# Battery Types: Flooded versus AGM and Gel

## On the kinds of batteries we may use on board:

The most common kind of battery in Marine use today is the lead acid battery. Using an electrolyte consisting of sulphuric acid, these cells can store impressive amounts of electrical energy in a relatively small space. This energy is stored in chemical form within lead grids mounted inside the battery. The reliance on lead grids and paste explains the great heft of lead-acid batteries.

The battery universe is further divided along the lines of battery construction. Currently, there are three common lead-acid battery technologies: Flooded, Gel, and AGM.

- *Flooded or Wet Cells* are the most common lead-acid battery-type in use today. They offer the most size and design options and are built for many different uses. In the marine business, they usually are not sealed so the user can replenish any electrolyte the battery vented while charging the battery. Typically, the cells can be access via small ~1/2" holes in the top casing of the battery.

  The plastic container used for flooded cells will have one or more cells molded into it. Each cell will feature a grid of lead plates along with an electrolyte based on sulphuric acid. Since the grid is not supported except at the edges, flooded lead-acid batteries are mechanically the weakest batteries.

  Since the container is not sealed, great care has to be taken to ensure that the electrolyte does not come into contact with you (burns!) or seawater (chlorine gas!). The water needs of flooded cells can be reduced via the use of Hydrocaps, which facilitate the recombination of Oxygen and Hydrogen during the charging process.
- *Gel Cells* use a thickening agent like fumed silica to immobilize the electrolyte. Thus, if the battery container cracks or is breached, the cell will continue to function. Furthermore, the thickening agent prevents stratification by preventing the movement of electrolyte.

  As Gel cells are sealed and cannot be re-filled with electrolyte, controlling the rate of charge is very important or the battery will be ruined in short order. Furthermore, gel cells use slightly lower charging voltages than flooded cells and thus the set-points for charging equipment have to be adjusted.
- *Absorbed Glass Mat (AGM)* batteries are the latest step in the evolution of lead-acid batteries. Instead of using a gel, an AGM uses a fiberglass like

separator to hold the electrolyte in place. The physical bond between the separator fibers, the lead plates, and the container make AGMs spill-proof and the most vibration and impact resistant lead-acid batteries available today. Even better, AGMs use almost the same voltage set-points as flooded cells and thus can be used as drop-in replacements for flooded cells.

Basically, an AGM can do anything a Gel-cell can, only better. However, since they are also sealed, charging has to be controlled carefully or they too can be ruined in short order.

Gel and Absorbed Glass Mat batteries are relative newcomers but are rapdily gaining acceptance. There are some very compelling reasons to use VRLAs:

- Gel and Absorbed Glass Mat (AGM) batteries can dispense charge at a higher rate than flooded cells due to their lower Peukerts exponent. Deep-cycle Flooded Cells cannot deliver more than 25% of their rated amp-hour capacity in amps without plummeting Available Capacity.
    - Deep-Cycle Flooded cell battery manufacturers recommend a 4 to 1 ratio between battery bank size and the largest load encountered on board.
    - AGM and Gel cell manufacturers recommend a ratio of at least 3 to 1, a significant difference for loads such as the engine starter or windlass.
- Virtually no gassing under normal operating conditions: Unlike flooded cells, gel cells and AGMs are hermetically sealed and operate under pressure to recombine the oxygen and hydrogen produced during the charge process back into water. You find VRLAs in the bilges of high end yachts such as Hinckley, Hans Christian, Island Packet, etc.. Every boat benefits from a low center of gravity over the keel (good for righting purposes) and the minimal venting requirements make it possible.
- The ability to put VRLAs in the bilges (they can operate under water should you hole yourself) also lengthens their lives: For every additional 15 degrees of heat over 77 deg F, lead acid battery life (regardless of type) is cut in half (batteries self-destruct with time, you can only slow that process). Chances are, the bilges are the coldest place on board (outside the freezer) and the keel provides protection.
- VRLAs can operate in any orientation (although you may lose some capacity that way) and even if a container is broken, a VRLA will not leak. This is a feature particularly important to blue water sailors who may encounter survival storms - you don't want to coat the inside of your boat with sulfuric acid if you ever get rolled. Proper (heavy duty) battery restraints are a must, regardless of battery type.
- Gel cells and AGMs require no maintenance once the charging system has been properly set up. No equalization charges (usually), no electrolyte to replenish, no specific gravity checks, no additional safety gear to carry on board in order to protect yourself. If you want to be anal retentive about VRLAs

you can load test them. However, proper charge control and protection is much more important with VRLAs because once fried it is impossible to revive them.

- The charge acceptance of AGMs can burn up an alternator if the charging system is not adequate for extended runtimes at full power. The larger the battery bank and the harder the charger is made to work, the more attention I would pay to ensuring that the charging system can handle the currents for extended periods of time. This caveat does not really apply to low-duty applications like starter banks, since they usually need so little charge to be topped up. Even the puny alternators found in Jet Skis should be able to handler an AGM starter battery, as long as that battery is just used for that - starting.
- On the other hand, if you need a large house bank and want to rely on a single charge source for much of the power, I'd aim for a high quality charge system from a respected company such as Ample Power, Balmar, Ferris, Hehr, JackRabbit Marine, SALT, etc. Ensure that the alternator receives enough cooling air as a hot alternator will produce less energy than a cool one and last longer to boot. AGMs and to a lesser extent gel cell systems can benefit from using the thermal alternator protection offered by the Balmar MaxCharge series of regulators, particularly if you expect to bulk charge your system for extended periods of time and don't have good engine compartment ventilation.
- The higher charge efficiency of AGMs allows you to recharge with less energy: Flooded cells convert 15-20% of the electrical energy into heat instead of potential power. Gel-cells lose 10-16% but AGMs as little as 4%. The higher charge efficiency of AGMs can contribute to significant savings when it comes to the use of expensive renewable energy sources (wind generators, solar panels, etc.) as your charging system can be 15% smaller (or just charge faster).
- While flooded cells lose up to 1% per day due to self-discharge, VRLAs lose 1-3% *per month*. Why employ a solar charger to trickle-charge your battery banks if you don't have to?
- High vibration resistance: The construction of AGMs allows them to be used in environments where other batteries would literally fall to pieces. This is another reason why AGMs see broad use in the aviation and the RV industry.

Thus, there are some significant differences between battery types in terms of features and construction. However, there are also some very important figures to consider when it comes to choosing the right battery: Various capacities, cost, warranty, etc. The following table tries to summarize across brands using batteries as close to the 8D Group Size as possible

Comparison of Battery Types using several different measurements

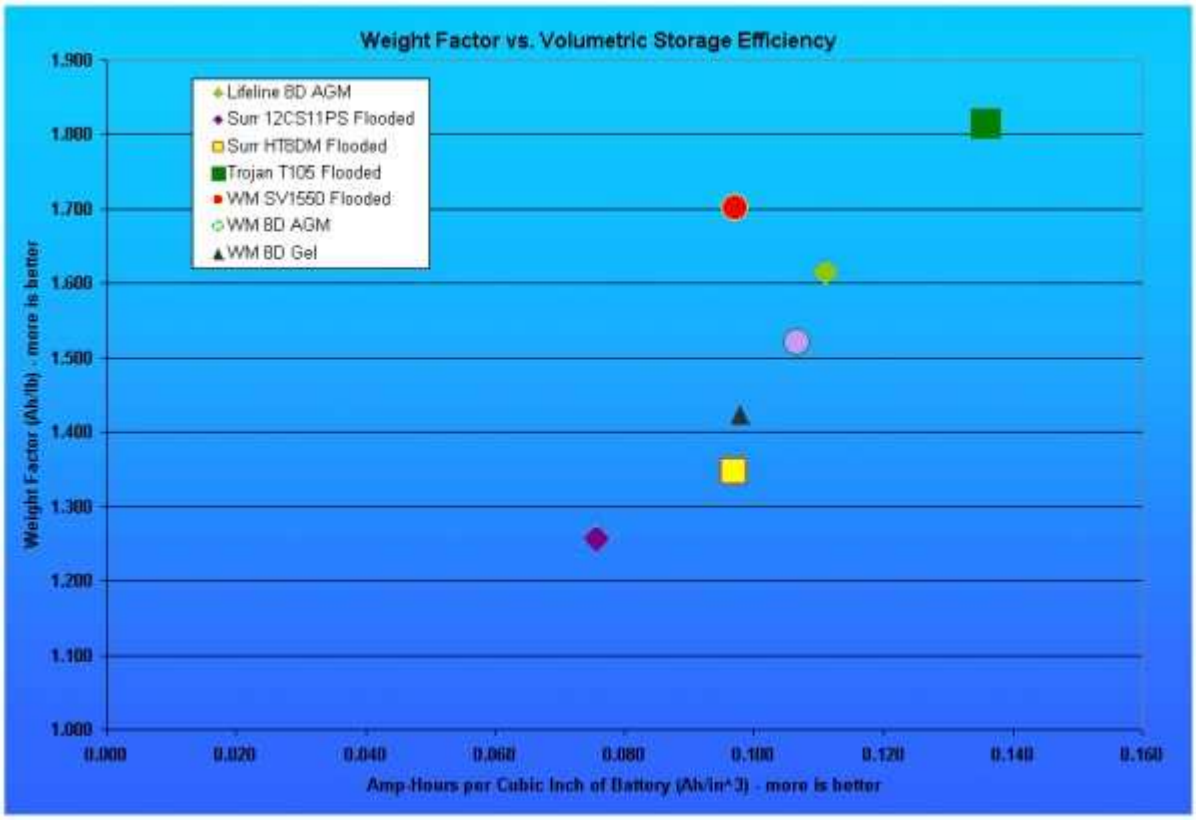
| **Comparing physical attributes between** | **VRLA** | | **Flooded** | | |
|---|---|---|---|---|---|
| | **Lifeline** | **West** | **Inexpensive** | **Premium** | **Premium** |

| VRLAs and Flooded Cells | AGM (8D) | Marine Gel (8D) | Trojan (2xT105) | Surrette 400 (HT8DM) | Surrette 500 (12CS11PS) |
|---|---|---|---|---|---|
| **Amp-hour capacity (20hr rate)** | 255 | 225 | 225 | 221 | 342 |
| **Warranty (Replacement/Pro rated)** | 1/5 Years | 1.5/5 Years | 0.5/3 Years | 2/5 Years | 3/7 Years |
| **Life Cycles (@ 50% DOD)** | 1,000 | 500 | 500 | 1,250 | 3,200 |
| **Initial Purch. Cost (USD/12V set)** | 387 | 449 | 152 | 246 | 683 |
| **Initial Purch. Cost (approx. $/Ah)** | $1.52 | $2.00 | $0.68 | $1.11 | $2.00 |
| **Energy Density (Ah/in^3)** | 0.111 | 0.098 | 0.136 | 0.097 | 0.076 |
| **Weight Factor (Ah/lb)** | 1.614 | 1.424 | 1.815 | 1.348 | 1.257 |
| **Max. net replenishment during bulk charge, accounting for charge limits, efficiency and assuming a 400Ah battery bank** | 1550A* | 177A | 85A | 85A | 85A |

I tried to level the playing field by selecting as many group 8D batteries as possible. The two exceptions are the Trojan T105's and the Surrette 12CS11PS (no series 500 Group 8D battery is manufactured by Surrette for the marine market). The larger battery size is to the advantage of the Surrette, although it does not impact results greatly. The Trojan T105's were used because I was not able to find ready pricing on the Trojan 8D. I would expect results to be somewhat comparable.

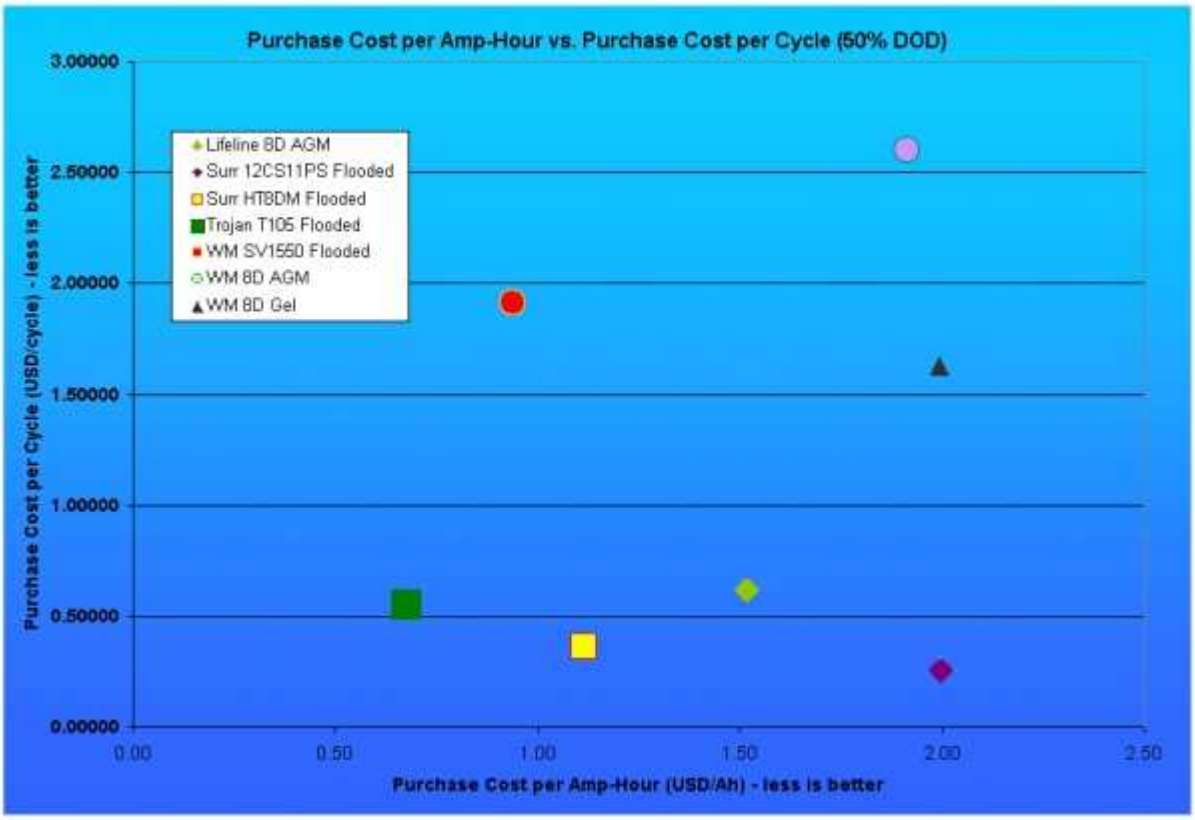
*Concorde Batteries used to claim no charge limit on its web-site, while Windsun.com claims 4x amp-hour capacity. I limit charge current in the cost model to 100% of amp-hour capacity just to be on the safe side.

## Energy Storage per unit Weight and Volume




Here is one of the classic comparisons that people like to make: How much charge the battery can store per unit weight and per unit volume. As you can see, the Trojan T105 comes out ahead in both departments due to its low weight and compact construction. However, this construction technique will also lead to a lower cycle and overall life.

## Purchase Cost per unit Weight and Volume




As we can see from this chart, the purchase cost per amp-hour and purchase cost per cycle still make the Trojan T105 look like the most attractive battery. Thus, if you are strapped for weight, space, and cash, such a battery might be ideal. The Trojan product has thin lead plates that make these batteries lighter but also shorter lived. Rolls advertises very long pro rata warranty replacement periods for their premium line that are indicative of the confidence they place in their product.

Premium cells are handicapped by lower energy storage density but offer longer lives and greater resistance to the self destructive habits of lead acid batteries: Thicker lead plates and a more complicated product make it possible. Hence, premium cells usually have a higher resistance to vibration, are easier to service, and have higher cycle lives than their budget competition. Many boat owners are willing to put up with the initial purchase price in return for reliability and not having to replace them every few years.

## So what is a "Marine" Battery?

Perhaps it's shocking condiering their retail prices, but most batteries sold through marine hardware stores do not qualify as premium batteries. Pay close attention to what you're buying. Batteries are not created equal and *brand or price are not the primary indicator for quality*. For example:

- Rolls/Surrette make a range of flooded batteries from the super-premium 500/CS series to the mid-range 300 series that is meant to compete with Trojan, Exide, etc.
- WestMarine is offering AGM batteries with a shorter warranty period and higher price than Lifeline AGMs.

Thus, Caveat Emptor! Try to get as much information about your prospective marine batteries before you buy or you'll be sorry. Furthermore, consider that premium batteries usually only exist in non-standard form factors. For example, you will probably have to make some custom modifications to properly mount/restrain the tall and heavy Rolls/Surrette 500 series (18"+ high, min. 128 lb+ each).

However, life cycle costs are not just a function of the initial purchase costs. You should also consider the fuel/engine wear savings of using VRLAs over flooded cells. AGMs offer the highest charge acceptance, efficiency, and a reasonably long life which makes them generally a better bargain (see results in cost model section). Unfortunately, there are fewer shapes and sizes of VRLAs to chose from (relative to the flooded cell universe anyway), and less familiarity and presence world-wide. On the other hand, VRLAs can be shipped anywhere by air. Flooded cells have to be bought locally or delivered by surface transport.

I used DEKA gel cells in the past for comparisons, but West Marine recently brought out a private label 6V gel cell series that they claim will sustain over 1,000 "full discharges". Given that reputable brands never claimed more than 600 cycles in the past, the West Marine claim may be a bit dubious. Due to West Marine's return policy, I'll give them the benefit of the doubt. West Marine also released a set of private label AGMs. Unless I missing something, these are very expensive and have a much lower cycle life than the Lifeline competition manufactured by Concorde Batteries. Thus, I don't see why anyone would want to buy a West Marine AGM.

## Can I Mix AGMs and Flooded Cells?

While several sources state that you can mix AGMs with regular flooded cells, I would not recommend it (gel cells have sufficiently different set points to make them totally incompatible with flooded cells or AGMs). Ideally, your house bank would consist of a number of identical batteries wired in series and/or parallel that were manufactured on the same day.

## So how can I save money with AGMs?

There are many attributes that determine the true cost of a battery technology. Much like incandescent versus compact fluorescent light bulbs, your choice of battery technology may cost you less up front but will cost you more over the life of the product. For example, the faster, more efficient bulk charging that AGMs and gel-cells allow will lead to reduced wear and tear on your charge source (engine, gen-

set, etc.). More on all that later down. Suffice to say that I do not believe the T105 to be a bargain.

**How about Nickel-Cadmium Cells?**

They have their place. Usually in power plants where there is lots of excess energy, etc. Learn more about them on my Nickel-Cadmium page.

Anyway, onwards to sizing and charging requirements! This is where Lifeline AGMs really start to shine, assuming your charging system can take advantage of them.