
1000	2981	2249	423	-18	-10	85	5600	3.2	2.2
1030	-	2249	423	-9	10	85	5600	3.2	2.0
1045	-	2249-1813	423	-	28	85	2880	1.6	-
1100	2468-1882	1807-1371	634	0	14	127	4768-3746	1.3	2.0
1130	-	1364-929	846	-9	0	169	3746	2.0	1.0
1200	632-544	929-546	846	-9	0	169	2247-1776	1.3	0
1230	-	546	846	0	3	169	1776	1.0	-1.0
1245	572-438	512-372	1904	-9	-	381	2616-2342	.7	-
1300	-	366-261	2113	-9	-76	423	2580-2440	.7	0
1330	-	261-218	2113	-	-110	423	2360-2318	1.3	0
1400	288	204	2536	-18	-160	507	2700	1.5	0
1430	-	183	3170	-18	-44	634	3070	1.7	-.6
1445	-	176	3383	-	-	677	3170	.9	-
1500	332-502	176-324	3383	-18	-	677	3230-3550	1.0	-.7
1515	559-0	184	7610	0	-	1522	6830	2.0	.3

1. Irreversible Heat
2. Reversible Heat, normal reaction
3. Heat of formation of gases
4. Radiation and convection to air
5. Evaporation loss to air
6. Reversible Heat, water electrolysis

Test No. 15.

Overcharge data.

Temperatures

Time	Couple Groups 1.	2.	3.	4.	5.	6.	7.	Air	Cell Box	Duct at Gooseneck
0830	70	72	71	71	71	71	71	73	71	71
0900	70	72	72	72	72	72	72	76	71	75
0925	70	73	73	73	73	73	73	77	71	76
0950	71	75	75	75	75	75	75	78	71	76
1010	71	75	75	75	75	75	75	78	72	78
1030	71	75	75	75	75	75	75	77	72	77

Couple Groups.

1. Electrolyte below elements.
2. Electrolyte above elements.
3. Between jar and elements.
4. Bottom part of elements.
5. Top part of elements.
6. Center group.
7. Near edge.

Time	Current	Gassing Current	Per Cent Hydrogen
0830	0-300	0	0
0900	300	16	.20
0925	300-200	32	.40
0950	200-100	23	.28
1010	100-50	10	.12
1030	50-0	6	.08

Voltages.

1. Voltage, open.
2. Voltage, closed.
3. Lead - mercurous sulphate, open.
4. Lead - mercurous sulphate, closed.
5. Lead peroxide-mercurous sulphate, open.
6. Lead peroxide-mercurous sulphate, close

Voltages.

Time	1.	2.	3.	4.	5.	6.
0830	2.125	-	.988	-	1.138	-
0900	-	-	-	-	-	-
0925	2.364	2.511	1.029	1.167	1.313	1.346
0950	2.348	2.465	1.025	1.131	1.309	1.333
1010	2.328	2.371	1.019	1.063	1.300	1.311
1030	2.301	2.317	1.010	1.027	1.285	1.292

Time	Heating Effects 1.	2.	3.	Cooling Effects 4.	5.	6.	Total Effect	Temperature Rise Estimated	Found
0830	-	522	0	10(est)	25(est)	0	-	-	-
0900	-	494	842	10	25	168	1766	-	-
0925	633	466	1686	10	25	337	2410	2	2
0950	336	308	1212	10	25	242	1580	1	2
1010	62	157	529	10	25	106	607	.2	0
1030	9	77	316	10	25	63	304	.1	0
							Total Effect	3.3°	4°

1. Irreversible heat.
2. Reversible heat, normal reaction.
3. Heat of formation of gases.
4. Radiation and convection to air.
5. Evaporation loss.
6. Reversible heat, water electrolysis.

Air flow 2.16 cu.ft. per minute.

Test No. 16.

Manufacturer's procedure.
Discharged at 4675 ampere-hours.

Time	Temperatures: Couple Groups 1.	2.	3.	4.	5.	6.	7.	Air	Bath	Duct at Gooseneck
0800	60	67	61	61	67	64	61	72	61	69
0830	59	68	62	61	68	67	62	76	61	73
0900	60	70	65	62	68	70	64	77	61	73
0930	60	72	66	63	69	71	66	79	61	75
1000	60	74	68	65	73	75	63	79	61	76
1030	61	75	68	68	74	75	66	81	61	78
1100	61	75	68	69	74	75	67	81	61	78
1130	62	75	70	73	76	78	73	75	58	76
1200	63	75	71	73	74	78	73	75	59	75
1230	63	73	70	74	74	77	75	74	60	75
1300	64	72	70	74	73	76	73	76	61	75
1330	65	72	69	74	73	76	72	76	58	75
1400	65	71	69	75	72	76	72	77	59	75
1430	65	71	69	75	72	75	72	78	60	75
1500	65	72	70	76	72	76	73	78	56	75
1530	64	73	70	77	73	77	74	78	57	76
1600	65	75	72	76	75	77	74	79	59	76
1620	65	75	74	75	76	77	74	78	60	76

1. Electrolyte below elements.
2. Electrolyte above elements.
3. Between jar and elements.
4. Bottom of elements.
5. Top part of elements.
6. Center group.
7. Group near edge.

Time	Air at Intake 1.	2.	3.	Air in Duct 1.	2.	3.	Gravity	Evaporation - grams per min.
0800	28.32	.65	.50	35.20	.77	.60	1163	.1493
0830	30.40	.55	.50	35.95	.65	.60	-	.1204
0900	28.32	.51	.57	37.20	.65	.65	1169	.1927
0930	-	.51	-	34.55	.58	.57	-	-
1000	29.42	.49	.43	36.50	.58	.60	1165	.2622
1030	-	.44	-	34.25	.56	.55	-	-
1100	29.50	.48	.43	33.40	.56	.55	1176	.0846
1130	-	.55	-	32.75	.56	.50	-	-
1200	29.50	.51	.50	28.90	.61	.50	1193	.0130
1230	22.66	.51	.37	22.80	.61	.40	-	.5030
1300	23.25	.58	.40	29.25	.61	.50	1207	.1302
1330	23.25	.52	.40	25.50	.61	.45	-	.0488
1400	21.85	.50	.35	28.90	.61	.50	-	.1530
1430	21.00	.51	-.30	30.60	.61	.50	1225	.2083
1500	45.00	.48	.60	29.75	.54	.50	1248	-.3310
1530	-	.53	-	29.45	.61	.55	1267	-
1600	29.42	.49	.43	31.40	.54	.50	1274	-.0430
1620	28.30	.49	.40	-	.54	-	1279	-

1. Grams water per 100 cu.ft. of air.
2. Relative humidity, wet-dry bulb thermometer.
3. Relative humidity, calculated.

Test No. 16 (Continued)

Time	Current	Gassing Current	Charging Current	Per Cent Charge	Per Cent Hydrogen	Cell Resistance (Calculated)
0800	0-1050	0	1050	-	0	.000206
0830	1050	0	1050	-	0	-
0900	1050	0	1050	-	0	.000116
0930	1050	0	1050	-	0	-
1000	1050	0	1050	-	0	-
1030	1050	4	1046	-	.05	.000131
1100	1050	6	1044	67	.08	-
1130	1050-330	8-4	1042-326	-	.10-.05	.000222
1200	330	6	324	82	.07	-
1230	330	6	324	-	.07	.000155
1300	330	7	323	88	.08	-
1330	330	7	323	-	.09	.000188
1400	330	8	322	96	.10	-
1430	330	16	314	99	.20	.000358
1500	330	34	296	102	.40	-
1530	330	73	257	105	.90	.000572
1600	330	89	241	108	1.10	-
1620	330-0	93	237	109	1.15	.000567

Time	Voltages					
	1.	2.	3.	4.	5.	6.
0800	2.013	2.229	.954	1.043	1.062	1.181
0830	-	-	-	-	-	-
0900	2.125	2.447	.980	1.077	1.134	1.173
0930	-	-	-	-	-	-
1000	-	2.291	-	1.088	-	1.203
1030	2.176	2.314	.992	1.087	1.177	1.230
1100	-	-	-	-	-	-
1130	2.220	2.404	.982	1.108	1.228	1.300
1200	-	-	-	-	-	-
1230	2.227	2.278	.974	1.020	1.239	1.260
1300	-	-	-	-	-	-
1330	2.261	2.323	.980	1.042	1.263	1.282
1400	-	-	-	-	-	-
1430	2.316	2.434	1.008	1.125	1.286	1.310
1500	-	-	-	-	-	-
1530	2.330	2.519	1.015	1.181	1.300	1.339
1600	-	-	-	-	-	-
1620	2.355	2.542	1.027	1.195	1.310	1.345

1. Voltage, open.
2. Voltage, closed.
3. Lead - mercurous sulphate, open.
4. Lead, mercurous sulphate, closed.
5. Lead peroxide - mercurous sulphate, open.
6. Lead peroxide - mercurous sulphate, closed.

Air flow 2.17 cu.ft. per minute.

Test No. 16 (Continued)

Time	Heating Effects			Cooling Effects			Net	Temperature Rise	
	1.	2.	3.	4.	5.	6.	Effect	Calculated	Found
0800	3250	1827	0	-27	85	0	5020	-	-
0830	-	1827	0	-27	69	0	3620	-	-
0900	1835	1827	0	-18	111	0	3570	-	-
0930	-	1827	0	-36	-	0	3580	-	-
1000	-	1827	0	-27	151	0	3625	-	-
1030	2077	1820	203	-27	-	51	3975	-	-
1100	-	1817	305	-27	49	76	4440	14°	10°
1130	2768-870	1813-567	406-203	9	-	102-51	4860-1560	2.5	3
1200	-	564	305	0	-7	76	1030	-	-
1230	241	564	305	-9	2	76	1030	-	-
1300	-	562	355	-9	75	89	1020	-	-
1330	293	562	355	-9	28	89	1100	-	-
1400	-	560	406	-18	89	102	1100	3	1
1430	558	546	812	-27	120	203	1620	1	-
1500	-	515	1725	-27	-191	431	2737	1.5	.5
1530	893	447	3704	-27	-	926	4200	2	-
1600	-	419	4516	-27	25	1129	4700	2.5	-
1620	884	412	4720	-18	-	1180	4850	2.5	3
							Total effect	29°	15.5°

Test No. 17.

Bureau Procedure.
Discharged at 4675 ampere-hours.

Time	Temperatures									
	Couple Groups									Duct at
	1.	2.	3.	4.	5.	6.	7.	Air	Bath	Gooseneck
0800	82	84	83	81	84	82	82	75	83	81
0830	81	88	85	83	89	86	84	82	82	85
0900	80	89	84	82	88	88	85	84	81	85
0930	80	86	85	83	88	90	87	84	81	85
1000	81	89	88	87	90	93	89	84	81	86
1030	81	90	89	89	92	96	92	84	75	86
1100	81	90	89	91	92	96	93	85	76	86
1130	81	89	89	93	92	96	93	84	77	85
1210	82	89	90	94	91	96	93	84	77	85
1245	83	89	90	94	91	95	93	83	79	84
1300	83	89	89	94	90	94	92	83	79	85
1340	85	88	89	94	89	94	92	82	79	83
1400	-	-	-	-	-	-	-	-	-	-
1430	85	89	89	94	89	93	91	82	80	83
1510	85	89	89	94	89	93	90	82	80	83
1530	-	-	-	-	-	-	-	-	80	-
1550	85	89	89	90	90	92	90	81	82	83

1. Electrolyte below elements
2. Electrolyte above elements
3. Between jar and elements
4. Bottom of elements
5. Top part of elements
6. Center group
7. Group near edges

Time	Current	Gassing Current	Charging Current	Percent Charge	Hydrogen Percentage	Gravity	Cell Resistance
0800	0-1300	0	1300	-	0	1174	.000183
0830	1300	0	1300	-	0	-	-
0900	1300	0	1300	-	0	1177	.000105
0930	1300	0	1300	-	0	-	-
1000	1300	6	1294	55	.08	1185	.000112
1030	1300-1050	9-8	1291-1042	70	.11-.10	-	.000116
1100	1050-800	9-8	1041-792	82	.11-.10	1206	.000143
1130	800-550	10	790-540	89	.12	-	.000168
1210	550-330	-	-	-	-	-	-
1245	330-190	28	302-162	97	.35	-	-
1300	190	24	166	98	.30	1247	.000216
1345	190-165	33	157-132	100	.40	-	.000347
1400	165	41	124	101	.50	1264	-
1430	165	57	108	101	.70	-	-
1510	165	73	92	102	.90	-	.000575
1530	165	77	88	103	.95	-	-
1550	165-0	85	80-0	104	1.05	1280	.000624

Air flow 2.17 cu.ft. per minute

Test No. 17 (continued).

Time	Air at Intake			Air in Duct			Evaporation
	1.	2.	3.	1.	2.	3.	Grams per min.
0800	31.15	.59	.50	41.05	.75	.57	.2148
0830	31.70	.52	.45	41.35	.64	.57	.2094
0900	32.00	.52	.40	41.35	.65	.50	.2028
0930	33.12	.52	.40	34.82	.66	.43	.0369
1000	32.00	.51	.40	35.95	.66	.43	.0857
1030	26.90	.45	.33	35.10	.65	.42	.1779
1100	29.73	.47	.36	39.35	.68	.48	.2089
1130	28.32	.44	.35	39.35	.65	.48	.2394
1210	-	-	-	36.52	.69	.43	-
1245	22.65	.44	.28	40.20	.69	.47	.3809
1300	26.05	.42	.33	37.65	.69	.45	.2518
1340	28.32	.42	.35	32.00	.64	.45	.0798
1400	28.32	.43	-	-	.64	-	-
1430	25.48	.44	.37	32.28	.64	.45	.1475
1510	26.90	.42	.35	37.10	.69	.50	.2214
1530	30.30	.42	-	-	.69	-	-
1550	-	.44	-	39.65	.69	.50	-

1. Grams water per 100 cu. ft. air
2. Relative humidity, wet-dry bulb thermometer
3. Relative humidity, calculated

Time	Voltages					
	1.	2.	3.	4.	5.	6.
0800	1.975	2.213	.949	1.034	1.035	1.177
0830	-	-	-	-	-	-
0900	2.128	2.264	.986	1.090	1.134	1.176
0930	-	-	-	-	-	-
1000	2.166	2.312	.995	1.103	1.161	1.213
1030	2.191	2.342	.986	1.091	1.197	1.261
1100	2.199	2.349	.981	1.072	1.213	1.277
1130	2.221	2.355	.978	1.074	1.233	1.283
1210	-	2.360	-	1.083	-	1.280
1245	-	-	-	-	-	-
1300	2.260	2.301	.992	1.042	1.252	1.259
1340	2.280	2.346	1.001	1.074	1.265	1.275
1400	-	-	-	-	-	-
1430	-	-	-	-	-	-
1510	2.300	2.395	1.012	1.106	1.274	1.296
1530	-	-	-	-	-	-
1550	2.305	2.408	1.013	1.109	1.277	1.300

1. Voltage - open
2. Voltage - closed
3. Lead - mercurous sulphate, open
4. Lead - mercurous sulphate, closed
5. Lead peroxide - mercurous sulphate, open
6. Lead peroxide - mercurous sulphate, closed

Test No. 17 (continued).

Time	Heating Effects			Cooling Effects			Net Effect	Temp. rise Cal.	Found
	1.	2.	3.	4.	5.	6.			
0800	4435	2262	0	54	124	0	6520	-	-
0830	-	2262	0	27	120	0	4650	-	-
0900	2533	2262	0	9	117	0	4670	-	-
0930	-	2262	0	9	21	0	4860	-	-
1000	2720	2252	315	18	49	76	5140	10°	6°
1030	2813	2247-1813	457-406	18	103	114-101	5280-4810	3	1
1100	2258	1811-1378	457-406	9	120	114-101	4280-3810	2.5	1
1130	1537	1375-940	507	9	138	127	3150-2720	2.5	0
1210	-	-	-	9	-	-	-	-	-
1245	-	526-282	1420	9	220	355	2070-1830	3	0
1300	112	289	1216	18	145	304	1150	.3	0
1345	180	273-230	1674	9	46	419	1660-1610	1	-1
1400	-	216	2080	-	-	520	1900	.7	0
1430	-	188	2891	9	85	723	2470	1.5	0
1510	225	160	3704	9	128	926	3030	-	-
1530	-	153	3906	-	-	977	3190	3	0
1550	244	139	4312	18	-	1078	3490	1.2	0
					total effect			28.7°	7°

1. Irreversible heat
2. Reversible heat, normal reaction
3. Heat of formation of gases
4. Convection and radiation to air
5. Evaporation loss
6. Reversible heat, water electrolysis

Test No. 18.

Overcharge data.

Time	Temperatures: Couple Groups 1.	2.	3.	4.	5.	6.	7.	Air	Bath	Duct at Gooseneck
0800	82	80	81	82	80	81	81	72	79	75
0830	81	82	82	82	82	82	82	77	78	79
0905	80	83	82	84	83	84	83	79	78	78
0935	80	83	83	85	85	85	85	79	78	78
1000	81	84	83	85	85	85	85	79	79	80
1015	81	84	83	85	84	85	84	78	79	80

Couple Groups.

1. Electrolyte below elements.
2. Electrolyte above elements.
3. Between jar and elements.
4. Bottom of elements.
5. Top part of elements.
6. Center group.
7. Group near edge.

Time	Current	Gassing Current	Hydrogen Percentage	Cell Resistance
0800	0-300	163	0-2.00	.00120
0830	300	-	-	-
0905	300-200	161-89	2.00-1.10	.000507
0935	200-150	93-81	1.20-1.00	.000630
1000	150-50	93-24	1.15-.30	.000713
1015	50-0	24	.30-0	.000640

Time	Voltages 1.	2.	3.	4.	5.	6.
0800	2.132	-	.988	-	1.146	-
0830	-	-	-	-	-	-
0905	2.344	2.496	1.027	1.164	1.301	1.333
0935	2.332	2.459	1.022	1.140	1.295	1.320
1000	2.324	2.431	1.019	1.121	1.290	1.312
1015	2.291	2.323	1.011	1.045	1.274	1.280

1. Voltage, open.
2. Voltage, closed.
3. Lead - mercurous sulphate, open.
4. Lead - mercurous sulphate, closed.
5. Lead peroxide - mercurous sulphate, open.
6. Lead peroxide - mercurous sulphate, closed.

Time	Heating Effect 1.	2.	3.	Cooling Effect 4.	5.	6.	Net Effect	Temp.Rise Calc.	Found
0800	1548	238	8172	50(est.)	125(est.)	2068	7815	-	-
0830	-	-	-	-	-	-	-	-	2°
0905	654-436	242-193	8172-4516	50	125	2043-1129	6850-4200	7.5	1
0935	364-273	179-120	4921-4012	50	125	1230-1028	4060-3205	2	1
1000	230-77	99-45	4720-1218	50	125	1180-304	3700-860	1.8	0
1015	23	45	1218	50	125	304	806	.2	0
						Total effect		11.5°	4°

Air flow, 2.17 cu.ft. per minute.

Test No. 19.

Bureau procedure.
Discharged at 4675 ampere-hours.

Time	Temperatures									
	Couple Numbers									Duct at
	1.	2.	3.	4.	5.	6.	7.	Air	Bath	Gooseneck
1200	97	96	96	96	96	96	96	74	96	94
0030	98	98	101	101	99	101	101	78	94	84
0100	99	99	101	101	100	103	102	78	94	84
0130	99	101	102	104	102	105	104	79	94	84
0200	99	101	105	105	103	107	105	78	94	84
0235	98	102	105	106	104	108	107	78	94	84
0300	100	102	106	108	104	111	108	78	94	84
0330	100	102	106	110	105	110	109	78	94	84
0400	101	102	106	111	104	110	109	78	94	85
0445	102	101	106	112	103	110	109	79	94	85
0500	103	103	106	111	103	109	109	-	-	-
0515	-	-	-	-	-	-	-	-	94	86
0530	102	103	103	111	105	108	108	78	-	-
0540	-	-	-	-	-	-	-	-	94	88
0600	103	103	103	107	105	107	107	79	-	-
0630	-	-	-	-	-	-	-	-	94	88
0700	-	-	-	-	-	-	-	-	-	-
0730	100	104	103	105	105	106	104	79	95	-
0800	100	104	103	104	106	106	104	83	95	90
0830	99	103	101	104	103	104	103	84	95	93
0900	99	102	103	105	103	104	104	83	95	90
0930	99	103	102	105	104	105	104	82	95	90
1000	99	102	102	103	104	104	103	80	95	89
1045	-	-	-	-	-	-	-	79	-	89
1130	98	101	100	100	101	102	101	80	94	-
1200	98	100	100	100	101	101	100	80	94	87
1235	98	99	100	99	101	101	100	80	94	86
1305	96	99	99	99	100	100	100	80	94	87

1. Electrolyte below elements.
2. Electrolyte above elements.
3. Between elements and jar.
4. Bottom of elements.
5. Top of elements.
6. Center group.
7. Group near edge.

Time	Air at Intake			Air in Duct			Evaporation
	1.	2.	3.	1.	2.	3.	grams per minute
1200	36.80	.74	.87	54.10	.83	.53	.3754
0030	-	.63	-	-	.75	-	-
0100	37.66	.65	.57	40.20	.75	.58	.0551
0130	34.27	.70	.80	56.10	.75	.50	.4738
0200	-	.61	.80	55.50	.75	-	-
0235	34.83	.65	.77	55.80	.72	.47	.4550
0300	28.32	.63	.72	54.65	.72	.40	.5715
0330	33.98	.63	.72	51.25	.72	.47	.3748
0400	-	.63	.55	39.35	.72	-	-
0430	-	.66	.47	32.55	.72	-	-
0445	34.55	-	-	-	.72	.45	-
0500	-	.63	.72	51.80	.72	-	-
0515	24.63	-	-	50.10	.72	.35	.5525
0530	28.32	.54	-	-	.72	.40	-
0540	-	-	-	-	.70	-	-
0600	30.87	.53	.52	37.10	.70	.40	.1352
0630	-	-	-	-	.69	-	-

1. Grams water per 100 cu.ft. air.
2. Relative humidity, wet-dry bulb thermometer.
3. Relative humidity, calculated.

Time	Voltages					
	1.	2.	3.	4.	5.	6.
1200	2.020	-	.995	-	1.066	-
0100	2.124	2.251	.987	1.083	1.129	1.172
0200	2.166	2.302	.995	1.093	1.164	1.213
0300	2.198	2.320	.977	1.078	1.205	1.278
0330	2.210	2.333	.980	1.063	1.218	1.273
0400	2.252	2.335	.990	1.064	1.244	1.273
0500	2.266	2.315	1.006	1.054	1.252	1.264
0600	2.285	2.348	1.012	1.073	1.262	1.276
0800	2.288	2.375	1.010	1.090	1.263	1.286
0900	2.300	2.420	1.014	1.121	1.271	1.301
0930	2.301	2.398	1.012	1.105	1.267	1.294
1000	2.276	2.337	1.007	1.063	1.261	1.276
1045	2.251	2.271	.998	1.019	1.249	1.253
1130	2.223	2.227	.992	.997	1.229	1.231

1. Voltage, open.
2. Voltage, closed.
3. Lead - mercurous sulphate, open.
4. Lead - mercurous sulphate, closed.
5. Lead peroxide - mercurous sulphate, open.
6. Lead peroxide - mercurous sulphate, closed.

Air flow constant at 2.17 cu.ft.

Test No. 19 (Continued)

Time	Current	Charging Current	Gassing Current	Hydrogen Percentage	Per Cent Charge	Gravity	Cell Resistance
1200	0-1300	1300	0	0	-	1168	.000161
0030	1300	1300	0	0	-	-	-
0100	1300	1292	8	.10	-	1171	.000097
0130	1300	1288	12	.15	-	-	-
0200	1300	1284	16	.20	55	1198	.000105
0235	1300-1050	1276-1030	24-20	.30-.25	71	-	.000080
0300	1050-800	1019-772	31-28	.38-.35	80	1228	.000080
0330	800-550	766-522	34-28	.42-.35	88	-	.000240
0400	550-330	514-302	36-28	.45-.35	94	1251	.000273
0430	330	298	32	.40	98	-	-
0445	330-250	294-218	36-32	.45-.40	100	-	.000250
0500	250	218	32	.40	101	1271	.000196
0515	250-190	210-156	40-34	.50-.42	103	-	-
0530	190	150	40	.50	104	1275	-
0540	190-165	142-141	48-24	.59-.30	104	-	-
0600	165	108	57	.70	105	1280	.000382
0630	165	101	64	.80	106	-	-
0700	165	85	80	1.00	107	-	-
0730	165	85	80	1.00	108	-	-
0800	165-250	82-115	83-135	1.05-1.70	109	1284	.000527
0830	250	-	-	-	110	-	-
0900	250-200	102-96	148-104	1.85-1.30	-	-	.000480
0930	200-100	84-48	116-52	1.45-.65	-	-	.000485
1000	100-50	44-22	56-28	.70-.35	-	-	.000610
1045	50-25	17-0	33-26	.38-.28	-	-	.000400
1130	25-0	7	18	.22	-	1286	.000160
1200	0	0	0	0	-	-	-
1235	0	0	0	0	-	-	-
1305	0	0	0	0	-	-	-

Test No. 19 (Continued)

Time	Heating Effect			Cooling Effect			Net	Temp. Rise	
	1.	2.	3.	4.	5.	6.	Effect	Calc.	/Found
1200	3914	2262	-	190	217	-	5800	-	-
0030	-	2262	-	60	-	-	4500	-	-
0100	2367	2248	423	60	32	102	4840	-	-
0130	-	2241	634	45	273	152	4830	-	-
0200	2534	2234	845	54	-	203	5080	10	9
0235	-	2221-1793	1268-1057	54	262	305-253	5680-4890	3	1
0300	1836	1773-1343	1637-1479	54	330	393-355	5070-3920	3	1
0330	1411	1333-908	1796-1479	54	216	431-355	3840-3170	2	0
0400	654	895-526	1902-1479	63	-	456-355	2680-2000	1.5	0
0430	-	519	1690	54	-	406	2100	-	-
0435	-	512-379	1902-1690	-	-	456-406	2010-1730	2	-
0500	176	379	1690	72	-	406	1470	-	1
0515	-	365-272	2113-1796	-	319	507-431	1740-1400	1	-
0530	-	261	2113	81	-	507	1740	-	-
0540	-	247-245	2536-1268	-	-	608-305	2150-1190	1	-
0600	148	188	3011	81	78	722	2470	-	0
0630	-	176	3380	-	-	811	2770	3	-
0700	-	148	4227	-	-	1014	3400	-	0
0730	-	148	4227	63	-	1014	3410	-	-
0800	206	143-200	4385-7117	81	-	1052-1708	3530-5660	4	0
0830	-	-	-	63	-	-	-	-	-
0900	430	178-167	7818-5492	81	-	1877-1318	6410-4640	6	-1
0930	[illegible]	146-84	6129-2747	90	-	1471-659	5040-2320	3	0
1000	87	77-38	2958-1479	-	-	710-355	2320-1160	1	-
1045	14	30-0	1743-1374	63	-	418-320	1300-1000	.5	-
1130	-	12	951	54	-	228	685	.5	-2
						Total Effect		41.5°	9°

1. Irreversible heat.
2. Reversible heat, normal reaction.
3. Heat of formation of gases.
4. Radiation and convection to air.
5. Evaporation loss.
6. Reversible, water electrolysis.

Test No. 20.

Bureau Procedure.
Cell discharged at 4330 ampere hours.

Time	Temperatures									
	Couple Groups									Duct at
	1.	2.	3.	4.	5.	6.	7.	Air	Bath	Gooseneck
0000	105	101	103	105	105	105	105	71	103	77
0030	106	102	106	106	106	107	106	75	105	84
0100	106	105	108	108	107	110	109	77	106	86
0130	106	105	110	110	110	113	111	77	104	86
0200	106	107	111	111	110	114	112	75	105	86
0230	106	108	112	114	112	116	114	76	106	88
0300	107	109	112	115	112	118	116	74	106	86
0320	109	109	114	117	112	119	118	74	105	86
0400	110	111	113	118	112	119	118	76	105	88
0430	111	111	111	118	113	118	116	76	104	88
0500	111	113	113	114	114	114	114	75	106	89
0530	-	-	-	-	-	-	-	75	106	89
0600	111	113	111	111	112	112	111	75	106	89
0630	-	-	-	-	-	-	-	75	106	89
0700	-	-	-	-	-	-	-	75	106	89
0720	111	111	111	111	111	111	111	78	106	91
0810	109	112	111	112	113	113	111	80	105	93
0845	108	110	109	111	111	111	111	80	104	93
0925	108	109	110	111	110	111	110	80	103	92
1010	107	108	108	109	110	110	110	80	102	91
1055	106	106	107	106	109	110	108	79	102	89
1130	106	106	106	106	108	108	107	79	101	89

1. Electrolyte below elements
2. Electrolyte above elements
3. Between cell jar and elements
4. Bottom of elements
5. Top part of elements
6. Center group
7. Group near edge

Time	Air at intake			Air in Duct			Evaporation
	1.	2.	3.	1.	2.	3.	grams per minute
0000	26.96	.55	.52	45.95	.89	.73	.4120
0030	27.50	.47	.45	51.00	.71	.73	.5100
0100	19.85	.45	.30	29.80	.77	.43	.2153
0130	25.50	.47	.40	54.80	.77	.77	.6340
0200	24.95	.56	.40	31.20	.85	.50	.1355
0230	24.95	.54	.40	48.00	.85	.67	.4980
0300	18.15	.57	.30	47.70	.85	.68	.6400
0320	25.80	.57	.40	44.30	.85	.65	.4000
0400	22.20	.48	.37	47.20	.80	.65	.5420
0430	27.20	-	.45	53.00	.80	.65	.5600
0500	26.20	.48	.42	54.40	.76	.70	.6145
0530	26.20	.50	-	55.30	.73	.65	.6340
0600	25.80	.50	.42	56.80	.73	.67	.6780
0630	26.90	.50	.43	53.80	.73	.63	.5840
0700	-	-	-	-	-	-	-
0720	-	-	-				

1. Grams of water per 100 cu.ft. air
2. Relative humidity, wet-dry bulb thermometer.
3. Relative humidity, calculated

Air flow 2.17 cu.ft. per min.

Test No. 20 (continued).

Time	Current	Gassing Current	Charging Current	Percent Charge	Percent Hydrogen	Gravity	Cell Resistance
0000	0-1300	0	1300	-	0	1170	-
0030	1300	0	1300	-	0	-	-
0100	1300	9	1291	-	.11	1176	.000098
0130	1300	15	1285	-	.19	-	-
0200	1300	20	1280	-	.25	1185	.000112
0230	1300-1050	28	1272-1022	74	.35	-	.000120
0300	1050-800	34-32	1016-768	88	.42-.40	1230	.000120
0320	800-550	34-32	766-518	94	.42-.40	-	.000120
0400	550-330	34-32	516-298	102	.42-.40	1260	.000182
0430	330-250	33-32	297-218	105	.41-.40	-	.000125
0500	250-190	32	218-158	108	.40	1277	.000333
0530	190-165	32	158-133	109	.40	-	-
0600	165	32	133	-	.40	1280	.000176
0630	165	33	132	-	.42	-	-
0700	165	36	129	-	.45	1283	-
0720	165-250	36-56	129-194	115	.45-.70	-	.000353
0810	250-200	73-59	177-141	-	.93-.75	-	.000400
0845	200-150	71-47	129-103	-	.90-.60	-	.000600
0925	150-100	63-39	87-61	-	.80-.50	-	.000800
1010	100-50	44-24	56-26	-	.55-.30	-	.001200
1055	50-25	25-21	25-4	-	.32-.26	-	.000800
1130	25-0	21-0	4-0	-	.26-.22	-	.000200

Time	Voltages					
	1.	2.	3.	4.	5.	6.
0000	2.025	2.220	.956	1.056	1.071	1.181
0100	2.132	2.260	.986	1.086	1.136	1.178
0200	2.165	2.310	.989	1.094	1.169	1.234
0300	2.200	2.337	.981	1.069	1.214	1.277
0400	2.262	2.346	.993	1.072	1.253	1.289
0500	2.280	2.320	1.004	1.049	1.259	1.274
0600	2.277	2.306	1.009	1.045	1.262	1.273
0720	2.279	2.321	1.012	1.053	1.254	1.268
0810	2.289	2.376	1.015	1.093	1.260	1.285
0845	2.286	2.362	1.014	1.084	1.258	1.279
0925	2.277	2.345	1.009	1.072	1.254	1.274
1010	2.267	2.313	1.003	1.051	1.254	1.264
1055	2.202	2.255	.997	1.014	1.239	1.243
1130	2.215	2.220	.991	.995	1.222	1.225

1. Voltage - open
2. Voltage - closed
3. Lead - mercurous sulphate, open
4. Lead - mercurous sulphate, closed
5. Lead peroxide - mercurous sulphate, open
6. Lead peroxide - mercurous sulphate, closed

Test No. 20 (continued)

Time	Heating Effects			Cooling Effects			Net Effect	Temp. rise Cal.	Temp. rise Found
	1.	2.	3.	4.	5.	6.			
0000	3634	2262	0	54	238	0	5604	-	-
0030	-	2262	0	81	294	0	4897	-	-
0100	2386	2247	456	81	124	114	4770	5.5°	5°
0130	-	2236	762	81	365	190	4906	-	-
0200	2702	2227	1014	99	77	254	5513	5.5	4
0230	-	2213-1778	1420	108	286	355	5586-5149	3	1
0300	2063	1767-1336	1726-1623	108	368	431-406	4649-4140	2.5	1
0320	-	1333-902	1726-1623	108	230	431-406	3390-2881	1	.5
0400	662	898-519	1726-1623	108	314	431-406	2433-2036	2	0
0430	-	517-379	1674-1623	108	324	418-406	1671-1494	1	0
0500	143	379-275	1623	126	354	406	1259-1155	.7	.5
0530	-	275-232	1623	-	365	406	1061-1018	-	-
0600	69	232	1623	126	390	406	1002	1	-1.5
0630	-	230	1674	-	336	418	1104	-	-
0700	-	225	1826	-	-	456	1223	1	-
0720	99	225-338	1826-2842	117	336	456-710	1241-2116	.5	-1
0810	312	308-245	3704-2994	117	336	926-748	2945-2350	2.5	1
0845	218	225-179	3602-384	117	336	901-596	2691-1732	1.5	-1.5
0925	146	151-106	3197-1979	108	336	799-495	2251-1292	1.5	-
1010	66	97-45	232-1218	99	336	558-304	1402-590	1	-1.5
1055	9	44-7	1268-1066	90	336	317-266	578-390	.5	-
1130	2	7-0	1066	90	336	266-0	383	-	-2
					total effect			30.7°	5.5°

1. Irreversible heat
2. Reversible heat, normal reaction
3. Heat of formation of gases
4. Radiation and convection to air
5. Evaporation loss
6. Reversible heat, water electrolysis