Standard Gas Volume Measuring Apparatus (VMA)

Eagle-Research Standard (Version May 3/2010)

I've seen dozens of different water displacement measuring devices, including many on You Tube. One fact has become seriously clear… there is no STANDARD.

The ability to reliably compare experimental results is a **vital requirement** to cooperative development and consistent innovation of different electrolyzer configurations.

Eagle-Research is now setting a **standard** for a simple gas volume measuring apparatus (and procedures of use) to compare electrolyzer outputs.

This will help all cooperative innovators find the most efficient designs and parameters; and (a second huge need) to reliably confirm reproduction of each other's efficiencies.

There is much debate about the accuracy of various gas volume testing apparatus and procedures. I'll discuss the options and issues elsewhere. It is my experience that (properly used) water displacement is a reasonably accurate, and inexpensive, means of measuring the volume of any given gas.

This particular apparatus is not intended to confirm **exact** gas production. *It is intended to confirm **comparative** gas production*. If everyone uses the same apparatus and the same testing protocol, then electrolyzer efficiencies can be reasonably compared. At this time, that is the most important goal.

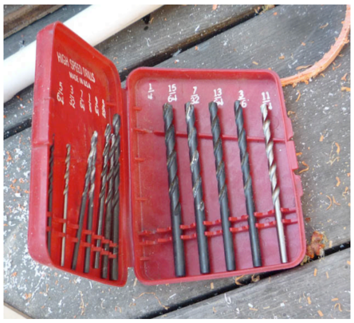
Parts:

1 length of 3" Drain or Sewer PVC pipe. *Color, thickness and quality (does not need to be CSA or pressure rated) do not really matter. The length will be determined from options below; it will be between 10" (simple version) and 24" (counter-weight version).*
1 of water bottle of about 740 mL volume *that slides easily (with about 1/4" side clearance all around the bottle) into the 3" PVC pipe (I use an Aquafina bottle).*
1 of water bottle about 500 mL volume (again Aquafina) to use as counterweight.
1 length of 1/2" PVC pipe. *It should be 3" longer than your bottle is high (calculate length below)*.
1 of 3" to 3" SxS PVC coupler for sewer pipe.
1 of 3" to 2" SxS PVC bushing (slides inside sewer pipe)
1 of 2" to 1/2" SxS bushing
These two pieces will be shaped and glued together to make a 3" to 1/2" SxS bushing.
Use whatever sizes you can find locally to achieve the same goal.
1 of 3" sewer cap (flat top)
1 of 6" sewer cap (flat top) to use as apparatus base.
1 of 3/8" FPT 90° to 1/2" Slip PVC pipe fitting.
1 of 3/8" MPT to 3/8" barbed fitting.
3/8" clear vinyl tubing, at least 3 feet.
2 of screen door pulleys. Note: I like to use plastic screen door pulleys about 1" in diameter. The plastic won't corrode and is light, so the mass of the pulley doesn't take much energy to start moving. 1" keeps the fishing line from bending too sharply.
2 of small eye hooks

Supplies:

Pipe sealant, *(prefer Teflon tape because that's what the HyZor needs)*
Transparent PVC solvent, *you'll need transparent to put together the clear HyZor*
Transparent PVC glue, *you'll need transparent to put together the clear HyZor*
Small tube of silicone sealant

Tools:



Hacksaw
1/8" drill bit
1/4" drill bit
27/32" drill bit
1/2" drill
1" hole saw
Jig Saw
Knife (for cleaning cut edges of pipe)
Syringe (or some means to accurately measure water volume)
Permanent, non-water soluble marker

Building the Apparatus:

Base Assembly Part 1:






Shape the two bushings and glue them together to achieve a 3”x1/2” bushing that has a large flat surface; so it can be securely glued to the base. I shortened the inner bushing and ground off the lip, so that it would slide into the outer bushing to achieve a flat surface.



Glue the 3”x1/2” bushing onto the bottom of the 6” cap (with PVC solvent and cement); glue both flat ends together. *The 6” cap will then serve as the apparatus base and the bushing as the bottom of the main chamber.* Glue the 3” coupling onto the bushing. Apply weight to the pieces to assure a good ‘weld’. Allow the glue to completely dry before proceeding with the base.

In the meantime, prepare your bottle, gas tube, chamber pipe and, if applicable, the pulley cap.

Gas Tube Length:

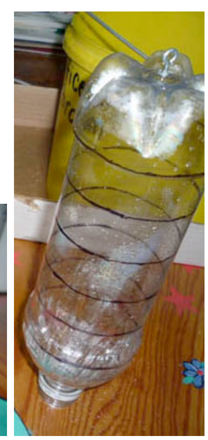

Gas tube length is the total of about 1” for the fitting, about 1” for the bushing, plus the height of your bottle (when your bottle is cut off at the 700 mL mark) and plus 1/2” for clearance (so bottle sits on the gas tube, not the bushing).

Glue the 3/8” x 1/2" slip fitting onto the 1/2” pipe.

700 mL Bottle Preparation:

Remove any labels from the water bottle (so it is clear).



Pour water into the bottle until the water in all the ‘stand holes’ is even with the rise in the center of the bottle. *This is to eliminate the inaccuracy caused by this ‘excess’ volume that will not fill with water when the bottle is on the stand pipe.*

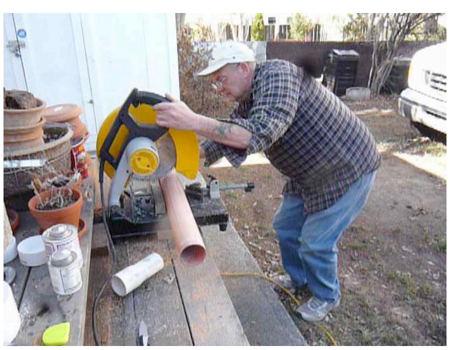
From this point, carefully measure 100 mL (cc) of water into the bottle. Use your marker to draw a line around the bottle at 100 mL mark. Repeat for each 100 mL until you have at least 500 mL marked.


Cut the top of the bottle off at about the 700 mL mark. *The idea is to have the bottle rise up the tube with minimal resistance, while water leaves the bottle with minimal restriction*.

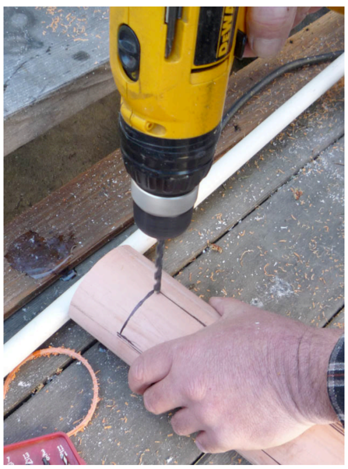

Screw an eyehook into the end of the (now 700 mL) bottle, and seal it with silicone.

Screw an eyehook into the cap of the 500 mL bottle.

Chamber Pipe Preparation:



If using the 'simplest configuration' the height of the 3" PVC pipe, when fully inserted into the coupler, *will be about 1/2" higher than your 1/2" gas tube so water doesn't fall out of your apparatus.*



If using the counterweight option, the pipe will be about twice the height of your bottle plus 2” for top clearance.

Then cut a 2” wide slot, starting 1/2" above the top of the gas tube and ending 1” or 2” below the top of the pipe. *Your slot needs to be wide enough so you can see the liquid level inside and outside of the bottle and high enough so you can easily reach the top of the bottle to push it back down.*

Drill some 1/4" holes around the pipe, just above the bottom of the slot, so light can come in and assist viewing the water levels.

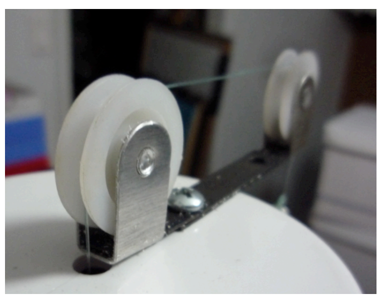
Pulley Cap Preparation:



Drill, using a 1/16” drill bit, a hole in the exact center of the pulley cap, then drill the hole out to 1/4".



Drill appropriate holes in the pulley mounts to allow them to fasten to the cap. I pre-punch the places where I’m going to drill, or it is difficult to drill accurately in the spring steel.

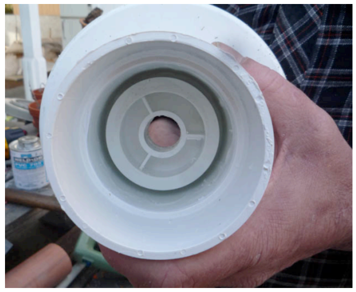
Screw the pulleys onto the cap. The edge of the inner pulley will allow a fishing line to fall directly to the middle of the bottle. *The pulley outside just needs to be far enough out to prevent the counter-weight bottle from rubbing on the 3” pipe.*

I overlap the pulley mounts, so that they support each other.

Base Assembly Part 2:

Now back to the Base assembly, once the glue is hard.

Use a 1/4" drill to pre-drill through the 1/2" portion of the bushing (for the web of the larger drill bit). Then use a 27/32 drill bit to enlarge the hole right through the base; so a 1/2" pipe can slide through (pressure fit) from the bottom.


Hold the base and drill firmly so the hole does not become oblong (a drill press works well, if you have one). If the hole is cleanly made, the gas tube will be held straight. *If the hole is oblong, then it will still seal (with the glue) but you'll need to hold the gas tube straight until the glue hardens*.

Glue the 1/2" gas pipe into the base (inserting it from the bottom). Use plenty of solvent (to soften the plastic) and glue (to assure a good seal). Make sure the 1/2" pipe will go straight up the center of the chamber.

Glue on the chamber pipe.



Drill a 1" hole in the side of the base, to allow the hose to come out. A slot would work too, if you don't have a hole saw.

Install the 3/8" MPT barbed fitting. Use thread sealant (I prefer Teflon tape).

Use PVC solvent and cement to glue the 3" pipe into the upper cap on the base. Hold down with weight.

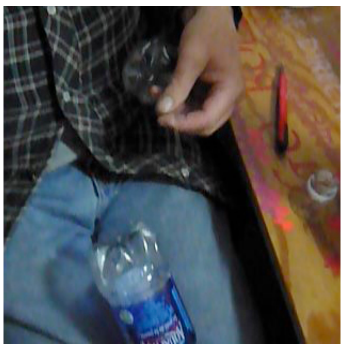
Put a 3 foot length of 3/8" hose, (I like to use clear vinyl) onto the barbed fitting.

Counter-weight option:

The main problems with the simplest design (non-counter-weight) are:
1. The gas needs to overcome the weight of the bottle as it is pushing it up. This will pressurize the gas and cause a low reading.
2. The bottle can tip to its side, causing friction and resistance; again causing a low reading.

Both these issues can be acceptably overcome by simply having a person hold the bottle straight and lift the bottle just enough so that the water inside the bottle is exactly the same level as the water on the outside of the bottle.

Counter-weight assembly:



Tie a 3 foot length of fishing line onto the eyehook on the bottom of the 700 mL bottle. Thread the fishing line up through the cap hole. Lightly press fit the 'pulley' cap onto the chamber tube. Run the fishing line up and over the pulleys. Make the length of the fishing line long enough to allow the 700 mL bottle to fully lower. Tie the fishing line onto the 500 mL bottle's cap eyehook.

I like to put the counter-weight bottle to the back of the gas-testing apparatus (away from the sight slot) so the weight doesn't get in the way of viewing the inner bottle.

There are two advantages to using a bottle as a counter-weight. It could happen that the masses are pretty much in balance already, but if not, it is an easy matter to add a bit of water to the smaller outside bottle, to add weight.

Add the amount of weight needed to balance the bottles when there is no water in the chamber. You want just enough weight to balance. I just squirt some water into the 500 mL bottle.

Note: The fishing line may have a 'memory' that doesn't allow the inner bottle to fully rest on the gas tube. Simply 'store' the apparatus with the 500 mL bottle fully lowered (700 mL bottle all the way up) so that the fishing line is held straight in the area that'll be 'active' when measuring. Then the memory will be erased.

Testing Tools:

1. Voltmeter: Pretty much any multimeter has a voltmeter function. Use test clips to assure a good continous connection.

2. Ampmeter: I generally prefer to use an amp-clamp but, as these can be pricy, an appropriate sized inline amp-gauge will work.

Note: If you are using an electrolyzer power supply that is not straight DC, it is a good idea to use an analog voltmeter and ampmeter. Most digital meters get confused (hunt) when reading signals that turn on and off many times a second (or quickly vary in other ways), and find it difficult to settle on a reading. Analog meters inherently 'average' the signal, so give a consistent and accurate reading of variable frequency, waveform and pulse width signals.

3. Thermometer: I prefer an infared 'laser' thermometer. For this purpose, pretty much any electronic indoor/outdoor thermometer will work (just attach the sensor to the HyZor).

4. Stopwatch: Mechanical or electronic is OK.

5. Eagle-Research Standard Gas **Volume Measuring Apparatus** (VMA).

6. Power Supply capable of variable amperage and voltage: This tool can be pricy but is SO NICE to have. Inexpensive options include building your own Capacitive Battery Charger / Power Supply and simply hooking your experiment up to your vehicle's battery and idling the engine.

The power supply needs to provide the voltage that your vehicle will be providing as it runs. Vehicle batteries have about 12.6 VDC when charged and require up to 13.6 VDC to charge them. Vehicle alternators are regulated to provide at least 13.6 VDC (up to 14 VDC) so the battery will charge and stay charged. *We design our HyZors to operate on 13.6 VDC and they will not perform well at lower voltages; so you cannot power these experiments directly from a 12.6 VDC (or lower voltage) battery*.

However, if you connect virtually any battery charger to a battery, it will rise in voltage to 13.6 VDC (or higher) and provide the voltage needed for your experiment. Make sure the battery charger is rated to provide the amperage the HyZor is using or your battery will become discharged (of course, you can simply charge it between experiments).

If you have a fixed voltage, amperage will tend to vary depending on the electrical resistance of the HyZor.

If you have a fixed amperage, voltage will tend to vary depending on the electrical resistance of the HyZor.

(Optional) If using variable frequency, pulse-width and/or waveform power supply, it is very helpful to have pulse-width meter(s), frequency meter(s) and an oscilloscope. Otherwise it is very difficult to know exactly how much wattage your electrolyzer is actually using. So, for comparitive purposes, I recommend only using straight DC. We are trying to test efficiencies of various electrolyzer designs, not power supply designs (that's a whole different subject).

Testing protocol:

Make sure the VMA is set to zero position; with bottle all the way pushed down and water level (inside and outside of the bottle) even with the top of the gas tube. Add water as needed, *excess water should drain back down the stand tube*. Make sure the gas tube is clear of water (would cause resistance to gas flow).

Have your HyZor operating and connect the VMA hose to the HyZor gas output fitting. *Can be done one handed if you hold the HyZor in a clamp*.

Start a stopwatch the instant you connect the VMA to the HyZor. Measure the time to acquire 500 mL of gas.

Note: If you permanently connect the HyZor to the VMA, you can insert a Tee into the hose, to act as a 'drain or relief' for the BG from both the VMA and the HyZor (as it runs continuously). As long as the leg on the Tee is open, the BG will not go into the VMA (if the Tee and hoses are large enough to prevent backpressure).
As soon as you plug the Tee, the BG is directed to the VMA and the bottle starts to rise.
This allows for quick and easy manual measuring (hold a finger on the Tee) or allows for a (large orifice) solenoid valve to be inserted, for remote and/or automatic control.

Measure and record:
1.The DC voltage (on the HyZor itself) . (best to record to 2 decimal places).
2.The DC amperage (flowing through the HyZor) I use an amp clamp. (best to record to 2 decimal places).
3.The temperature of the HyZor (should be close to the temperature of the gas). I measure at the base of the tower with a laser thermometer. Use either °F or °C but be consistent.
4.The time (in seconds) it takes to produce 500 mL of BG.
5.The hour/minute for each volume test.

Enter the data onto the spreadsheet. Here is a website
http://aquauto.com/blogs/nickstone/mmw-calculator
that has a very good MMW spreadsheet
http://www.4shared.com/u/zvmszps/94d1bc4f/Bob_Campbell.html
you can download so you can know the efficiency of your experiments.

Record (on the spreadsheet) the year/month/day of the tests, who is performing the tests, any changes you made to the experiment prior to the volume test (like electrolyte density, plate configuration, power supply variables, etc.) and any particulars of the test that seem odd (like foaming, bubbles going wrong way, etc.)

With this data you will start to see and confirm parameters that significantly enhance (and retard) gas production.

Specifically, we are finding that electrolyzer temperature and electrolyte density are **CRITICAL**. We still can't predict exactly what electrolyte to use, what density and what temperature for any given electrolyzer design; but we have determined that if you can control these variables, gas production can often be doubled with NO INCREASE in wattage drawn by the electrolyzer.

Calculating Electrolyzer Efficiency:

MMW is an acronym for MilliLiter(s) per Minute per Watt.

MMW is meant to measure the efficiency of any given electrolyzer technology; particularly electrolyzers designed for on-board vehicle use. The idea is to know the relationship of the volume of BG being produced (milli-liters) for each watt-minute of work.

MMW came into the public domain (I haven't tracked down the originator) during the explosion of on-board electrolyzer experimentation that happened during 2008. The originator popularized the measurement even though there was already (for decades) an electrolyzer efficiency standard in place and accepted worldwide by the scientific community.

The 'official' standard for electrolyzer efficiency is Watt-hour(s) per Liter (Wh/L). Watt-hours are a measurement of work, so this measurement gives the actual amount of electrical energy it took to make 1 liter of BG, (no matter how long it took to make).

So, an on-board electrolyzer (like the Mighty Mite version of the HyZor Technology) that takes 15 seconds to fill a 500 mL volume, using a steady 13.8 VDC and 8.5 ADC would calculate:

Given:
13.8 VDC * 8.5 ADC = 117.3 watts.
15 seconds to fill 500 mL = 120 liters/hr or 2000 mL/minute
117.3 watts * 1 hr = 117.3 Wh

Results:
117.3 Wh / 120 L/hr = 0.9775 Wh/L (for Wh/L smaller is better)

2000 mL / 1 minute / 117.3 watts = 17.05 MMW (for MMW larger is better)

Testing the VMA:

Shut off the power to the HyZor with the hose still attached and the bottle still suspended at the 500 ml. mark. Leave it this way overnight. The purpose for the test is to determine if there are any gas leaks in the HyZor or the VMA.

Incidentally this will also indicate that there is no significant volume change in the BG. One would expect that if the BG is hot, there will be some volume loss when the gas cools (you'll be able to measure that) but if the gas is close to room temperature during the test, you should see no change in volume. A change in volume indicates a leak that needs to be fixed.

Note: Do not allow 'stored' BG to sit in sunlight, it will devolve into ordinary water vapor with H2 and O2 with a corresponding loss in volume.

Changes to design:

We are open to any suggestions to improve this design.