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Maintenance, Logistics & Facilities

MAINTENANCE, TESTING AND REPLACEMENT OF VALVE REGULATED LEAD ACID BATTERIES (VRLA) FOR UPS APPLICATIONS

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SUMMARY OF REVISIONS: This instruction supersedes NWSI 30-2115 Maintenance, Testing and Replacement of Valve Regulated Lead Acid Batteries (VRLA) for UPS Applications, dated, June 29, 2004. Minor edits included new OPR points of contact and correcting paragraph 8.d. second sentence word above to below.

Signed August 20, 2014

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Maintenance, Testing and Replacement of Valve-Regulated Lead Acid Batteries (VRLA) For UPS Applications

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1. Introduction. Uninterruptible power supplies (UPS) provide backup power for a wide range of applications. The UPS battery is the most common point of failure in critical power distributions. Battery failures do not generally occur without warning. With proper maintenance, testing, replacements and inspections, defective batteries can be identified and replaced before a catastrophic failure occurs. A good battery maintenance program may prevent, or at least reduce, the cost and damage to critical equipment due to an AC mains outage. Personnel knowledgeable in batteries should perform battery maintenance. Staff servicing batteries will follow safety guidance provided by the battery manufacturer and guidance provided in NWSM50-1115, procedure 15, “Battery Charging and Storage Operations.” The following measures will be followed to identify defective and potentially defective batteries to increase system reliability.

2. Personal Protection. The following personal protective equipment should be readily available for use during the battery test and maintenance procedures:

a. Chemical resistive gloves.

b. Protective aprons.

c. Sodium Bicarbonate mixed 0.1 kg to 1 L (1 lb to 1 gal) of water to neutralize acid spillage.

d. Portable or stationary water facilities for rinsing eyes and skin in case of contact with electrolyte.

e. Face shield/goggles.

NOTE: Anytime electrical work is being performed on live conductor or a live bus, rubber-insulating equipment should be used. Always ensure that equipment is being used as designed for the application and voltage to which the maintenance personnel will be exposed and has been inspected within the inspection period. Always inspect safety equipment prior to use. Clean and inspect after use prior to proper storage.

3. Protection Procedures. The following protective procedures will be observed during battery testing and maintenance:

a. Use caution when working on batteries since they present a shock hazard.

b. Ensure that battery area and/or cabinet ventilation is operable.

c. Ensure unobstructed egress to and from the battery area.

d. Prepare plan of action in case of single or multiple battery failures affecting both performance and safety.

e. Be sure the maintenance bypass switch is set prior to doing maintenance on UPS.

CAUTION: Work on UPS batteries will be performed by at least two qualified people (according to 2002 NEC Article 100 – Qualified Person) using the proper tools and protective equipment listed in this document. Good safety practices should be followed when lifting or carrying any storage batteries. Personnel who understand these systems and have been properly trained will perform maintenance.

4. Optimizing Battery Life and Preventing System Failures. The objectives of any battery maintenance program are to maximize the service life of the battery and prevent abrupt system failures. This can be accomplished by:

a. Maintaining a uniform battery room ambient temperature at or slightly below 25° C (77° F).

b. Controlling the battery manufacturer's recommended value of float voltage, measured at the battery terminals.

c. Eliminating any unnecessary battery cycling.

5. Maintenance, Testing and Inspection Procedures. Routine tests and inspections will be conducted on each UPS to include the Weather Forecast Office (WFO) and the Transition Power Source (TPS). The following procedures will be noted:

a. All initial battery float voltage and internal ohmic/conductance measurement will be recorded in the maintenance log and observations made should be compared to prior inspection values (Trend Analysis).

b. All inspections and tests should be conducted with the batteries disconnected from the charger.

c. Identify each battery to ensure subsequent data is correlated to the same battery.

d. Always test on the battery lead posts. Avoid tests through stainless hardware, bolts, and cables (false data may result).

6. New and Replacement Batteries. All new and replacement batteries should be of the same type, size, manufacturer and model number, if possible. The new and/or replacement batteries should be less than two months old shelf life and have the same terminal voltage and amp-hour rating as the battery being replaced. New batteries may have less than rated capacity when delivered. String replacement battery should be charged to a range of 90 to 95 percent of rated capacity. Capacity will rise to rated value after several charge-discharge cycles or after a period of float operation. The following procedures should be used when replacing or installing new batteries:

a. Record and document the lot number and production date of the individual battery.

b. Clean the connectors and terminals. Refer to the battery manufacturer's installation instructions for connecting the terminals.

c. Measure and record the float voltage.

d. Establish an internal resistance benchmark. Measure and record the internal ohmic/conductance measurement of new and replacement batteries. Refer to the battery manufacturer's operating instructions for the acceptable resistance readings.

e. Replace the battery if its capacity as measured by test is 85 percent or less than its rated capacity.

7. Monthly Inspections. The following items will be performed along with the actions necessary for corrections and/or replacement:
(Visual inspections only) – Always wear eye protection equipment when working on or around batteries.

a. Check battery integrity for evidence of corrosion at terminals, connections, racks or cabinets.

b. Check general appearance and cleanliness of the battery, the battery rack or cabinet, and the battery area including accessibility.

c. Check battery cover integrity for cracks and distortion.

d. Check for battery electrolyte leakage.

8. Biannual Inspections. The following items will be performed along with the actions necessary for corrections and/or replacement:

a. Include the requirements to be performed in the monthly inspections.

b. Check the condition of ventilation in the UPS cabinet. Measure and record the temperature inside the battery cabinet (see Appendix B).

c. If loose connections are noted, re-torque and retest. If terminal corrosion is noted, clean the corrosion and check the connections. If any electrolyte leakage is found, determine the source and institute repair or replacement. When excessive dirt is noted on cells or connectors, wipe with water-moistened clean wiper. Remove any electrolyte seepage on cell covers and containers with a bicarbonate of soda solution 0.1 kg to 1 L (1 lb to 1 gal) of water. Also, use extreme caution when using this solution. If any should find its way into any of the battery cells, the cells will go flat and the battery must be replaced. Do not use hydrocarbon- type cleaning agents (oil distillates) or strong alkaline cleaning agents, which could cause containers and covers to crack or craze. Use extreme care when cleaning battery systems to prevent ground faults.

d. Record the internal ohmic/conductance measurement of each battery. Replace any battery with internal ohmic/conductance reading greater than 50 percent below the established benchmark.

e. Measure and record the float voltage at the battery terminals. When the float voltage is measured at the battery terminals and the readings are outside of its manufacturer's recommended operating range, the charger voltage should be adjusted.

f. Perform and record a load test on any battery only when an internal ohmic measurement reading of 20 percent to 50 percent above the established benchmark.

9. Annual Inspections. The following items will be performed along with the actions necessary for corrections and/or replacement:

a. Include the requirements to be performed in the biannual inspections.

b. Tighten all connections to manufacturer's torque recommendations and terminations internal to the UPS and bypass switch.

10. Special inspections. If the battery has experienced an abnormal condition (such as a severe discharge or an extreme high ambient temperature), a battery internal ohmic/conductance measurement test will be made immediately to ensure that the battery or batteries have not been damaged. In addition to the test results, other determinants for complete battery replacement, such as age, number of cycles, and number of defective batteries in a string should be considered.

Replace the entire string of batteries if:

a. 20 percent or more of the batteries have not met the minimum requirements of the test and inspection procedures previously mentioned. In most cases this amounts to six (6) batteries.

CAUTION: A battery unit with an internal short should not be placed on charge. The charger must have its output adjusted for the reduced overall system voltage for the remainder of the batteries.

b. The batteries are three or more years of age. (Historical data has shown that battery failures do occur within a 3 year cycle).

11. Battery Disposal. Battery disposal will be in accordance with NWS Environmental Management manual NWSM 50-5116.

Appendix A Voltages

A.1 Battery Float Voltage. The correct battery float voltage measured at the battery terminals is critical to valve-regulated cells. The battery float voltage must be within the manufacturer's recommended limits and manufacturer's recommendations for considering temperature compensation.

A.2 Individual Battery Voltages. It is not unusual to observe a wide float voltage range between valve-regulated batteries than what is normal for vented-type cells. This is especially true for the first six months after installation. Equalization is not normally used to correct apparent imbalances.

(i) Low-voltage cells. Low voltage alone is not an indication of the state of charge of a cell. Prolonged operation of cells below the manufacturer's low-voltage limit may reduce the life expectancy of cells.

> NOTE: A cell voltage consistently below normal float conditions and not caused by elevated temperature of the cell, indicates internal cell problems that may require battery replacement.

(ii) High-voltage cells. A cell voltage that exceeds the cell's high-voltage limit (as specified by the battery manufacturer) has a detrimental effect (e.g., accelerated dry out).

A.3 Effect of Temperature. The ideal ambient temperature of battery storage areas/cabinets should be at or slightly below 25^{o} C (77^{o} F). At a constant battery voltage, the charging current will increase as the temperature of the electrolyte increases. Therefore, cells in a battery at a higher temperature than others indicate a lower battery voltage. An effort should be made to eliminate the cause of any temperature differential between batteries. As a general rule, continuous prolonged use at elevated temperatures will reduce the battery life by approximately one-half for every 8^{o} C (15^{o} F) that valve-regulated batteries operate. This affect can be mitigated to some extent by use of temperature-compensated chargers. Operation at elevated temperatures can also lead to battery thermal runaway.

Appendix B Temperature Correction for Load Testing

Discharge rates published by the manufacturers are normally based on a cell temperature of 25° C (77° F). When a load test is performed at a different temperature, a correction factor should be applied. Temperature correction factors may be applied to the test discharge rate, or to the tested discharge time. It is more common to adjust the discharge rate, and at extreme temperatures, this method is likely to give more accurate results.

The effect of temperature on VRLA battery performance varies considerably, depending on factors such as the acid specific gravity and immobilization technique. Therefore, the manufacturers should be contacted for correct factors specific to each VRLA cell design.

Appendix C Corrective Actions

C.1 Thermal Runaway. When a VRLA cell is operating on float or overcharge in a fully recombinant mode, there is no net chemical reaction and almost all the overcharge energy results in heat generation. If the design of the system and its environment are such that the heat produced can be dissipated and equilibrium can be reached, then there is no thermal runaway problem. However, if the recombination reaction gives rise to a rate of heat evolution that exceeds the rate of heat dissipation, the battery temperature will rise and more current will be required to maintain the float voltage. The additional current results in still more recombination and heat generation, which further raises battery temperature and so on. The net effect can be accelerated dry out and/or melting of the battery. This potential problem is further aggravated by elevated ambient temperatures or by battery or charging system malfunctions. The possibility of thermal runaway can be minimized by the use of appropriate ventilation between and around the batteries and by limiting the charger output current and voltage, such as by using temperature compensated chargers. In the gelled electrolyte system, the gel has intimate contact with the plates and the container walls and provides better heat dissipation characteristics than the absorbed electrolyte system, but not as good as the vented (flooded) system.

C.2 Equalizing charge. Periodic equalizing is not normally required to correct cell/unit imbalance.

Note: Equalize charging should not be performed unless specifically recommended by the manufacturer.

C.3 Cell/unit Internal ohmic Measurements.

a) These measurements provide information about circuit continuity and can be used for comparison between batteries and for future reference.

b) The internal impedance of a battery consists of a number of factors including: the physical connection resistances, the ionic conductivity of the electrolyte and the activity of the electrochemical processes occurring at the plate surfaces. With multicell units, there are additional contributions due to intercell connections. The resultant lumped impedance element can be quantified using techniques such as the following:

i) Impedance measurements can be performed by passing a current of known frequency and amplitude through the battery and measuring the resultant AC voltage drop across each cell/unit. The AC voltage measurement is taken between the positive and negative terminals of individual batteries.

ii) Conductance measurements can be performed by applying a voltage of known frequency and amplitude across a cell/unit and observing the AC current that flows in response to it. The conductance is the ratio of the AC current component that is in-phase with the AC voltage, to the amplitude of the AC voltage producing it.

iii) Resistance measurements can be performed by applying a load across the cell/unit and measuring the step change in voltage and current. The ohmic value is calculated by dividing the change in voltage by the change in current.

iv) When measurements are taken, the type of test equipment used, the test points selected, cell/unit voltages, and the cell/unit temperatures measured at the negative terminal posts should be recorded.

v) Impedance and resistance are inversely related to conductance. If a cell's ohmic value changes, it may be an indication that the cell's capacity is changing. Cell/unit ohmic values measured will vary with the specific measurement technique and the conditions under which the measurements are taken.

NOTE: In doing a battery internal ohmic measurement analysis the means of collecting the data should be consistent.

Significant changes in the values typically indicate a significant change in the battery, which may be reflected in its performance. However, limited changes in the specific values obtained do not necessarily indicate that the battery is free of defect or deterioration.

In the absence of specific guidelines from the instrument manufacturer, changes in ohmic values in excess of 20% should be considered significant. Such changes should be discussed with the battery manufacturer; a capacity test should be run to determine the reliability of the battery system.

C.4 Ripple current. A battery charger with low electrical noise levels should be used for VRLA batteries to limit the ripple current. An acceptable charger is one that does not raise the average fully charged battery operating temperature, as measured at the negative terminal, by more than 3^{o} C (5^{o} F) above ambient in a free-standing condition.

Appendix D UPS Storage Battery Specifications – Minimum Requirement

(Also see Attachments A, B, and C)

The size of the UPS battery determines how long the inverter will continue to provide power to the critical load.

Required stand-by operation – 15 minutes

Item	Rating
Nominal Voltage	12 volts
Weight	Approximately 72 lbs (each)
Maximum discharge current	800 Amperes
Charging voltage @ 77^{o} F	2.25 volts per cell
Float (full service)	13.5 to 13.8 VDC
Equalization voltage (full service)	14.4 to 14.8 VDC
End voltage	1.67 volts per cell
Physical dimensions	10.5 in x 7.0 in x 10.0 in
Battery room temperature	74 – 77^{o} F and at least two air changes per hour (minimum).
Shelf Life	Should not lose more than 2.78 percent of nominal voltage per month on open circuit

Appendix E Recommended UPS Battery Maintenance Test Equipment and Calibration Cycles

a) Digital Voltmeter rated 600 VDC minimum. Due to the close tolerance needed for battery maintenance, the voltmeter should be checked and calibrated at yearly intervals.

b) Thermometer (surface contact type) – Individual battery systems block temperature. Individual batteries within the string should not exceed the ambient temperature by more than 18° F (10° C).

c) Internal Impedance Battery Tester (example: Midtronics (630 321-8006).

d) Automatic Battery Impedance Monitor

Consistent testing down to individual battery cell level is essential for power assurance and peace of mind.

NOTE: Battery life is greatly affected by ambient temperature, excessive cycling, and float voltage regulation.