LAB 5.2: Wet Cell Electrolyte Testing - Handout

INTRODUCTION: Vented lead-acid batteries are often referred to as flooded or wet cell. Such batteries require both constant and scheduled maintenance and inspection in order to assure consistent performance as well as battery health. Inspections are performed during material acceptance, prior to installation steps, and during scheduled maintenance routines. Each type of inspection and/or testing has a different level of sub-tasks performed to support the intended task.

ITEMS NEEDED:

Components: Enersys 3CC-3M wet cell battery, seismic battery rack, distilled water, Enersys 3CC-3M Installation Manual

Tools: Insulated tools, hydrometer, thermometer, calculator

PPE: Rubber gloves, rubber apron, face protection/shield, safety goggles, fire extinguisher, eye wash system/shower, acid spill cleanup kit

OBJECTIVE: The purpose of this exercise is to conduct an inspection of the electrolyte level in a wet cell battery. This inspection will include determining the appropriate level of electrolyte, measuring the specific gravity of the electrolyte and applying any applicable correction factors.

Background Information: Specific gravity is defined as the ratio of the density of the electrolyte to the density of water, or in equation form:

$$Specific\ gravity = \frac{Density\ of\ electrolyte}{Density\ of\ water}$$

The electrolyte in a lead-acid battery is a solution of sulfuric acid and water. The electrolyte in a typical battery contains approximately 30% sulfuric acid and 70% water by volume combined to obtain a nominal specific gravity of 1.215. The electrolyte participates in an electro- chemical reaction to produce electrical current. During discharge, the sulfuric acid combines with lead dioxide from a battery's positive plates and lead from its negative plates to form lead sulfate and water. As a result, the sulfuric acid's concentration and electrolyte's specific gravity decrease. When a battery is recharged the process is reversed resulting in the original sulfuric acid concentration being restored.

If the specific gravity of a cell's electrolyte is below normal, the cell is not fully charged. The interpretation being, a low specific gravity means that the cell might not have the capacity needed to perform its design basis discharge because it is not fully charged. In this case, corrective action is needed to restore the cell to a fully charged condition. But, a perfectly normal specific gravity does not alone mean that a cell has its full capacity; it only means that it is fully charged. This is an important distinction; fully charged does not mean full-rated capacity. Both a brand-new cell with over 100% capacity and a cell at its end of life (< 80% capacity) will usually have a normal electrolyte specific gravity measurement.

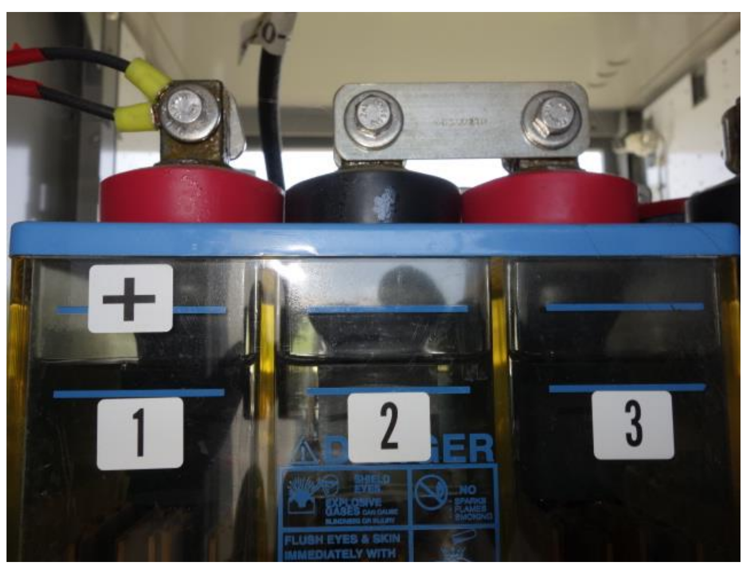
Summarizing, a below normal specific gravity measurement is a sign that a cell is not fully charged and corrective action is needed. However, a normal specific gravity measurement only means that a cell is probably fully charged, but is not alone an indicator of adequate cell capacity. Other factors, such as a battery's age and condition of its plates, also have an impact on its capacity.

Electrolyte Level Operability Considerations

Keeping a battery fully charged during normal float operation means that there is always a slight amount of charging current flow in excess of that required to offset the self-discharge of the cells. This excess charging current passing through a fully charged cell causes the electrolysis of water into hydrogen and oxygen gas. These gases are often referred to as charge gases. Charge gases escape through the flame arrestor of a vented cell. This dissociation of water into gas results in a gradual and predictable decline in the electrolyte level. Evaporation also contributes to a loss of the electrolyte's water composition.

Vented lead-acid stationary batteries are designed with excess electrolyte (termed *highly flooded*) to minimize maintenance as well as increase the interval required to add water (known as "watering"). A low electrolyte level does not indicate a loss of sulfuric acid; only that water is lost by evaporation or charge gases. Thus, the sulfuric acid is still available to participate in the electrochemical reaction necessary to produce electrical power. A decrease in electrolyte level increases the concentration of sulfuric acid, thereby increasing its specific gravity. Unless the active material of the plates becomes exposed, the increase in specific gravity can actually increase available capacity by a small amount. If a portion of the plates becomes exposed, the exposed area is not fully capable of participating in the electrochemical reaction and capacity might be reduced.

Cells are marked with high- and low-level marks so that maintenance personnel can judge when to add *distilled water* to a cell, and how much. An electrolyte level below the low-level mark does not necessarily mean that the battery is inoperable or incapable of producing its rated capacity; as long as the electrolyte is above the battery plates, battery capacity should not be affected.



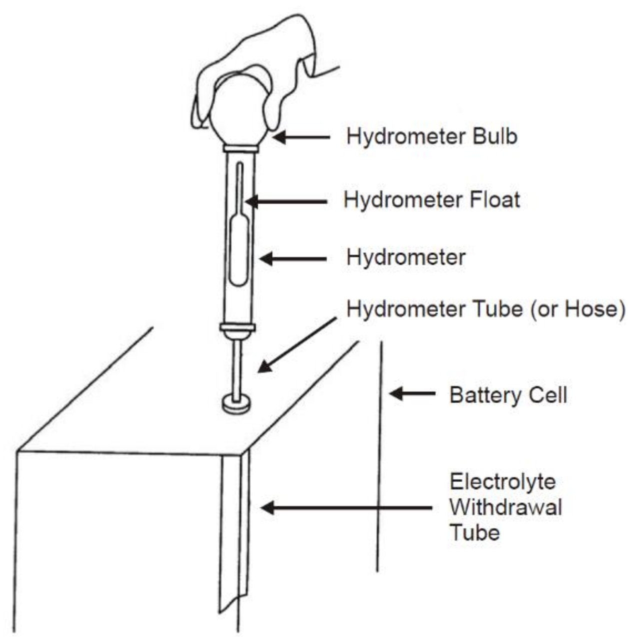
If the electrolyte level falls below the bottom of the filling funnel, gases can exit the cell via the funnel rather than through the flame arrestor, this situation could present an explosion hazard during excessive charging because an unprotected path exists for flame back into the cell. For this reason, the level should always be above both the plates and the bottom of the filling funnel.

If the plates are exposed because of a low electrolyte level, the exposed portion can experience accelerated sulfation, which results in loss of battery capacity. If a low level is allowed to persist permanent damage to the plates can also occur. If a low electrolyte level has caused plate exposure for a prolonged period of time, the manufacturer should be consulted to determine the extent of the damage caused. The battery may need to be removed for capacity testing or replaced completely depending its intended use.

If the electrolyte level is above the high-level line an overflow of electrolyte could occur during an equalizing charge when the cell is gassing vigorously. Overflowing electrolyte can result in shock and short circuit hazards, as well as a loss of electrolyte acid.

Specific Gravity Measurements

Specific gravity measurements are taken with a hydrometer, a calibrated float device, which is placed inside a clear cylinder. When the cylinder is filled with electrolyte, the hydrometer float indicates the specific gravity by its position in the electrolyte. A specific gravity measurement is read where the calibration on the hydrometer float meets the top of the liquid level in the clear cylinder. Stationary battery hydrometers are usually calibrated for 77°F (25°C) with a calibrated range of 1.100 to 1.250 (or higher) specific gravity. The hydrometer float sinks lower in the electrolyte as the electrolyte's specific gravity decreases. A typical hydrometer is shown in the figure to the right.



Digital hydrometers are also readily available; the manufacturer's literature should be reviewed for information as to how to use a specific digital hydrometer.

Lead-acid batteries are rated for performance at 77°F (25°C). The desired average operating temperature is 77°F (25°C), with a temperature variation among all cells of less than 5°F (3°C). The specific gravity of the electrolyte varies with the electrolyte temperature. Higher temperatures cause the electrolyte to expand, and result in a decrease in density and thus a decrease in specific gravity. The opposite is true for cooler temperatures. This temperature effect is often accounted for during specific gravity measurements so that readings can be compared against a reference set of conditions as well as against different sets of data taken at different temperatures.

Most hydrometers are calibrated for use at 77°F (25°C), consistent with conventional battery ratings. If the electrolyte temperature is not at 77°F (25°C), the electrolyte specific gravity measurement can be corrected for temperature in accordance with the table below.

Specific Gravity Temperature Correction Factors			
Temp (°F)	**Correction to Specific Gravity**	**Temp (°F)**	**Correction to Specific Gravity**
91 90 89	+ 0.004	74 73 72	- 0.001
88 87 86	+ 0.003	71 70 69	- 0.002
85 84 83	+ 0.002	68 67 66	- 0.003
82 81 80	+ 0.001	65 64 63	- 0.004
79 78 77 76 75	0		

During float (here float refers to the “float” charging cycle) operation, water in the electrolyte slowly converts to hydrogen and oxygen gas because of electrolysis caused by the float current; consequently, the electrolyte level gradually drops. Only the water in the electrolyte is lost to the atmosphere by the electrolysis process. As a result, the sulfuric acid’s concentration and the electrolyte’s specific gravity increase as the liquid level drops within the battery cells.

As the electrolyte level drops from the high-level mark to the low-level mark, it is not unusual for the specific gravity to increase from the nominal 1.215 to as high as 1.240. The table below shows level correction factors for one particular type of cell. The level correction factors in the table are interpreted as follows. An electrolyte’s specific gravity measurement is taken; then the measured value is adjusted by the correction factor to predict the expected specific gravity at the high-level mark.

Example of Specific Gravity Level Correction Factors	
Level Measured from High Level Mark (inches)	**Correction to Specific Gravity**
0 (high level mark)	0.000
-1/8	-0.004
-1/4	-0.008
-3/8	-0.011
-1/2	-0.015
-5/8	-0.019
-3/4	-0.023
-7/8	-0.026
-1	-0.030

Annex A of IEEE 450-1995 states that level correction is not required, provided that the electrolyte level is between the high and low level marks, and the temperature-corrected specific gravity is within the manufacturer's nominal specific gravity range.

The effect of temperature on electrolyte specific gravity is a physical phenomenon applicable to any vented lead-acid battery. However, the effect of electrolyte level variations on specific gravity for a given battery must be obtained from the manufacturer. The amount of increase in electrolyte specific gravity as the level declines from the high-level to the low-level line varies with the cell dimensions, construction, rated capacity, and other manufacturer-specific factors. Manufacturers can provide the expected change in specific gravity as the level drops from the high-level to the low-level mark.

Activity: Perform specific gravity measurements for each of an Enersys 3CC-3M wet cell battery's three cells.

Procedure Overview: Follow the procedure outlined below to perform a basic specific gravity measurement of the wet cell battery. If instructed, repeat the procedure so that measurements are taken for each cell.

Steps:

1. Verify that battery area safety equipment is available and operational. Review their operational procedures. (This includes equipment such as an eye wash station, shower and fire extinguisher, as applicable.)
2. Verify that personal protective equipment (PPE) is available and in good condition. (This includes equipment such as goggles, face shields, plastic or rubber aprons, gloves and acid spill cleanup kit as applicable.) Review acid spill kit instructions.
3. Put on appropriate PPE.
4. Measure and record the cell electrolyte level. (Measurement accuracy should be within 1/8 inch (3.175 mm). The high-level mark should be treated as the zero point.)

> CAUTION: Never interchange hydrometers and thermometers among lead-antimony, lead-calcium, and nickel-cadmium batteries. Sulfuric acid traces from a lead-acid battery will permanently damage a nickel-cadmium battery. Antimony traces from a lead-antimony battery will eventually contaminate a lead-calcium cell and result in long-term degradation.

5. Measure and record the cell electrolyte temperature to the nearest whole degree.

> NOTE: The electrolyte temperature of all measured cells should be within 5°F (3°C) of one another for an ideal battery installation. Temperature variations in excess of 5°F (3°C) should be investigated and resolved, if possible. Minor temperature variations in excess of 5°F (3°C) do not represent a battery operability concern, but can reduce battery life. An excessive temperature variation can result in some cells being overcharged or undercharged; this situation is known to reduce battery life.

6. Measure and record the cell electrolyte specific gravity. Use the hydrometer as follows to determine specific gravity:
   a. Slowly squeeze the hydrometer bulb to force air out of the hydrometer.
   b. Place the hydrometer hose or tube in the cell electrolyte withdrawal tube opening.

   c. Release pressure on the hydrometer bulb to allow electrolyte to draw up into the clear barrel of the hydrometer. Ensure sufficient electrolyte is inside the hydrometer so that the hydrometer float is floating freely.
   d. Hold the hydrometer vertically so the float is not in contact with the sides of the hydrometer barrel. Read the hydrometer at the true liquid level along the calibrated scale.
7. If temperature correction is desired, refer to the cell temperature measurement previously recorded for the cell and obtain the appropriate temperature correction factor from the Table - Example of Specific Gravity Temperature Correction Factors. Calculate and record the temperature-corrected specific gravity.
8. If level correction is desired, refer to the electrolyte level previously recorded for the cell and obtain the appropriate level correction factor from information provided by the manufacturer for the specific cell type and size. Calculate and record the fully corrected specific gravity by applying the level correction factor to the temperature-corrected specific gravity. (See Table - Example of Specific Gravity Level Correction Factors.)
9. Further investigation is warranted if the corrected specific gravity is outside the manufacturer's recommended range. An equalizing charge might be required if the corrected specific gravity is less than approximately 1.200 because this indicates that the cell has been undercharged and is not fully charged. (Consult the manufacturer's technical manual for equalizing charge recommendations.)
10. Review the specific gravity readings for all measured cells to determine whether the specific gravity variation between cells is excessive. Investigate any specific gravity readings that exhibit a significant variation from the rest of the measurements.
11. Compare the results to previous inspection results to identify any trends in specific gravity.
12. Specific gravity problems should rarely be a real technical issue for a properly maintained and fully charged battery. If the specific gravity of a cell or group of cells appears to be out of specification, consider the following possible problems for applicability:
    - Was the hydrometer read properly?
    - Is the hydrometer accurate?
    - If the specific gravity was corrected for temperature, was the calculation performed properly?
    - If the specific gravity was corrected for level, was the calculation performed properly?
    - Were the levels read correctly?
    - Are the cells fully charged? Compare to the float voltages. Discuss the effects of state of charge and specific gravity measurements with your training director if your measurements are not as expected.
    - Has water been added recently? If so, stratification effects can cause incorrect readings. Agitation of the electrolyte may remedy this by either a

long duration charging cycle as determined by your instructor, or by performing multiple flushing cycles of the hydrometer.

- Is water purity acceptable? Was non-distilled water added?
- Have the cells been overfilled or overflowed during an equalize charge? This may require addition of acid, which is extremely rare. Discuss with your instructor.
- For a high specific gravity, is it possible that acid rather than water was added to the cell? This would require the removal of electrolyte and careful additions of acid and water to return the solution to the proper specific gravity and acid molar concentration. This occurrence is also extremely rare and beyond the scope of this training. Discuss with your instructor.
- Does a visual inspection indicate an unusual plate condition or cell condition? Discuss with your instructor.