Battery Testing by the Standards and Field Experiences

Introduction

Batteries are the heart of electrical substations and telecommunications infrastructure; nothing works in the substation if DC power is not present. However, despite existing regulations and standards, batteries are not always maintained and tested as they require.

IEEE, NETA, and NERC are references that indicate what, when, who, and how batteries should be tested. Each document from those entities contains pieces of information that are very important when scheduling and performing a battery test in the field.

Maintenance and testing practices are defined by several factors, such as electrolyte used and construction type; it is important to consider both similarities and key differences for maintenance and test procedures between different battery types.

The paper summarizes and put the most important aspects of field testing in a simple and easy to follow document for three different type of batteries (VLA, VRLA, Vented NiCad), providing quick reference tables and comparison with the current mandatory testing requirements, the reader will be able to determine which activities should be included in their maintenance program, the appropriate schedule, types of tests required and specific procedures, as well as best practices and field recommendations for capacity and impedance testing.

Types of Batteries

Construction

The construction of a battery will not only determine the application it can be installed for, but also important parameters for testing, these include current and time duration for a discharge test and the criteria to analyze impedance measurements. An essential first step when planning battery testing is to identify the batteries to assess. For the applications concerning this paper, three different types of batteries construction are discussed:

- Vented Lead Acid (VLA) batteries – also called flooded – which contain flat pasted plates that are submerged in an electrolyte inside a container that allows the battery to vent flammable gases, or, in other words, recombination of gases does not happen.
- Valve-regulated Lead Acid (VRLA) batteries are constructed in a way the container will allow gasses to escape only when excessive pressure has built up inside the battery. Another important characteristic that differentiates VRLA from VLA batteries is the immobilization of the electrolyte; VRLA cells will either have a gelled electrolyte or glassmat separators (AGM cells).
- Nickel-Cadmium (NiCd) batteries constructed with nickel oxide hydroxide and metallic cadmium as electrodes and can be vented or valve regulated. This document covers only the vented type.

Voltages

Each construction type defines characteristic voltages under different conditions. Some of these characteristic voltages depend not only on the type but also on the manufacturer and the application.

VRLA batteries can be kept at higher float voltage and consequently will have higher open circuit voltage than VLAs. Recommended float voltages should be followed to avoid under or overcharging. Undercharging can lead to plates sulfating and overcharging can lead to dry out the cells.

End-of-discharge voltage range for lead acid batteries is the same, though manufacturer tables should be followed for proper testing.

NiCd batteries have lower voltage per cell than the lead acid type and they can withstand very low discharge voltages with low risk of permanent degradation, and they also can have a high-rate voltage characteristic.

The table below summarizes the following voltages:

- Float voltage: the voltage whit the charger on and battery fully charged
- Open circuit: voltage of the battery with the charger off
- End-of-discharge: minimum voltage allowed on the battery without damage
- High-rate voltages: voltage of batteries used on high rate applications

Voltages	VLA [V/cell]	VRLA [V/cell]	Vented NiCd [V/cell]
Open Circuit Voltage (Fully charged)	2.06 - 2.10	2.06 – 2.17	1.20 – 1.30
Float Voltage	2.15 – 2.30	2.20 – 2.35	1.20 – 1.47
End-of-discharge Voltage	1.60 – 1.90	1.6 – 1.90	1.00 – 1.10
High-Rate Voltage	NA	NA	1.45 – 1.65

Table 1. Batteries Voltages Characteristics

Applications

Based on the construction characteristics, standby batteries can be classified as long duration, general purpose and short duration. The following table displays the main features of each class.

Feature	Long duration	General Purpose	Short duration
Plate characteristic	Thick positive plates	Moderately thick plates	Thin positive plates
Application	Telecommunications	Switchgear and control Suitable for UPS	UPS
Type of load	Constant and low current	Constant and switching loads	High current loads
Minimum supply time	3 hours	1 to 3 hours	1 hour or less
Nominal discharge rate	8 hours	8 hours	15 minutes

Feature	Long duration	General Purpose	Short duration
Cycles per year	Less than 10	2 to 5	10-20
Performance under high discharge/short time rates	Poor	Good	Good
Performance under low discharge/long time rates	Good	Good	Poor

Table 2. Batteries classification per application

Considering this information when preparing maintenance programs can help in defining the proper practices and testing approach, such as appropriate discharge settings and testing frequency.

Effects of Temperature

Battery performance and life is affected by temperature but it affects lead-acid and nickel-cadmium batteries differently. The environment and arrangement of the batteries should maintain a stable temperature around a reference temperature of 25 °C though some manufacturers use 20 °C. Prolonged elevated temperature in the battery or its environment will drastically reduce the life expectancy. The table below shows the general rule of thumb for life expectancy reduction in lead-acid and nickel-cadmium batteries when temperature is above the reference value.

Battery Type	Life reduction for every 8°C above reference temperature
Lead-acid	50%
Nickel-cadmium	20%

Table 3. Effects of temperature

Temperature differentials of 3 °C or higher among cells or jars should be investigated to avoid electrical unbalance and look for specific conditions that could be creating hot or cold spots on certain cells or internal shorting.

A generalized elevated temperature on the battery unrelated to ambient temperature can be associated with high ripple current or overcharging. The maximum recommended ripple voltage is 3.5% (of the rms voltage) and the maximum recommended ripple current is 5% of the eight-hour rated discharge rate.

Elevated temperature in flooded type- batteries causes increased water consumption, in valve regulated batteries can lead to dry-out and eventually, to thermal runaway.

Under regular operation and testing conditions, the performance will be ideal when the ambient temperature is close to the reference temperature. Both, lead-acid and nickel-cadmium, will have a reduced performance when the operating temperature is below the reference. When the temperature is above the reference, lead-acid batteries will improve their performance while nickel-cadmium batteries would not have a significant improvement.

Lead acid batteries have standardized correction factors for temperatures ranging from +5 °C to 45 °C, for both types of capacity calculation methods, time and rate based.

In nickel-cadmium batteries, the decrease in the capacity when temperature is below the reference value will vary depending on the design and discharge rate used; it is recommended to consult with the manufacturer to determine the specific correction factor. For temperatures ranging from +20 °C to +40 °C the correction factor is 1.

Standards and Regulations

IEEE provides recommended practices for maintenance and testing for each of the type of batteries discussed in this paper as well as a guide for batteries to be used in uninterruptible power supply systems (UPS). Further reference information is provided by the acceptance and maintenance testing specifications from NETA.

All the references from these entities are recommendations provided for users to develop specific maintenance and testing programs considering their own applications, issues, needs and requirements and not necessarily to be implemented fully.

Nonetheless, NERC has issued a regulation that establishes the minimum maintenance program to be implemented for entities subject to audits from NERC. Hence, in addition to the importance of establishing and following a maintenance and testing program for batteries to assure the proper operation of the system being backed up, some entities, as per NERC PRC-005-6, need to document and keep records of the maintenance and testing activities to avoid fines. Implementing a maintenance program and not following it can result in, fines that can go from $1,000 up to $1,000,000, daily.

Documents from IEEE, NETA and NERC were reviewed to identify the fundamental tests required to correctly assess the health of a battery system and make the best decisions in terms of reliability. The following sections in this document summarize recommendations described in IEEE and NETA references [1], [2], [3], [4], [5], [6], the recommended Personal Protective Equipment (PPE), safety measures, inspection and testing activities as well as corrective actions. The information is presented in tables for easier and faster handling of the information and NERC requirements are also shown.

Safety

Working with batteries is potentially dangerous. The electrolyte is harmful if it enters in contact with skin or eyes, they produce gases that can explode, and they are always energized. Observe precautions when working around them and use the appropriate tools when performing maintenance. A minimum amount of PPE is recommended to be available and worn in accordance with the activity to be performed.

Although the standards discussed in this paper are not meant to enforce safety, security, health and environmental protection, all standards include recommendations in such regards. The four IEEE standards reviewed for this paper concur on recommending the following protective equipment, precautions and safety methods.

a) Goggles and face shields.

b) Chemical-resistant gloves.
c) Protective aprons and overshoes.
d) Portable or stationary water facilities for rinsing eyes and skin. The use of pH buffered neutralizing eyewash solution is recommended.
e) Spill absorbing/neutralizing materials, or another suitable neutralizing agent recommended by the manufacturer for alkaline electrolyte spillage.
f) Class C fire extinguisher. Some battery manufacturers do not recommend the use of CO2-type fire extinguishers due to the potential for thermal shock on the battery cases.
g) Adequately insulated tools.
h) Lifting devices of adequate capacity, when required.

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Inspections and Testing

Standards discussed in earlier sections include specific recommendations for each particular type of battery. The two tables below will compare what each standard recommend to help the reader integrate a comprehensive maintenance plan for each particular battery installation.

The table below includes recommendations for VLA and VRLA batteries, from IEEE (I), NETA (N) and NERC-PRC (P).

Activity	Monthly					Quarterly/ Tri-annual*				Yearly/18-months*					
	VLA		VRLA			VLA		VRLA		VLA			VRLA[1]		
Float voltage measured at the battery terminals	I		I			I	P	I		I	N	P	I	N	P
General appearance and cleanliness of the whole installation	I	N	I	N		I		I		I			I		
Charger output current and voltage	I		I			I		I	P	I			I		
Crack in cells (evidence of electrolyte leakage)	I		I			I		I		I			I		
Evidence of corrosion at terminals, connectors, racks or cabinets	I	N	I	N		I		I		I			I		
Ambient temperature and ventilation	I	N	I	N		I		I		I			I		
Pilot cells (If used) voltage and electrolyte temperature	I					I				I					
Battery float charging current or pilot cell specific gravity	I					I				I					
Unintentional battery grounds	I	N		N		I	P		P	I					
Electrolyte levels	I	N				I	P			I					
Voltage of each cell						I		I		I	N			N	
Specific Gravity of 10% of the cells of the battery						I[2]				I					
Temperature of at least 10% of cells						I				I					
Temperature of the negative terminal of each cell								I					I		
Specific Gravity of all cells										I[2]					
Cell condition										I		P			
Cell/unit internal ohmic values								I	P[10]		N	P[4]	I	N	P
Cell-to-cell and terminal connection resistance		N[6]		N[6]						I	N	P[3]	I	N	P
Structural Integrity of the battery rack		N		N						I		P			P
AC ripple current and/or voltage imposed on the battery													I		
Performance or modified performance capacity test of entire bank										I[8]	N[8]	P[4]	I[9]	N[9]	P[10]

Activity	Monthly		Quarterly/ Tri-annual*		Yearly/18-months*	
	VLA	VRLA	VLA	VRLA	VLA	VRLA[1]
Verify tightness of accessible bolted electrical connections [5]	N[6]	N[6]				
Perform a thermographic survey under load[7]	N[6]	N[6]				
Verify presence of flame arresters	N					
Verify existence of suitable eyewash equipment	N	N				
Verify Equalizing Voltage Setting is in accordance to Battery's Manufacturer recommendation					N	N
Measure negative post temperature						N
Verify all charger functions and alarms					N	N

Table 4. VLA and VRLA: Inspections and tests comparison

* Time frames indicated in NERC-PRC-005-6

1 - This inspection applies for the initial installation as well, according to IEEE Std 1188

2 - For lead-antimony batteries. For other technologies, only if float charging current is not used to monitor state of charge

3 - Standard indicates to verify battery continuity, terminal connection resistance, intercell or unit-to-unit connection resistance

4 - Standard indicates to evaluate battery performance by indicative measurements like internal ohmic values or float current every 18 months or perform a capacity test every 6 years

5 - NETA MTS Table 100.12

6 - Only one of the three actions is required

7 - According to NETA MTS Section 9

8 - Intervals and test procedure according to IEEE Std 450, every 25% of life expectancy or two years (whichever is less)

9 - Intervals and test procedure according to IEEE Std 1188, every 25% of life expectancy or two years (whichever is less)

10 - Measure internal ohmic values every 6 months or perform a capacity test every 3 years

The table below includes recommendations for Ni-Cd batteries, from IEEE (I), NETA (N) and NERC (P).

Activity	NiCd						
	Quarterly/ Tri-annual*		Semi-annually	Yearly[1] / 18 months*			6 Years
Float voltage measured at the battery terminals	I		I	I	N		
General appearance and cleanliness of the whole installation	I		I	I	N	P	
Charger output and voltage	I		I	I		P	
Charger float and equalizing voltage levels. Adjust to manufacturer's recommended settings					N	P	
Verify all charger functions and alarms					N		
Electrolyte levels	I	P	I	I			
Unintentional battery grounds		P					
Crack in cells (evidence of electrolyte leakage)	I		I	I			
Evidence of corrosion at terminals, connectors, racks or cabinets	I		I	I			
Ambient temperature and ventilation	I		I	I	N		
Pilot cells (If used) voltage and electrolyte temperature	I		I	I	N		
Voltage of each cell			I	I	N[5]		
Intercell connection torque				I			
Condition and resistance of cable connections				I	N[2]	P	
Verify tightness of accessible bolted electrical connections by calibrated torque-wrench[3]					N[2]		
Perform thermographic survey[4]					N[2]		
Structural Integrity of the battery rack				I	N	P	
Verify existence of suitable eyewash equipment					N		
Verify application of an oxide inhibitor on battery terminal connections					N		
Perform internal ohmic measurements					N		
Perform load test					N[6]		
Measure battery system voltage from positive-to-ground and negative-to-ground					N		
Verify Station DC supply voltage		P					
Performance or modified performance capacity test of entire bank							P

Table 5. NiCd Inspections and tests comparison

* Time frames indicated in NERC-PRC-005-6
1 - This inspection applies for the initial installation as well, per NETA-ATS
2 - Only on of the three methods is required
3 - Method in accordance with manufacturer's published data or Table 100.12 of NETA-MTS
4 - Method in accordance with NETA-MTS - Section 9
5 - NETA-MTS specifies float voltage measurement for each cell and total battery
6 - Optional, in accordance with manufacturer's published data or IEEE 1106

Special Inspections

When the batteries have been operated under unusual circumstances that expose them to deterioration or damage, unscheduled inspection and testing should be performed. Situations that trigger special inspections include deep discharges, extended or high overcharges, high temperature, or excessive cycling. Semi-annual or yearly inspections requirements are suggested for the unscheduled testing.

Alternate Inspections: Ohmic Measurement

Pending construction type and health condition, battery cells will have a characteristic ohmic value. If this value is measured under consistent conditions and good testing practices, the battery can be characterized and trended to identify degradation. As a general rule, if the internal resistance increases the capacity of the cell will be reduced, however there is no direct correlation to apply for capacity calculation. Three different technologies are available to measure ohmic values: conductance, resistance and impedance.

An impedance tester provides the voltage of each cell, float and ripple current, and strap resistances in addition to the ohmic value. All these measurements are included in the monthly, quarterly or yearly requirements, so it makes sense to use one single instrument to perform all the measurements in one single operation for each cell.

Degradation of a cell can be defined based on trending and identifying cells for further investigation based on the fact of a significant change, variation or deviation from a baseline value. However, a significant change is subject to the characteristics of each battery type and manufacturer, therefore it is recommended to establish specific warning values over time, with knowledge of the battery and consultation with the manufacturer. Industry practices suggest the following percentages of change for impedance testing:

Type of Battery	Single Test	Trending	
	% change from average	% change from last test	Overall % change
VLA	5	2	20
VRLA	10	3	50
NiCd	15	10	100

Table 6. Impedance variation

For ohmic measurements the battery should be in electrical, chemical, and thermal equilibrium. To obtain repeatable and reliable results it is recommended to perform the measurements when the battery is fully charged and 72 hours after adding water or charging the battery. Changing floating signal, such as the one influenced by ripple or noise from the charger or the loads will also affect repeatability.

In addition to the requirements above, a constant use of the same measurement technology (instrument type and leads) will guarantee reliable and consistent data for analysis.

Corrective Actions

IEEE

1. Electrolyte levels should be maintained above the low-level line and up to the full-level line using either distilled or approved-quality water.
2. Remove any corrosion in posts or terminals
3. When inter-cell connection resistance values are not acceptable, even after retorque, connections should be disassembled, cleaned, reassembled, and retested.
4. If individual cell temperatures deviate more than 3 ˚C from each other, the problem should be investigated and corrected. For multi-tier installations, 3 ˚C might not be achievable and the battery manufacturer should be consulted.
5. Equalizing charge – for applicable battery types, details in section below – when:
    a. Individual float voltages deviate from the average value recommended by manufacturer
    b. Undercharge condition is suspected and confirmed by lower than expected specific-gravity measurements
    c. Plate sulfation
    d. Immediately if ay cell voltage is below the manufacturer’s recommended minimum cell voltage
6. Hydration: a battery in this condition should be replaced as soon as possible

Best practices

Ohmic Measurements

The different types of signals used for ohmic measurements will generate their own result not directly comparable with each other, however, independent of the signal, the characteristic of the result on the same cell with different signals should present the same trend. Figure 1 shows the results of ohmic values for 24 cells with two different instruments, it evidences the different result for each cell as well as the correspondence in the result independent on the signal applied.

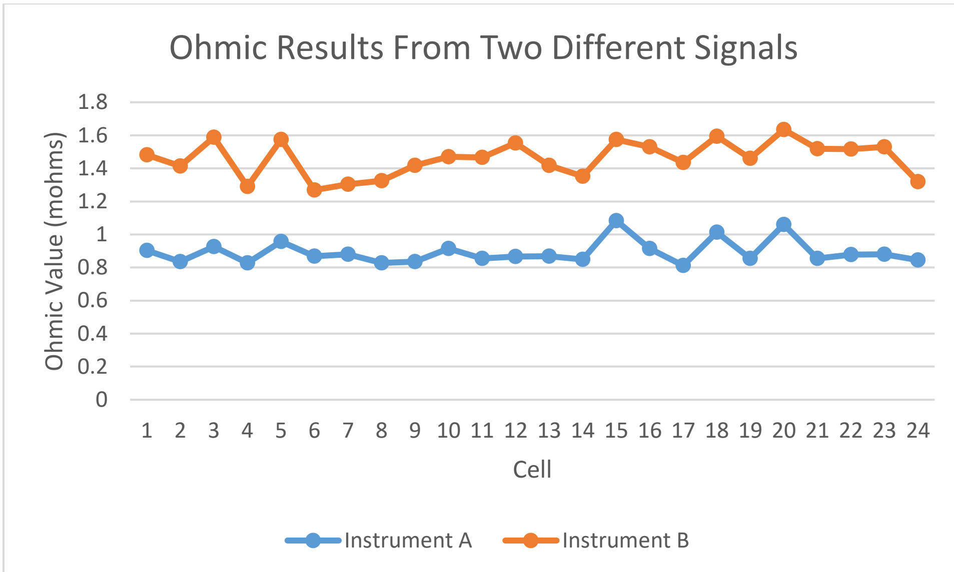

Figure 1. Comparison of ohmic values from a 24-cell battery with two different instruments

Figure 2 shows the ohmic values from the same instrument of a battery moderately discharged and fully charged/floating.

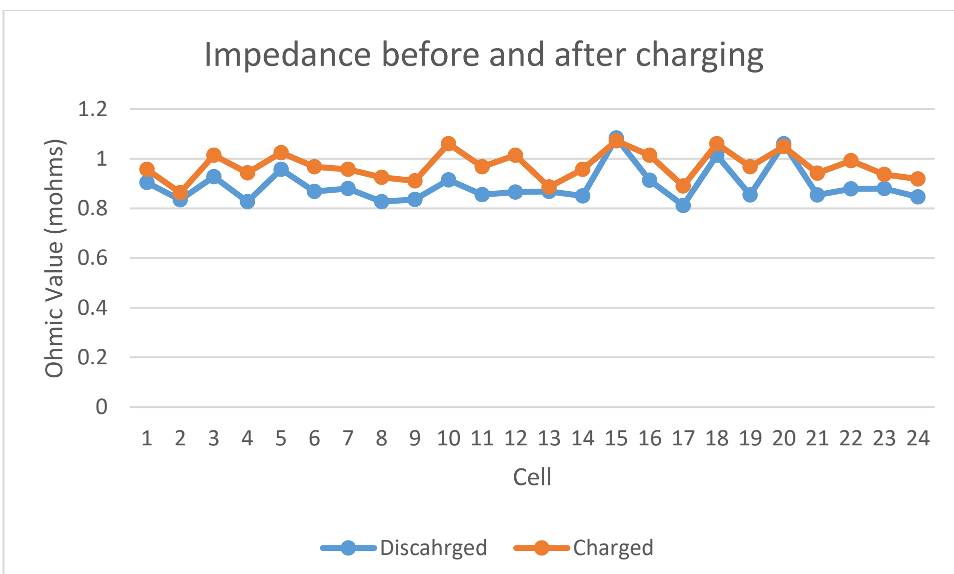

Figure 2. Impedance before and after charging

If the analysis of results shows an important change between tests or from the established baseline, it is important to question and investigate the instrument, leads and battery conditions before making a conclusion about the condition of the battery.

Equalizing Charge

Regular maintenance on a battery also includes an equalizing charge process. This method will bring all cells of a battery bank to the same level of charge and will also help to correct or reverse certain problems, such as sulfation and acid stratification. This process is achieved by means of applying a 10 percent higher than recommended charge voltage.

The process increases temperature and consequently causes evaporation of the electrolyte (gassing and bubbling). In the case of flooded cell type the electrolyte can be replaced with water, however in valve regulated type this is not possible and can lead to dry out of the cells, which is the reason why this process is not recommend as a regular maintenance activity for VRLA batteries and perform it only when recommended by manufacturer.

During the process on flooded type batteries, it will be necessary to take specific gravity readings every hour until the value no longer increases, at which point the equalization is considered as completed.

Due to the need of taking specific gravity measurements, equalization is mostly recommended only on flooded batteries.

Frequency for applying an equalizing charge varies per manufacturer as well, and it ranges from once every month up to once or twice per year.

Discharge Test

A discharge test is that in which the battery delivers current to a load to determine is ability to meet specific criteria such as duty cycle, service or a determined capacity before or at reaching its end of discharge voltage. The best way to perform the test is by using a controllable load to be able to simulate specific duty cycles, service conditions or constant and stable currents for capacity calculations as per manufacturer requirements. Each cell should be monitored throughout the discharge to identify weak cells. The test result will define if the battery needs to be maintained, relocated or replaced, either totally or partially.

Capacity Test

The most typical and convenient test is the capacity test, which is the only test that will indicate the true condition of the battery. To perform this test, the following is required:

- Battery fully charged, in equilibrium, and properly maintained
- Record the temperature at the beginning of the test
- Desired discharge time (typically longer than 1 hour)
- Manufacturer specified constant current or constant power for the desired discharge time at a specified temperature
- End of discharge voltage
- Load bank capable to draw a constant current or power from the battery with the ability to stop the test when the overall voltage reaches the end of discharge level
- Means to measure individual cell voltages throughout the test

The purpose of the test is to determine the true capacity of the battery by finding the time that it takes the battery to reach the end of discharge voltage and compare it to the desired time. The ratio between the resulting time and the expected time defines the capacity of the battery in percentage. If the temperature of the battery is different than 25 °C (in some cases 20 °C) a correction factor should be applied for lead acid batteries. This type of discharge test is known as acceptance test and/or performance test.

When defining the desired discharge time, duration of the test, it is recommended to select a time close or equal to the duty cycle of the battery, to confirm, in addition to the capacity, the ability of the battery bank to meet the expected load.

Also, when performing the test periodically, it is recommended to always use the same duration in order to trend historic results easier.

The standardized passing criteria is above 80%. At the beginning of the life of the battery is very common to see capacities ranging from 90% to 110% or above. Below 80% of capacity provisions should be taken to replace the battery within a year per the standards.

Service tests

In some cases, depending on the application or specific conditions, it is necessary to confirm or verify the ability of the battery to meet specific working conditions rather than determining its capacity. This type of discharge is known as modified performance and service test. In such cases the requirements to perform the test are:

- Battery in as-found conditions
- Specific load conditions to be simulated: load profile and expected duration
- End of discharge voltage
- Load bank capable to simulate different load profiles with the ability to stop the test when the overall voltage reaches the end of discharge level
- Means to measure individual cell voltages throughout the test

The main purpose of the test is to determine if the battery will be capable to supply power for the specific load conditions and as such the battery passes the test if it meets the imposed duty cycle.

In some cases, the test is continued further to reach a manufacturer expected time in order to determine the capacity of the battery as a secondary objective of the test.

If a battery does not pass this test it is not necessarily a bad battery, it is just not capable to meet the load conditions and might be relocated to a different application with a less demanding duty cycle.

Individual cell voltage measurement and Polarity Reversal

Cell voltages should be recorded throughout the test but traditionally a minimum of three instances are recorded: at the beginning, the middle and at the end of the test. The purpose is to identify weak cells and determine if they should be bypassed or not in order to avoid polarity reversal and damage, based on the following recommendations industry practices and standard recommendations:

Type of Battery	% of test completion	Cell Voltage [V]	Action
Lead acid (VLA & VRLA)	<50%	< +1	Bypass the cells approaching polarity reversal. Recalculate stop voltage.
	>90%	< +1	Continue the test until reaching the specified terminal voltage without bypassing the cells that are approaching polarity reversal.
NiCd	Not damaged due to polarity reversal, hence, not needed to bypass, but stop criteria should be recalculated by subtracting the stabilized voltage of the cells with polarity reversal.		

Table 7. Cell bypass criteria

Bypassing a cell should be done in less than 6 minutes typically which requires preparation and appropriate practices to avoid accidents. It also implies resetting the float and equalizing voltages in the charger for the operation after the test. Hence, the decision should be based on proper amount of data from the cells. Measuring the cell voltage in prolonged intervals might lead to a late identification of a weak cell risking a polarity reversal in lead acid batteries. Technology now allows to monitor the voltage of each cell throughout the test and identify weak cells accurately and in a timely manner.

Figures 3, 4 and 5 show the discharge curve of several cells from a 24-cell battery bank during an 8-hour discharge test. The test was stopped after 4 hours due to the overall voltage reaching the stop limit, therefore, the capacity was around 50%. From the individual voltage measurements, three different situations can be clearly identified: Cells that performed very well (figure 3), cells with questionable performance (figure 4) and bad cells (figure 5). After replacing the questionable and bad cells a discharge test was repeated and the battery passed with a result of 118% of capacity.

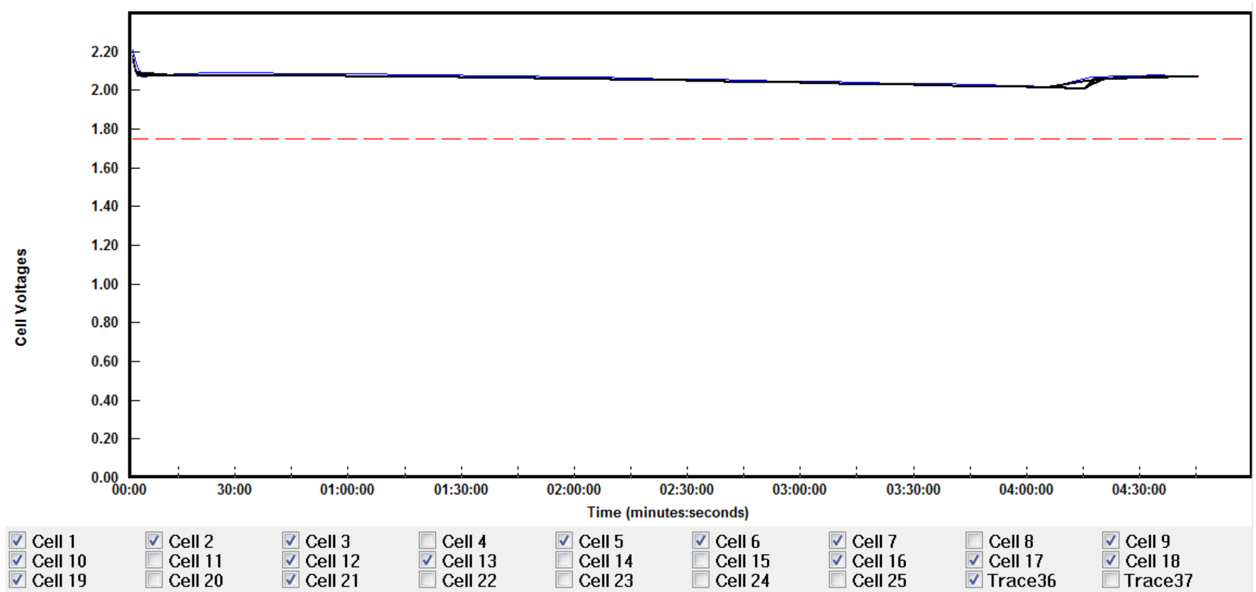

Figure 3. Fifteen good cells in a 24-cell bank during an 8-hour capacity test

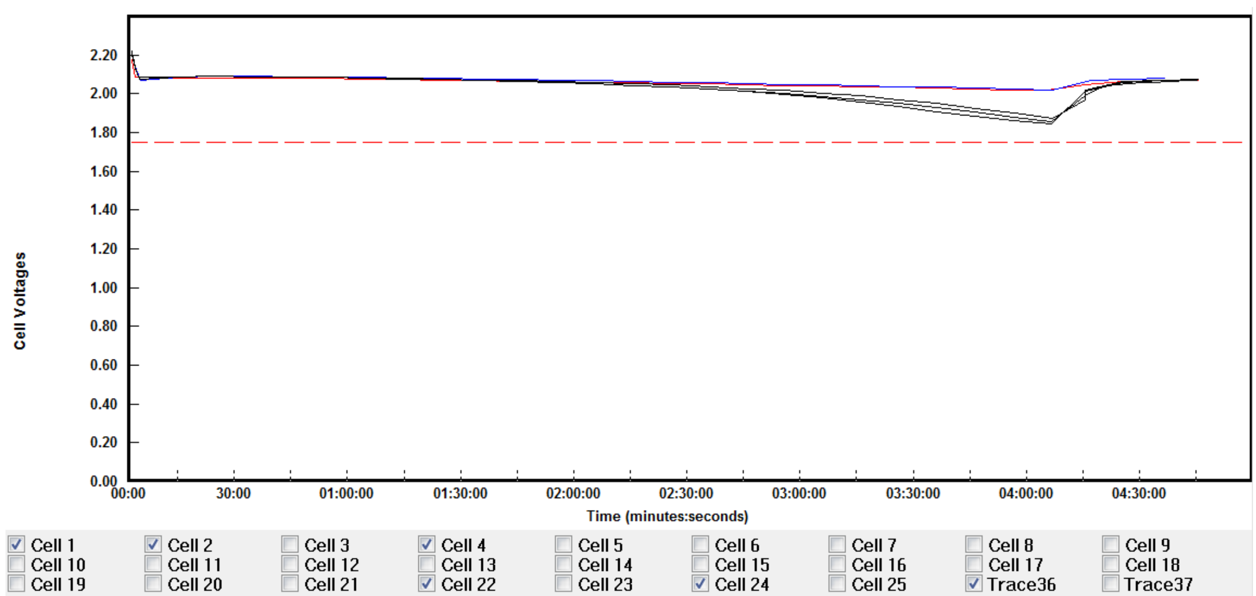

Figure 4. Three questionable cells in a 24-cell bank during an 8-hour capacity test. Two cells (blue and red curves) shown as reference of good cells

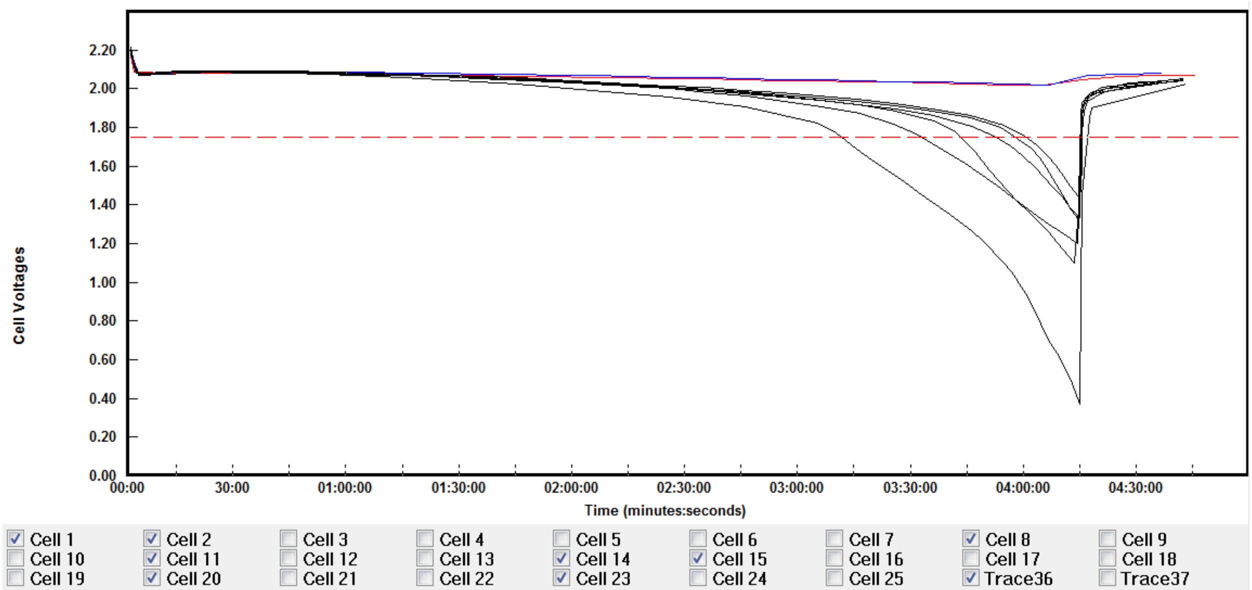

Figure 5. Six bad cells in a 24-cell bank during an 8-hour capacity test. Two cells (blue and red curves) shown as reference of good cells

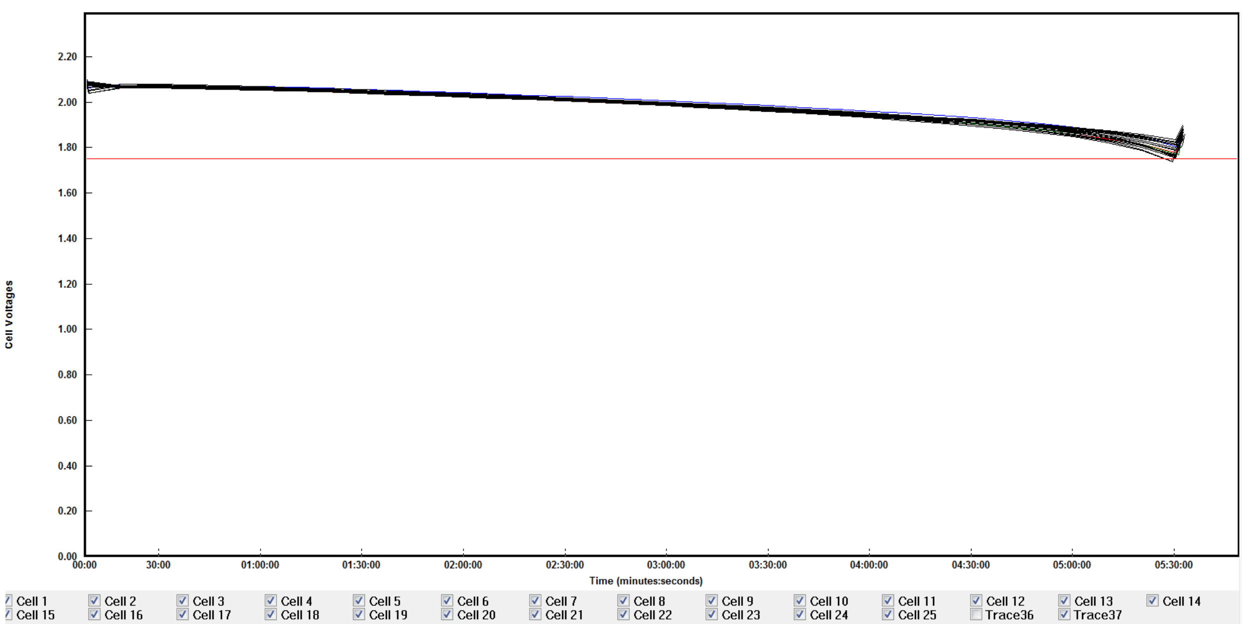

Figure 6. Discharge test after replacing bad and questionable cells

If a cell or cells are identified as weak or were bypassed, pending the age of the battery and the final capacity result it might be applicable to replace these cells to improve the capacity of the battery. If the cells are removed and not replaced, the charger voltages should be recalculated to the appropriate levels to avoid overcharging or overvoltage that can lead to a dry-out of the cells.

Considering that the battery might operate with weak cells or even without them, then it arises the question of the maximum number of cells to be bypassed or to remain weak in the battery. Recommended criteria to define this is to determine the minimum voltage required by the system being supplied by the battery to avoid reaching under-voltage limits.

An additional application of individual voltage monitoring technology, is the measurement of the voltage while recharging the battery bank. This can be used to identify cells that do not charge normally. Figure 6 shows the charging curve of a 24-cell bank during a period of almost 5 days.

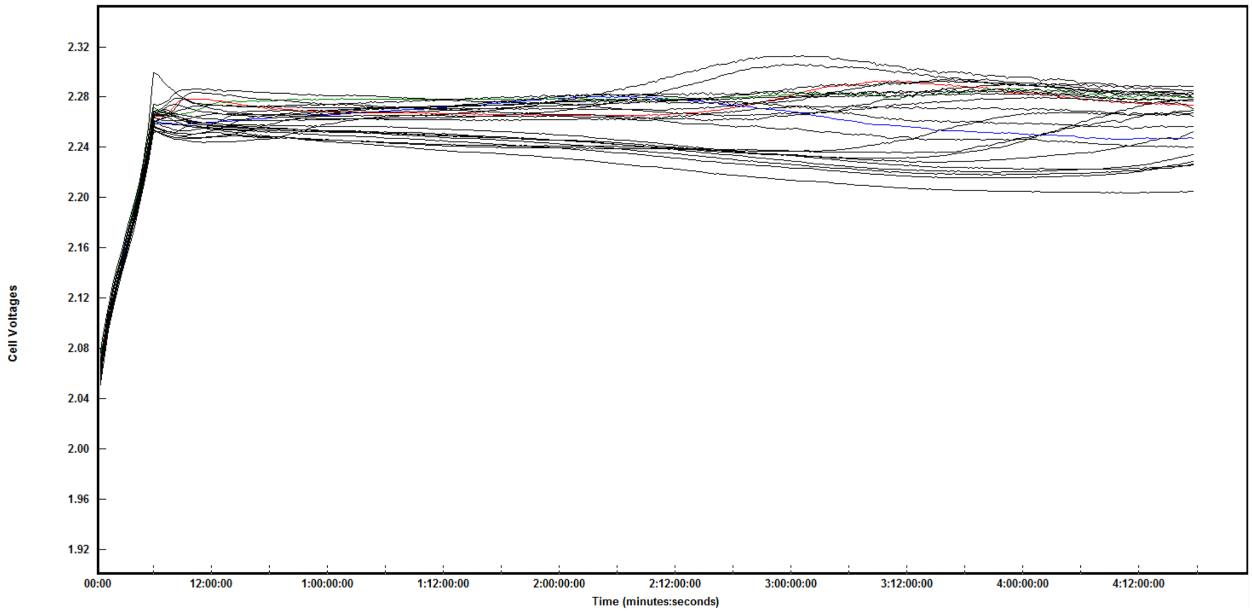

Figure 7. Detailed measurements of cell voltages during charge and discharge activities are valuable information when troubleshooting a battery issue and for interaction with manufacturers

Coup de fouet

Coup de Fouet, commonly translated as whiplash, corresponds to an electrochemical phenomenon that happens at the initial minutes of a discharge of lead acid batteries and is evidenced in the voltage curve by a dip. The voltage will drop from the initial open voltage value to minimum or "Trough" and recovers to a value lower than the open voltage called "Plateau". Both, the trough and the plateau, are related to the battery capacity but are affected also by the discharge rate, temperature, time under float conditions and previous discharge depth. Research works are oriented to determine the correlation between the Coup de Fouet and the battery capacity as a method to determine the actual capacity of the battery, however there is no direct correlation defined.

The Coup de Fouet can be used to get a coarse indication of the state of health of the battery: when comparing a capacity test with its baseline, a deeper voltage drop indicates a lower state of health. Ageing and capacity reduction of the battery will increase the depth of the voltage drop.

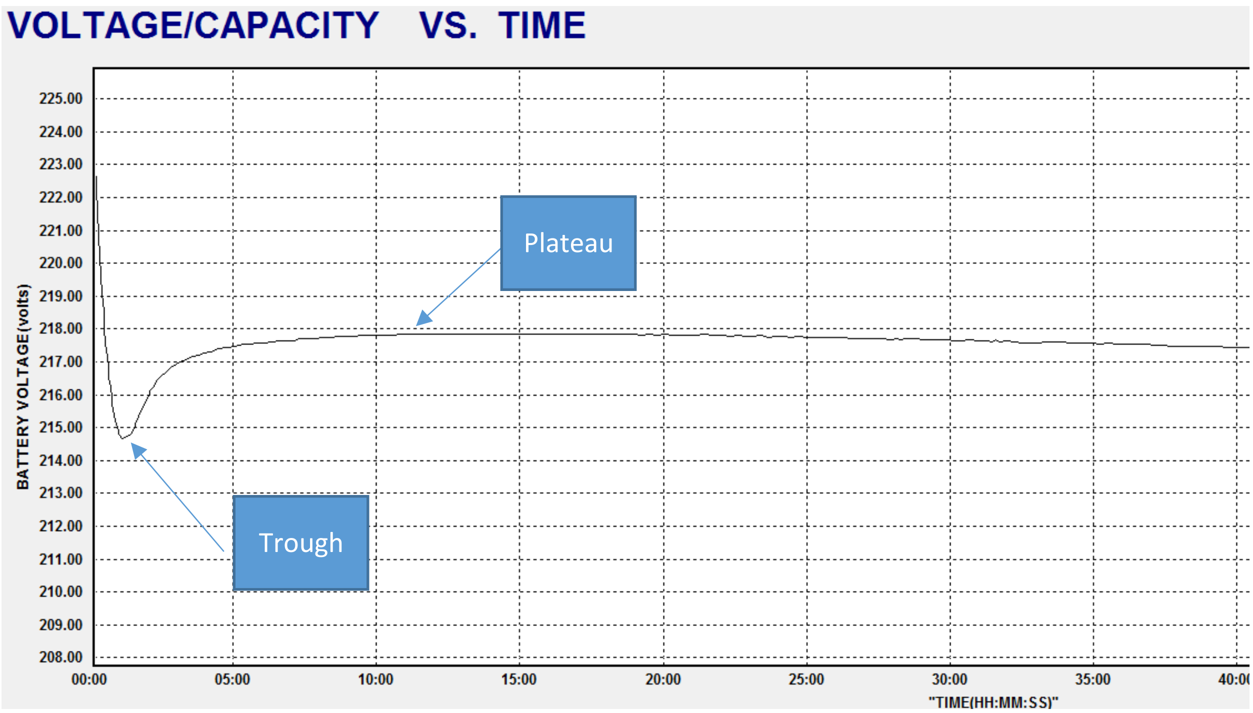

Figure 8. Coup de Fouet

Tips for easier and faster testing

Impedance

- Measurements should be made when the battery is fully charged and in float condition
- Impedance tests analysis is based on tending and comparisons. Measurements are method and instrument dependent; it is recommended to use the same instrument and leads used in previous tests to the same battery.
- When making measurements, leads placement in the cell posts should be consistent
- Admittance measurements cannot be compared against impedance measurements. The original references test should be used for future trending purposes

Discharge test

- Always follow manufacturer's recommendations for end of discharge voltages and current rates
- For a specific battery bank, always use the same calculation method for capacity results and keep records of all tests, including cells by-passed and or replaced
- It is highly recommended, and in some instances required, to connect a backup battery bank to the supported load of the battery bank under test

- Always correct the results based on the temperature conditions in which the test was performed and the reference temperature
- Be prepared with the tools necessary to bypass a cell, including connection cables to join non-adjacent cells
- Know the loading capabilities of the test instrument for discharge test. An adjustment on current rate and duration of the test might be necessary
- When designing a battery installation, it is good to consider oversized positive and negative terminal posts to facilitate connection to an instrument when performing a discharge test

References

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