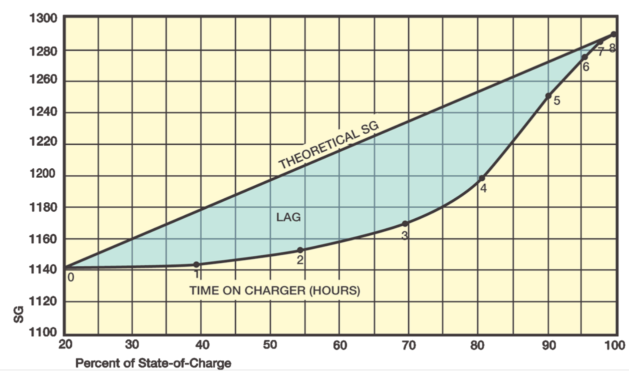
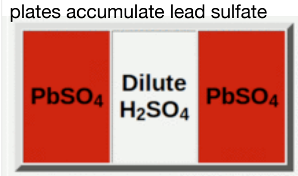
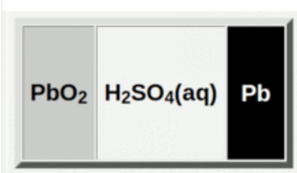
Variable	Effect	Details
Temperature [1]	Capacity	Cold temperature increases the internal resistance and diminishes the capacity. Batteries that would provide 100 percent capacity at 27°C (80°F) will typically deliver only 50 percent at –18°C (0°F). The capacity decrease is linear with temperature.
Temperature [1]	Voltage	Cold temperatures require higher charging voltages, increase 0.03V / 18°F less than reference)
Temperature [1]	Gassing	At a comfortable temperature of 20°C (68°F), gassing starts at 2.415V/cell, and by lowering the temperature to –20°C (0°F), the gassing voltage rises to 2.97V/cell.
Temperature [2]	Charge Voltage (inc. as temp dec.)	The recommended compensation is 3mV per cell per degree Celsius applied on a negative coefficient, meaning that the voltage threshold drops as the temperature increases.
Heat [3]	Battery Life	Heat increases battery performance but shortens life by a factor of two for every 10°C increase above 25–30°C (18°F above 77–86°F).
Specific Gravity [4]	Charge Lag	Specific gravity does not respond instantly throughout the electrolyte. Instead, the specific gravity is highest at the plates, where sulfate ions are released and the greatest number of them are concentrated. Farther from the plates, specific gravity remains lower until the freed sulfate ions have diffused evenly throughout the electrolyte.
Specific Gravity [4]	Charge Lag	FIGURE 18: LAG OF SG MEASURED DURING CHARGING PROCESS AGAINST THEORETICAL SG VS STATE-OF-CHARGE 
Specific Gravity [5]	Equalization	To avoid erroneous readings, specific gravity measurements should only be taken after an equalizing charge and subsequent float charge for at least 72 hours.
Specific Gravity [6]	Acid Stratification	The acid concentration is light on top and heavy on the bottom. This raises the open circuit voltage and the battery appears fully charged. AGMs do not suffer from this. Acid stratification occurs if the battery dwells at low charge (below 80 percent), never receives a full charge and has shallow discharges.
Specific Gravity [7]	Temperature	Correct the readings to 80° F: Add .004 to readings for every 10° above 80° F Subtract .004 for every 10° below 80° F.
Specific Gravity [7]	Low Value	1. The battery is old and approaching the end of its life. 2. The battery was left in a state of discharge too long. 3. Electrolyte was lost due to spillage or overflow. 4. A weak or bad cell is developing. 5. Battery was watered excessively previous to testing.
Specific Gravity [8]	Error	It takes several hours for the electrolyte to mix so that you get an accurate reading at the top of the battery. Always try to take readings after a period of no charge or discharge.
Surface Charge [9]	Higher Volts	Lead acid batteries are sluggish and cannot convert lead sulfate to lead and lead dioxide quickly enough during charge. As a result, most of the charge activities occur on the plate surfaces. This induces a higher state-of-charge on the outside than in the inner plate. A battery with surface charge has a slightly elevated voltage. To normalize the condition, switch on electrical loads to remove about one percent of the battery's capacity, or allow the battery to rest for a few hours. Surface charge is not a battery defect but a reversible condition resulting from charging.
Sulfation [10]	Soft	Soft is a a recently discharged battery and very easy to recharge. If you apply the low charge rate long enough you will convert all the sulfation due to discharge. It is like soft moss on the plates.
Sulfation [10]	Medium	Medium sulfate is a battery that has been left in a partially discharged state for one to four months. Like maple syrup, the sulfate will start to crystalize after a month or two. This can usually be recovered with a charge of greater then 10% to 20% AH capacity rate in amps. Some small hardened crystals may flake off and eventually drop to bottom of cell.
Sulfation [10]	Hard	Hard crystal sulfate is for all practical purpose impossible to break down back into sulfuric acid in electrolyte and lead in plates. It builds up on the lead plates when battery is not recharged within two to six months.
Sulfation [10]	Charge Current	Sulfation is unrelated to charge current - it is instead dependent on the charge state of the battery
Charge Voltage [10]	>14.4V = Gassing	FLAs can handle higher voltage than AGMs due to ability to vent hydrogen (aka 'gas' under heavy charge), AGMs can handle heavier current than FLAs

Variable	Effect	Details
Charge Current [11]	70% SOC = Absorb	It takes 7-10 hours to complete the absorb current and return the battery to 100% SOC
Charge Current [11]	100% SOC = Float	Float maintains the batteries at full charge, 13.5V used (80°F)
Charge Efficiency (SOC > 90%) [12]	CEF < 50%	Charge efficiencies at 90% SOC and greater were measured at less than 50% for the battery tested here, requiring a PV array that supplies more than twice the energy that the load consumes for a full recovery charge. Many batteries in PV systems never reach a full state of charge, resulting in a slow battery capacity loss from stratification and sulfation over the life of the battery.
Charge Efficiency (SOC 0-84%) [12]	CEF = 91%	These tests indicate that from zero SOC to 84% SOC the average overall battery charging efficiency is 91%
Charge Efficiency (SOC 79-84%) [12]	CEF = 55%	the incremental battery charging efficiency from 79% to 84% is only 55%. This is particularly significant in PV systems where the designer expects the batteries to normally operate at SOC above 80%, with deeper discharge only occurring during periods of extended bad weather. In such systems, the low charge efficiency at high SOC may result in a substantial reduction in actual available stored energy because nearly half the available energy is serving losses rather than charging the battery.
Heavy Load [13]	Needs Recovery	Lead acid is sluggish and requires a few seconds of recovery between heavy loads. This will show as a drop in voltage.
Charge/Discharge [14]	C1 vs. C/4	C1 = 1 hour to discharge a battery completely, C/4 = 4 hours to... Battery capacity diminished with increased discharge rate, T-105 battery has a C/20 = 225Ah and C/100 = 250Ah, and is caused by internal resistance of the battery; Peukert Effect describes this phenomenon
Watering [14]	After full charge	Batteries should be watered after charging unless the plates are exposed, then add just enough water to cover the plates. After a full charge, the water level should be even in all cells and usually 1/4" to 1/2" below the bottom of the fill well in the cell (depends on battery size and type).
Depth of Discharge (DOD) [14]	50%	Lead-Acid batteries do NOT have a memory, and the rumor that they should be fully discharged to avoid this "memory" is totally false and will lead to early battery failure.
Electrochemical Reaction [15]	Discharge	During discharge, both plates return to lead sulfate. The process is driven by the conduction of electrons from the positive plate back into the cell at the negative plate. **Negative plate reaction:** $Pb(s) + HSO^-_4(aq) \rightarrow PbSO4(s) + H+(aq) + 2e^-$ **Positive plate reaction:** $PbO2(s) + HSO^-_4(aq) + 3H+(aq) + 2e^- \rightarrow PbSO4(s) + 2H2O(l)$ In the discharged state both plates accumulate lead sulfate 
Electrochemical Reaction [15]	Recharge	Subsequent charging places the battery back in its charged state, changing the lead sulfates into lead and lead oxides. The process is driven by the forcible removal of electrons from the negative plate and the forcible introduction of them to the positive plate. **Negative plate reaction:** $PbSO_4(s) + H+(aq) + 2e- \rightarrow Pb(s) + HSO^-_4(aq)$ **Positive plate reaction:** $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + HSO(aq) + 3H+(aq) + 2e^-$ Pos. electrode: lead oxide Neg. electrode: lead 
Electrochemical Reaction [15]	Overcharging	Overcharging with high charging voltages generates oxygen and hydrogen gas by electrolysis of water, which is lost to the cell. Periodic maintenance of lead acid batteries requires inspection of the electrolyte level and replacement of any water that has been lost.
Electrochemical Reaction [16]	Acid Dissociation	Measure of the strength of an acid in solution. The pKa increases with decreasing temperature in exothermic reactions; decreasing temperature = decreased dissociation of an acid into solution. Strong acids are almost completely dissociated in aqueous solution, to the extent that the conc. of the undissociated acid becomes undetectable.
Electrochemical Reaction [17]	Gassing	After full charge, gassing releases about 1 cubic foot of hydrogen per cell for each 63 ampere-hours supplied. Since a 4 % concentration of hydrogen in air is explosive, ventilation of battery rooms is required for safety.
Electrochemical Reaction [18]	Solubility of Gasses (760mm HG)	density = 1.43 mg/mL (700x less dense than water)

oxygen in fresh water			
°C	°F	mg/L	ml/L
0	32	14.6	10.2
5	41	12.8	9.1
10	50	11.3	8.2
15	59	10.1	7.5
20	68	9.1	6.8
25	77	8.3	6.3

oxygen in 3.5% salt water			
°C	°F	mg/L	ml/L
0	32	11.2	7.8
5	41	9.9	7
10	50	8.8	6.4
15	59	7.9	5.9
20	68	7.2	5.4
25	77	6.6	5

Variable	Effect	Details								
		30	86	7.6	5.9		30	86	6.1	4.7
Electrochemical Reaction [19]	Detecting Hydrogen	Hydrogen gas in the air “tastes” salty when you breathe it. It reminds me of being near the ocean, and this is a good indicator that more ventilation is needed.								

1	http://batteryuniversity.com/learn/article/discharging_at_high_and_low_temperatures
2	http://batteryuniversity.com/learn/article/charging_at_high_and_low_temperatures
3	http://batteryuniversity.com/learn/article/discharge_methods
4	http://evbatterymonitoring.com/WebHelp/Battery_Book.htm#Section_2.htm
5	http://giantbatteryco.com/GLOSSARY/Specific.Gravity-Industrial.Batteries.html
6	http://batteryuniversity.com/learn/article/how_to_restore_and_prolong_lead_acid_batteries
7	http://www.trojanbattery.com/BatteryMaintenance/Testing.aspx
8	http://www.movre.com/information5.php
9	http://batteryuniversity.com/learn/article/how_to_restore_and_prolong_lead_acid_batteries
10	http://www.wind-sun.com/ForumVB/showthread.php?14228-Low-Amperage-Battery-Charging
11	http://batteryuniversity.com/learn/article/charging_the_lead_acid_battery
12	http://photovoltaics.sandia.gov/docs/PDF/batpapsteve.pdf
13	http://batteryuniversity.com/learn/article/discharge_methods
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