LEAD-ACID TYPE STORAGE BATTERIES
CONTINUOUS VARIABLE CURRENT CHARGE OPERATION

1. GENERAL

1.01 This section describes the continuous variable current charge operation of lead-acid-type storage batteries.

1.02 This section replaces information previously in a section which is now cancelled. The information is brought up to date and individual cell readings are discontinued. Changes from previous recommendations are marked with arrows.

1.03 Charging current may be supplied over cable pairs from another office or from a local charger. In either case, the output of the charging source is "fixed" in that it is not adjusted frequently to hold the battery voltage or state of charge within narrow limits. Operation is based on a period of time (usually a week). There will be some discharge and drop in specific gravity during the busy period each day. Part of this discharge will be replaced during the light load period (usually at night) but complete recharge, plus some excess charge, will be at the extended light load period (usually at the week end) Figure 1 and references in the text to a particular day of the week assume this usual weekly cycle. With different cycles, some interpretation is necessary. For example, at a resort town, where the week end is the heavy load period and Saturday morning is the end of the extended light load period, references in the text to Monday morning should be changed to Saturday morning.

1.04 Too high a setting of the output of the charging source, called charger output herein, results in excessive charging which will increase the water loss and reduce the life of the positive plates and separators. On the otherhand, a charger output that does not provide complete recharge will cause sulfation of the negative plates. Also, too much daily discharge in excess of charge will reduce the battery capacity to too low a value at some point or points of the cycle.

1.05 The state of charge of a battery is indicated by the relation of the corrected specific gravity of the electrolyte to the full charge corrected specific gravity, assuming the level of the electrolyte to be the same at both readings. In other words, a drop of 10% of the gravity range indicates approximately 10% discharged and 90% remaining capacity. Height of the electrolyte in eighths of an inch below maximum level should be recorded whenever hydrometer readings are recorded. Do not discharge beyond the gravity range and do not allow cells to remain fully or nearly discharged. For other definitions see 157-601-101.

1.06 Fig. 1 illustrates typical changes to be expected in the state of charge of the battery during the week. It shows that hydrometer readings taken at different points in the weekly cycle are not comparable. About 15% daily discharge in excess of charger output for the load section of the day is the maximum with which this method of operation will prove successful. Where greater daily discharge would be unavoidable with one charging rate, it may be feasible to use two rates, one for the heavy load or attended portion of the day and one for the light load period or possibly one for the working portion of the week and one for the weekend. Two charger out put rates should be resorted to only with the approval of the supervisor. Whether there is one or two charger output rates, there must be some discharge of the battery every working day and the battery should get back to full charge only near the end of the weekly light load period.

1.07 Water should be added after rather than before taking specific gravity readings. The electrolyte level in the pilot cell should be maintained in the upper quarter of the allowed range so that there will be less error in comparing specific gravity readings.

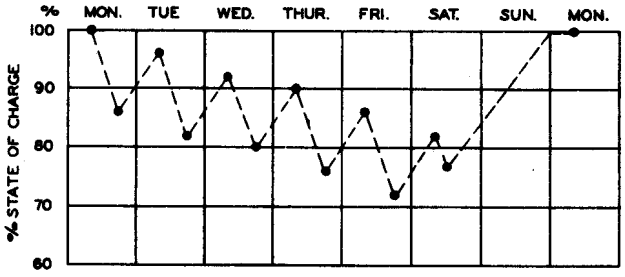


Fig. 1 - Typical State of Charge Curve for Office Having Appreciable Day Loads During a Business Week and Light Loads at Night and During Week Ends.

1.08 Except where special corrective action has been recommended for a particular battery, these routines apply at all room temperatures between electrolyte freezing temperature and 100F and for cells with full charge corrected specific gravity below 1.225. Temperatures below 80F are preferred. Where average temperatures for the 24-hour day exceed 100F special operating methods may be necessary.

1.09 This type of operation is not generally applicable to plants having emergency cells. If, however, there are emergency cells, they shall be operated as outlined in 157-601-302 for emergency cells.

1.10 See 157-601-701 for nominal charging rates, gravity ranges, maximum and minimum levels, ampere-hour rated capacities, electrolyte specific gravity and voltage requirements, method of reading hydrometers, method of correcting specific gravity readings for temperature, approved water, precautions against explosions, spilled electrolyte, etc.

Caution: Avoid creation of sparks, including those from static electricity, or the use of an open flame near batteries since the gas given off by the battery is explosive.

1.11 Information in this section is arranged under the following headings:

1. GENERAL

2. OPERATION

3. RECORDS

2. OPERATION

2.01 Set the charger output initially at approximately 120% of the average 24-hour working day load of the office or if this is difficult to determine, set it at two-fifths of the busy-hour load. On Monday morning before heavy load starts, determine the corrected specific gravity of the pilot cell. Lower the charger output rate 5% weekly until the Monday morning pilot cell corrected specific gravity readings show a downward trend (2.02). Then raise the charger output setting 5% and leave at this value.

2.02 A downward trend shall be two Monday morning corrected specific gravity readings each lower than the previous when there has been no appreciable change in load, charger output setting or pilot cell electrolyte level. Lowering of the charger setting (2.01) should be discontinued when the first lower specific gravity is observed. This is to see if the drop is really part of a downward trend.

2.03 Where convenient and load is not too irregular, it is suggested that a chart similar to Fig. 1 be prepared for each office based on the pilot cell corrected specific gravities taken morning and night each working day for one week. Each actual chart will not only give a good indication of proper setting but will also permit interpretation of specific gravity readings taken at any hour of any day. On such chart for a particular office, it will be more convenient to plot corrected specific gravities rather than state of charge in per cent but the state of charge at the lowest point (Friday afternoon) should be determined to be sure adequate battery reserve is maintained in accordance with local requirements. Draw curve from end of load on last working day to full charge at same slope as Monday recharge curve.

2.04 Charger output should be increased on indications of inadequate charge such as

(a) Evidence of sulfation. See 157-601-701. Increase charger output 5% and report to supervisor.

(b) Red charge indicators down or hydrometer reading indicating two-thirds discharged at any time except after a power failure. Recharge as soon as practicable at a rate not exceeding the battery nominal charge rate until the white charge indicators have been floating for at least an hour or hydrometer readings indicate 85 to 90% charge. Except where load was nonrecurrent, increase charger output 10% and report to supervisor.

(c) Corrected specific gravity more than 15% of the gravity range below the value to be expected for that point in the weekly cycle from an office charge similar to Fig. 1. Increase charger output 5%.

Example: The battery shown in Fig. 1 is expected to be 78% charged (down 22%) at 4 P.M. Thursday. If there has been no high and nonrecurrent load on the office, the charging rate is too low when the corrected specific gravity is down more than 22+15=37%. This would be .37x86=32 points for a cell with a gravity range of 86.

(d) White charge indicators down or hydrometer readings showing one-third discharged. Unless load was nonrecurrent, increase charger output 5%.

(e) Corrected specific gravity more than 10% of the gravity range below the initial (or last equalizing) charge value at the end of the extended light-load period (Monday morning). Increase charger output 5%.

2.05 Charger output should be decreased 5% on indications of excessive charge such as

(a) Voltage above 2.30 volts per cell or above maximum circuit voltage limits for the office at any time during the load period of the day.

(b) Water loss in excess of values shown in Fig. 2 or excessive gassing. With some installations, excessive over charge and associated excess water loss are unavoidable if there is not to be too low state of charge at the point of maximum discharge (Friday afternoon). Where this unfavorable condition exists, operate at the excessive rate but notify the supervisor. To determine per cent daily discharge for use in applying Fig. 2, subtract pilot cell specific gravity at end of working day from that at start of day. This value divided by the gravity range of the cell is the per cent discharged.

(c) Water loss on KS-5361, List 120 or 120A, cells sufficient to cause white charge-indicator to float but below the white line provided the cell had been filled to maximum level within six weeks.

2.06 Charger output settings are based on cut and try procedures and changes are suggested based on possibly contradictory indications. In case of conflict, follow the suggestion which seems most likely to give the desired result. Suggested changes in charger output settings are so small that the effect of conflicts will be absorbed in a reasonable time without damage to the battery.

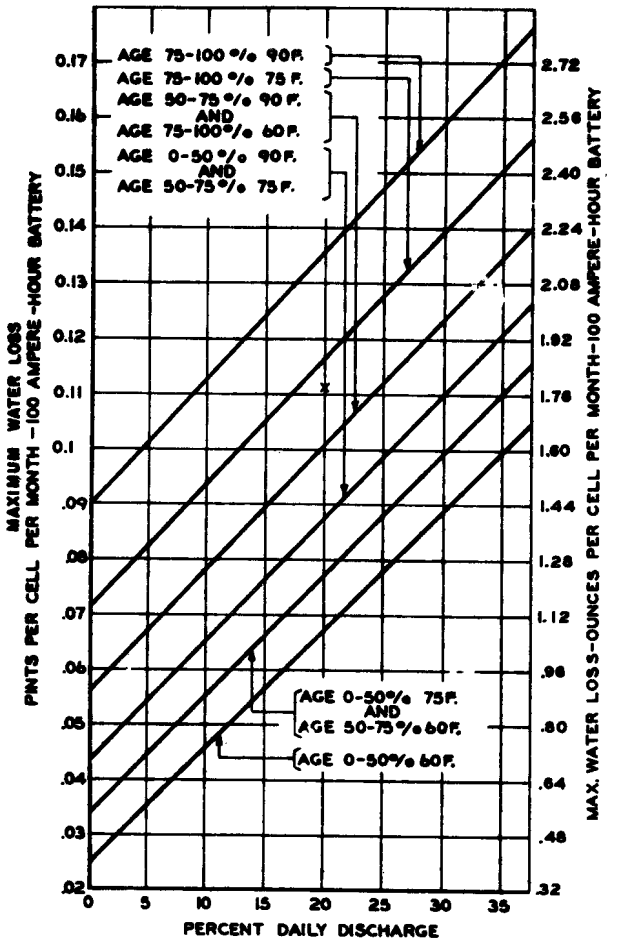
2.07 An equalizing charge may be necessary:

(a) In case of charging current interruption known to have lasted more than one working day.

(b) If, with electrolyte at the same or lower level, the full charge corrected specific gravity decreases more than 5 points (0.005) in any one year.

2.08 If an equalizing charge is ordered, it should be by the constant current method as outlined in 157-601-302 but using average instead of constant values of the current actually applied to the battery as the basis of the charge.

2.09 Where operation by this method is unsuccessful, the supervisor may wish to consider use of a larger battery or the provision of some form of charge control such as a voltage relay.



NOTES:
1. PINTS (OR OUNCES)-ARE PER CELL PER MONTH AND SHOULD BE MULTIPLIED BY THE NUMBER OF MONTHS AND NUMBER OF CELLS. VALUES ARE FOR A 100 AMP.-HOUR BATTERY. DIVIDE BY 100 AND MULTIPLY BY RATED 8 HOUR CAPACITY OF THE BATTERY FOR OTHER SIZES.
2. PERCENT DAILY DISCHARGE-IS IN PERCENT OF 8 HOUR CAPACITY.
3. TEMPERATURES-ARE OF ELECTROLYTE AND ARE THOSE AVERAGING OVER THE PERIOD FOR WHICH WATER LOSS WAS MEASURED.
4. AGE-IS IN PERCENT OF THE ANTICIPATED LIFE GIVEN IN THE REQUIREMENT SECTION.
5. EXAMPLE-IF LOSS FOR 3 MONTHS AT 75 F. ON A 12 CELL KS-5361 L.150 BATTERY IS 4 PINTS, THE LOSS PER CELL PER MONTH IS 4 ÷ 36 = 0.111 PINTS. SINCE THIS FALLS BELOW THE 75-100% 75 F. DIAGONAL IT IS SATISFACTORY. ASSUMING 20% DISCHARGE AND 80% AGE.

Fig. 2 - Maximum Water Loss for Sealed-Type Batteries with Specific Gravity Below 1.225

2.10 In some cases, due to plant design, customer relations or other local considerations the supervisor may authorize replacing the continuous variable current charge by a charge-discharge routine. In such case, the charge should be started

when voltage drops below 1.95 volts per cell or specific gravity readings indicate the battery is between 1/2 and 1/3 discharged. The charge rate should be greater than the busy hour load in amperes but less than the eight hour discharge rate of the battery. It should be continued until three voltage readings at 15-minute intervals show no increase in voltage or until three hydrometer readings at 15-minute intervals show no increase in specific gravity. During such charge, neither 2.30 volts per cell nor office maximum voltage limits should be exceeded. The supervisor should authorize a return to continuous variable current as soon as feasible.

3. RECORDS

3.01 Record the date and time of taking any recorded readings.

3.02 The attendant at a manual board should be asked to advise the proper plant department employee whenever a red or white charge-indicator is down. (White indicator below the white line for KS-5361, List 120 and 120A cells). In addition, the responsible plant department employee should check the condition of the battery often enough to be sure of proper operation. When personal inspection is inconvenient, the attendant may be questioned by phone as to the position of the charge-indicators.

Optional Observations (Use form E-2141)

3.03 The observations and records discussed in 3.04 to 3.06 are desirable and give the most dependable indication of good operation with least danger of power plant failure. It is obvious, however, that they are impossible, if the cells are not equipped with charge indicators and that all or part of them are impracticable at unattended offices unless arrangements have been made with some other department (possibly the traffic department in manual offices or building maintenance forces in dial offices) to make them as well as to notify the proper plant department employee when certain adverse conditions (3.04) exist. Discuss with supervisor.

3.04 Each working day, preferably during the first half hour, note position of charge-indicators in pilot cell. Also note and record whether or not charger ammeter, if any, is registering. If these observations are made by other than responsible plant department employee, he should be notified if ammeter is not registering or if white charge-indicator is below the white line for KS-5361, List 120 or 120A, cells or at bottom of cage for other cells not marked with the white line. He should be called at any time of the day that it is noted that a red charge-indicator is at the bottom of the cage.

3.05 Weekly on Monday morning and, if convenient, on Sunday morning also, record whether green and white charge-indicators of the pilot cell are down or up.

3.06 Monthly at any time Sunday or before noon on Monday, record whether green and white charge-indicators of all cells so equipped are down or up. Any white charge-indicator down at this time indicates the need for a check of conditions and possibly an increase in charger output (2.04) or an equalizing charge (2.07).

Regular Required Observations

3.07 When water is added to all cells, record the amount of water added to the battery and which cell if any required appreciably more water than other cells. The water record may be on E-2141, E-2006 or local forms as convenient. The water added at more frequent intervals to the pilot cell only to maintain its level in the upper quarter of the range need not be recorded.

3.08 When charger output is changed, record rate in amperes before and after the change.

3.09 When hydrometer readings, are recorded, record also electrolyte temperature and level of electrolyte in eighths of an inch below maximum.

3.10 Monthly record (E-2006), the pilot cell corrected specific gravity, the battery voltage and charger output in amperes. Note position of all charge-indicators but this need be recorded only for cells with red indicators down. These "monthly" readings are required weekly during charger output adjustment (2.01) after which they may be scheduled for any period from one to six weeks depending on the importance of the office, frequency of visits by the attendant and past experience with similar installations. After a major change in office load or indications of unsatisfactory operation, the readings should return to the weekly basis until setting is satisfactory.

3.11 Record at any time irregularities in gassing, charger operation, etc., as well as local conditions affecting cell temperatures and too frequent high- or low-voltage alarms.

FORM E-2141

STORAGE BATTERY REPORT
NO. 102 - D POWER PLANT FOR NO. 12 OFFICE

SHEET NO.________

PLANT ATTENDANT____________________ ____________________CITY AND STATE

____________________OFFICE

APPROVED BY____________________ FROM______________19______ TO______________19______

DAILY IS AMMETER INDICATING? √= YES X = NO				WEEKLY IS INDICATOR UP IN PILOT CELL? √= UP X = DOWN			CHARGE ADJUSTMENT			PILOT CELL NO.______ BATTERY TYPE______ BATTERY NO.______	QUARTERLY DATE______	
DAY	MONTH			DATE	GREEN	WHITE	DATE	BEFORE	AFTER	REMARKS	CELL NO.	CELL VOLTS
1											1	
2											2	
3											3	
4											4	
5											5	
6											6	
7											7	
8											8	
9											9	
10											10	
11											11	
12											12	
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21											21	
22											22	
23											23	
24												
25											AVG	
26												
27												
28												
29												
30												
31												

MONTHLY IS INDICATOR UP IN EACH CELL HAVING INDICATORS? √= UP X = DOWN	GREEN								WHITE								ADDITION OF WATER EXCEPT TO PILOT CELL	
CELL NO.	2	5	8	11	14	17	20	23	2	5	8	11	14	17	20	23	DATE	PINTS
DATE																		

Form E-2141

FORM E-2006
(1-48)

STORAGE BATTERY REPORT
AUTOMATICALLY CONTROLLED BY____________
CONTINUOUS VARIABLE CURRENT
PILOT CELL READINGS

SHEET NO.______

____________________CITY AND STATE

READINGS TAKEN BY____________________ ____________________OFFICE

APPROVED BY____________________ FROM______________19______ TO______________19______

DATE	TIME	HYDROMETER READING	TEMP. ELEC. F.	SP. GR. CORRECTED TO F.	METER PERCENT DISCHARGE	70 OR 77 F. SP. GR. CORRECTED TO FULL CHARGE	BAT. VOLTS	CHARGE EQUIP. OUTPUT AMP.	
BATTERY NO.______ PILOT CELL NO.______ AMP. HR. METER CAP.______ AMP.______ AMP. HRS. COR. FACTOR______ PER 1%									
BATTERY NO.______ PILOT CELL NO.______ AMP. HR. METER CAP.______ AMP.______ AMP. HRS. COR. FACTOR______ PER 1%									

			BATTERY NO.			REMARKS
BAT. DATA	CELLS	NUMBER				
		TYPE				
	PLATES PER CELL	EQUIPPED				
		CAPACITY				
NOMINAL CHARGING RATE						
NOMINAL GRAVITY RANGE						
DATE AND SP. GR. OF LAST EQUAL. CHARGE						

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Form E-2006