

Engineering Procedure

SAEP-350

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Regular Maintenance and Testing for Industrial Stationary Batteries

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1 Scope

This engineering procedure provides maintenance, test schedules and test procedures that optimize the life and performance of batteries used for stationary applications in Saudi Aramco industrial facilities. It also provides guidelines to predict the remaining life of the battery and determine when the battery is due for replacement.

2 Applicable Documents

2.1 Saudi Aramco References

Saudi Aramco Engineering Standard

[SAES-P-103](#) *Direct Current and UPS Systems*

Saudi Aramco Material Specification

[17-SAMSS-511](#) *Stationary Storage Batteries*

Saudi Aramco General Instruction

GI-0002.100 Work Permit System

2.2 Industry Codes and Standards

Institute of Electrical and Electronics Engineering, Inc

IEEE 450 Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications

IEEE 1106 Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications

IEEE 1188 Recommended Practice for Installation, Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Application

National Fire Protection Association

NFPA 70 National Electrical Code

3 Safety

3.1 Testing and maintenance of batteries shall be in full compliance with GI-0002.100 "Work Permit System".

- 3.2 Maintenance shall make sure the following personal protective equipment are available in the battery room before working with the batteries:
- a) Safety face shields and goggles
 - b) Safety aprons
 - c) Acid resistance rubber gloves
 - d) Eye washing facility (in case of acid contact with your eyes or skin, flush your with water for continuous 15 minutes and contact a physician immediately)
 - e) Safety shoes
 - f) Dry chemical fire extinguisher
 - g) Thermometer
 - h) Ample amount of neutralizing agent to neutralize electrolyte spillage
 - Lead acid battery: Bicarbonate of soda, mixed 0.1kg to 1.0 liter water
 - Ni-Cd battery: Boric acid solution, mixed 50gram to 1.0 liter water
 - Or other suitable neutralizing agent recommended by the manufacturer for acid electrolyte spillage or the manufacturer of alkaline electrolyte spillage, whichever applicable.
- 3.3 Use the following precautions when working on the batteries
- a) Use adequately insulated tools.
 - b) Use caution when working on batteries since they represent electric shock hazard.
 - c) Prohibit smoking and open flames, and avoid the chance of arcing in the immediate vicinity of the battery.
 - d) Ensure the battery room ventilation is operational and the battery room temperature is maintained at 25°C.
 - e) Ensure unobstructed egress from the battery room area.
 - f) Avoid wearing metallic object such as jewelry.
 - g) Ensure that the load test leads are clean, in good condition, and connected with a sufficient length of cable to prevent accidental arcing in the vicinity of the battery.
 - h) Ensure that the load test leads ampacity is adequate for the discharge current of each battery bank.
 - i) Ensure that all connections to load test equipment include short-circuit protection.
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- j) Neutralize static buildup just before working on a battery by having personnel contact nearest effectively grounded surface.
- k) Make sure that all vents of the cells/batteries are closed tightly before starting the battery testing process.

4 Battery Preventive Maintenance

Efficient battery maintenance practice will lengthen the battery life and will assist in guaranteeing its capability to fulfill its design requirements.

Maintenance and test data shall be dated, recorded, and maintained in a permanent file to facilitate required future maintenance, testing and analysis of the operating data.

Abnormalities in any of these items shall necessitate immediate corrective action.

Commentary Notes:

- 1) *For measurements at temperatures other than the 25°C ambient, applicable correction factors of Attachment 1 of this standard shall be used to calculate the actual data that reflects real operating condition.*
- 2) *Complete maintenance and test records shall be kept in a safe location inside the battery room.*

4.1 Preventive Maintenance for Vented Lead-Acid Batteries

4.1.1 Monthly Preventive Maintenance Activities

The following monthly check and record activities shall be conducted for vented lead-acid batteries:

- a) Visual inspection of batteries, battery rack and/or battery cabinet general appearance and cleanliness.
 - b) Overall float voltage measured at the battery terminals.
 - c) Charger output voltage and current. Adjust charging voltage as recommended by battery manufacturer.
 - d) Electrolyte level of each cell. If necessary, add distilled water to reach electrolyte max level.
 - e) Cracks in cells or leakage of electrolyte; and replace cracked cells.
 - f) Any evidence of corrosion at terminals, connectors, racks or cabinets. Take immediate corrective action on any abnormality.
 - g) Room temperature (Reference = 25°C) and ventilation mechanism.
 - h) Electrolyte specific gravity and temperature of pilot cell.
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(Specific Gravity Reference: Refer to battery manufacturer data)

4.1.2 Quarterly Preventive Maintenance Activities

The following quarterly preventive maintenance activities shall be conducted for vented lead-acid batteries. Check and record the following:

- a) Conduct all monthly PM activities.
- b) Electrolyte specific gravity of 10% of the cells in the battery bank.
- c) Voltage of each cell and voltage of the overall battery bank. Take immediate corrective action on every cell that measures an abnormal value.

4.1.3 Yearly Preventive Maintenance Activities

The following yearly preventive maintenance activities shall be conducted for vented lead-acid batteries

- a) Conduct all quarterly PM activities.
- b) Temperature of electrolyte of 10% of the cells in the battery bank (Maximum acceptable deviation shall be 3°C from the average temperature of all the cells).
- c) Electrolyte specific gravity of each cell.
- d) Remove all inter-cell connectors, clean them and cell/battery terminals, apply anticorrosion grease, then refit all inter-cell connectors and tighten each bolt to maximum torque that is recommended by battery manufacturer.
- e) Inter-cell connection resistance measured using a micro-ohmmeter [Ranges from less than 10 $\mu\Omega$ for large batteries (i.e., capacity > 100Ah) to around 100 $\mu\Omega$ for small batteries (i.e., capacity $\leq$ 100Ah)]. Immediate corrective action shall be taken if the results show more than 20% change in value from the previously established baseline value or a value that exceeds the manufacturer recommended limit. Refer to Appendix D.2 in IEEE 450 - 1995 for more details.

4.2 Preventive Maintenance for Vented Nickel-Cadmium Batteries

Inspection of vented nickel cadmium battery shall be performed on a regularly scheduled basis and shorter intervals shall be selected based on site conditions.

Immediate corrective action shall be taken for any abnormalities in the measurements and/or physical conditions.

4.2.1 Monthly Preventive Maintenance Activities

Monthly maintenance activities are not required for vented nickel-cadmium batteries.

4.2.2 Quarterly Preventive Maintenance Activities

The following quarterly preventive maintenance activities shall be conducted for vented nickel-cadmium batteries; and shall include checking and recording the following:

- a) Visual inspection of batteries, battery rack and/or battery cabinet; general appearance and cleanliness.
- b) Voltage at each cell and the battery bank overall float voltage. Take immediate corrective action on every cell that measures an abnormal value.
- c) Charger output voltage and current. Adjust charging voltage as recommended by battery manufacturer.
- d) Electrolyte level of each cell. If necessary, add distilled water to reach electrolyte max level.
- e) Cracks in cells or leakage of electrolyte; and replace cracked cells.
- f) Any evidence of corrosion at terminals, connectors, racks or cabinets. Take immediate corrective action on any abnormality.
- g) Room temperature (Reference = 25°C) and ventilation mechanism.
- h) Electrolyte temperature of Pilot cell.

4.2.3 Yearly Preventive Maintenance Activities

The following yearly preventive maintenance activities shall be conducted for vented nickel-cadmium batteries:

- a) Conduct all quarterly PM activities.
- b) Integrity of the battery rack or cabinet.
- c) Temperature of each cell electrolyte in the battery bank. (Maximum acceptable deviation shall be 5°C from the average temperature of all the cells).
- d) Remove all inter-cell connectors, clean them and cell/battery terminals, apply anticorrosion grease, then refit all inter-cell connectors and tighten each bolt to maximum torque that is recommended by battery manufacturer.

4.3 Preventive Maintenance for Valve Regulated Lead-Acid Batteries (VRLA)

Inspection of VRLA batteries shall be performed on a regularly scheduled basis.

Shorter intervals shall be selected based on site conditions but the intervals not to exceed the following recommendations. Abnormalities of any of these shall necessitate immediate corrective action.

4.3.1 Monthly Preventive Maintenance Activities

Monthly preventive maintenance activities shall be conducted for VRLA batteries; check and record the following:

- a) Visual inspection of batteries, battery rack and/or battery cabinet general appearance and cleanliness.
- b) Overall float voltage measured at the battery terminals.
- c) Charger output voltage and current. Adjust charging voltage as recommended by battery manufacturer.
- d) Cover integrity and check for cracks in cells or leakage of electrolyte. Replace cracked cells immediately.
- e) Any evidence of corrosion at cells terminals. Take immediate corrective action on any abnormality.
- f) Room temperature (Reference = 25°C) and ventilation mechanism.

4.3.2 Quarterly Preventive Maintenance Activities

The following quarterly preventive maintenance activities shall be conducted for VRLA batteries:

- a) Conduct all monthly PM activities.
- b) Measure voltage of each cell and compare with the manufacturer recommended value. Take immediate corrective action on every cell that measures an abnormal value.
- c) Temperature of the negative terminal of each cell (Maximum acceptable deviation shall be 3°C from the average temperature of all the cells).
- d) Cell internal resistance. Conduct performance (load) test if results show 20% upward trend from the established baseline values.

4.3.3 Yearly Preventive Maintenance Activities

The following yearly preventive maintenance activities shall be conducted for VRLA batteries:

- a) Conduct quarterly PM activities.
- b) Check integrity and tightness of inter-cell connectors.
- c) Inter-cell connection resistance measured using a micro-ohmmeter [Ranges from less than $10\mu\Omega$ for large batteries (i.e., capacity > 100Ah) to around $100\mu\Omega$ for small batteries (i.e., capacity $\leq$ 100Ah)]. Immediate corrective action shall be taken if the results show more than 20% change in value from the previously established baseline values. Refer to Appendix D.1 in IEEE 1188 - 1996, for more details.

5 Battery Capacity Test

Battery capacity test has same procedures for both acceptance test and performance (load) test for each battery type.

Exception:

Other testing methods practiced by Saudi Aramco maintenance organizations that are proven to satisfy the objective of the capacity test described in this section are acceptable.

5.1 Capacity Test Duration

The test period shall be the time it takes the battery to be discharged according to the manufacturer design to reach the battery end of discharge voltage. The test shall be continued until the new terminal voltage (calculated as 1.75 V/cell for lead acid batteries and 1.10 V/cell for nickel cadmium batteries) is reached.

5.2 Capacity Test Discharge Rate

The battery shall be discharged at a constant current equal to the discharge current provided in the battery manufacturing for the designed battery back-up time. If the design battery back-up time is more than 8 hours, then the test discharge rate shall be based on the 8 hours discharge rate of the battery as specified by the battery manufacturer regardless of the battery back-up time. It is required, for future comparison purposes, that the capacity tests are consistently conducted at the same discharge rate.

5.3 Capacity Test Schedule

5.3.1 Battery Acceptance Test

Acceptance test shall be performed in accordance with [17-SAMSS-511](#) paragraph 14.2. The test procedures for battery acceptance shall be the

same as those mentioned in the performance (load) test for each battery type below.

5.3.2 Performance (load) test for Vented Lead-Acid batteries

- a) A performance test shall be conducted within the first two years of installation.
- b) Additional performance tests shall be conducted at five-year intervals until battery starts to show signs of degradation.
- c) Annual performance test shall be made when the battery shows signs of degradation or has reached 85% of its expected life. Degradation is indicated when battery drops more than 2% per year of rated capacity from its capacity on the previous performance test, or is below 90% of the manufacturer rating.

5.3.3 Performance test for Vented Nickel-Cadmium batteries

- a) A performance test shall be conducted within the first two years of installation.
- b) Additional performance tests shall be conducted at five-year interval until battery shows signs of degradation.
- c) Annual performance test shall be made when the battery starts to show signs of degradation. Degradation is indicated when battery drops more than an average of 1.5% per year of rated capacity from its capacity on the previous performance test.

5.3.4 Performance Test for Valve Regulated Lead-Acid Batteries (VRLA)

Performance test shall be conducted on annual bases for VRLA batteries unless the test result is less than 90% of the manufacturer rating or drops more than 10% per year from the previous test result, then the test shall be done on a semi-annual basis.

5.4 Capacity Test Procedures

5.4.1 Capacity Test Procedure for Vented Lead-Acid Batteries

The following procedures shall be followed in order to conduct the capacity test for vented lead-acid batteries:

- a) Equalize the batteries for 72 hrs (subject to battery manufacturer recommended practice) and then return to float charge within 30 days before the test start date.
 - b) Perform all the monthly, quarterly and yearly maintenance activities specified in this procedure.
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- c) Disconnect the charging source and critical load from the battery set, connect the load bank to this battery set and start timing.
- d) Maintain a constant discharge current equal to the manufacturer's rating of the battery for the selected test length until the terminal voltage reaches end of discharge voltage of 1.75VDC per cell (Battery bank terminal voltage = 1.75VDC X Number of cells).
- e) Read and record individual cell and the battery terminal voltage at specified intervals during the test. As an example, for 30 minutes battery autonomy: Approx. one reading/measurement every 5 minutes; but for 30 minutes battery autonomy: Approx. one reading/measurement every 10 minutes could be satisfactory.
- f) If one or more cells reach reversal of its polarity (+1.0 V or less) and the test is 90-95% near completion, continue with the test until the desired terminal voltage is reached.
- g) If earlier in the test an individual cell is approaching reversal of its polarity, stop the test to bypass this faulty cell. The new terminal voltage shall be 1.75 VDC X Number of remaining cells.
- h) When the battery terminal voltage reaches the end of discharge voltage, terminate the test and record the time.
- i) Calculate the test result using the following equation:

$$\% \text{ Capacity at } 25^{\circ}\text{C} = (T_a/T_s) * 100 \quad (1)$$

Where:

T_a = Actual discharge time to reach 1.75VDC per cell

T_s = Rated discharge time to reach 1.75VDC per cell

Commentary Note:

If the average electrolyte temperature is different from 25°C by more than $\pm 1^{\circ}\text{C}$, the battery capacity test result shall be corrected according to Table 1 in Attachment 1 of this procedure.

5.4.2 Capacity Test Procedure for Vented Nickel-Cadmium Batteries

The following procedures shall be followed in order to conduct the capacity test vented nickel-cadmium batteries:

- a) Equalize the batteries for 24 hrs (subject to battery manufacturer recommended practice) and then return to float charge within 30 days before the test start date.

- b) Perform all the monthly, quarterly and yearly maintenance activities specified in this procedure.
- c) Disconnect the charging source and critical load from the battery set, connect the load bank to this battery set and start timing.
- d) Maintain a constant discharge current equal to the manufacturer's rating of the battery for the selected test length until the terminal voltage reaches the end of discharge voltage (End of Discharge Voltage = 1.1 VDC per cell X Number of cells).
- e) Read and record individual cell and the battery terminal voltage at specified intervals during the test.
- f) If one or more cells reach reversal of its polarity and the test is 90-95% near completion, continue with the test until the terminal voltage is reached.
- g) If earlier in the test an individual cell is approaching reversal of its polarity, stop the test to bypass this faulty cell. The new terminal voltage shall be (1.1 VDC X Number of remaining cells).
- h) Observe abnormal inter-cell connector heating.
- i) When the battery terminal voltage reaches the end of discharge voltage, terminate the test and record the time.
- j) Calculate the test result using the following equation:

$$\% \text{ Capacity at } 25^{\circ}\text{C} = (T_a/T_s) * 100 \quad (2)$$

Where:

T_a = Actual discharge time to reach 1.1VDC per cell

T_s = Rated discharge time to reach 1.1VDC per cell

Commentary Note:

If the electrolyte temperature is different from 25°C by more than $\pm 1^{\circ}\text{C}$, the battery capacity test result shall be corrected according to Table 2 in Attachment 1 of this procedure.

5.4.3 Capacity Test Procedures for Valve Regulated Lead-Acid (VRLA) batteries

The following procedures shall be followed in order to conduct the capacity test valve regulated lead-acid (VRLA) batteries:

- a) Equalize the batteries for 72 hrs (subject to battery manufacturer recommended practice) and then return to float charge within 30 days before the test start date.
- b) Perform all the monthly, quarterly and yearly maintenance activities specified in this procedure.
- c) Disconnect the charging source, connect the load bank and start timing.
- d) Maintain a constant discharge current equal to the manufacturer's rating of the battery for the selected test length until the battery terminal voltage reaches the end of discharge voltage (1.75 VDC per cell X number of cells).
- e) Read and record individual cell and the battery terminal voltage at specified intervals during the test.
- f) If one or more cells reach reversal of its polarity (0V) or a module voltage lower by 2V or more (compared to the average module voltage) and the test is 90-95% near completion, continue with the test until the end of discharge terminal voltage is reached.
- g) If earlier in the test an individual cell is approaching reversal of its polarity, stop the test to bypass this faulty cell and the new terminal voltage shall be (1.75 VDC X Number of remaining cells).
- h) When the battery terminal voltage reaches the end of discharge voltage, terminate the test and record the time.
- i) Calculate the test result using the following equation:

$$\% \text{ Capacity at } 25^{\circ}\text{C} = (T_a/T_s) * 100 \quad (3)$$

Where:

T_a = Actual discharge time to reach 1.75VDC per cell

T_s = Rated discharge time to reach 1.75VDC per cell

Commentary Note:

If the average negative terminal temperature is different from 25°C by more than ± 1°C, the battery capacity test result shall be corrected according to Table 3 in Attachment 1 of this procedure.

5.5 Battery Acceptance Criteria

The new batteries shall be accepted if the % capacity is more than 90% of the battery rated capacity. Cells delivering less than 90% of the rated capacity shall be rejected.

Commentary Note:

It is a common phenomenon that some new batteries deliver less capacity during the beginning of their services. After few years of float operation, battery stabilizes, and its capacity tends to improve over time to reach its rated value.

5.6 Battery Replacement Criteria

The battery shall be considered due for replacement if the %capacity of the performance (load) test drops below 80% of the battery rated capacity. The complete battery bank shall be replaced if 15% of the cells meet battery replacement criteria.

Commentary Notes:

- 1) Monitoring the rate of degradation by means of load testing helps effective planning for battery replacement.*
- 2) Reversal of cell polarity indicates immediate replacement required.*

5.7 Battery Put Back Into Service

Batteries shall be in fully charged state before putting them back into service. Charging procedures recommended by battery manufacturer shall be followed.

31 May, 2004

Revision Summary
New Saudi Aramco Engineering Procedure.

Attachment 1 – Temperature Correction Factor

Table 1 – Temperature Correction Factor for Vented Lead-Acid Batteries

Initial Temperature °C	Temperature Correction Factor	Initial Temperature °C	Temperature Correction Factor	Initial Temperature °C	Temperature Correction Factor
-3.9	1.520	21.7	1.034	29.4	0.960
-1.1	1.430	22.2	1.029	30.0	0.956
1.7	1.350	22.8	1.023	30.6	0.952
4.4	1.300	23.4	1.017	31.1	0.948
7.2	1.250	23.9	1.011	31.6	0.944
10.0	1.190	24.5	1.006	32.2	0.940
12.8	1.150	25.0	1.000	35.0	0.930
15.6	1.110	25.6	0.994	37.8	0.910
18.3	1.080	26.1	0.987	40.6	0.890
18.9	1.072	26.7	0.980	43.3	0.880
19.4	1.064	27.2	0.976	46.1	0.870
20.0	1.056	27.8	0.972	48.9	0.860
20.6	1.048	28.3	0.968	51.7	0.850
21.1	1.040	28.9	0.964		

Table 2 – Temperature Correction Factor for Vented Nickel-Cadmium Batteries

Initial Temperature °C	Temperature Correction Factor Range
-17.8	1.1-2.0
-12.2	1.1-1.6
-6.7	1.1-1.5
-1.1	1.1-1.3
4.4	1.0-1.2
10.0	1.0-1.1
15.6	1.0-1.1
21.1	1.0-1.1
25-45	1.0

Table 3 – Temperature Correction Factor for Valve Regulated Lead-Acid (VRLA) Batteries

Initial Temperature °C	Temperature Correction Factor Range
-1.1	1.16-1.43
10.0	1.10-1.19
21.1	1.01-1.04
25.0	1.00
32.2	0.94-0.96
43.3	0.88-0.92