



## Sealing Brushless Motors – MTB-001

**Background:** In underwater robotics there are a number of motors available for use with ROVs. To meet MATE safety specifications, all of these must be sealed from external environment. Because they are brushless, there is a temptation to place the motor directly into the water and apply power. The connections from the manufacturer for these motors are not designed to be submerged. Typically, the magnet wires are brought together and then soldered to a larger power lead. That soldered connection is then covered with heat shrink tubing. When these motors are placed in water, initially they may function fine and do not exhibit any malfunctions, however this can be misleading and problems will arise later during operation.

Water will seep under the heat shrink tubing, creating a direct path to ground for the electrons. Also a path becomes established from phase to phase of the motor leads. Problems with this include the following:

1. **Electrolysis of motor leads.** With the motor leads submerged and in water, electrolysis can take place between your motor leads and other items of lower electrical potential. Over a period of time (usually a few hours of operation) the copper in your wires etches away causing two things: the reduced size results in the wire acting like a fuse and it burns open under current, or the wires just fall off from the connection point.
2. **Safety hazard.** Exposed wires are especially dangerous with ROVs where the motor voltage can be as high as 48V.

Salt water is highly conductive, streams of bubbles can be observed at those connection points which are not properly sealed. This electrolysis process splits the oxygen and hydrogen bonds in the water, and the newly formed hydrogen and oxygen bubbles are observed floating to the surface.

Many teams desire to use brushless motors because, "they are easy and we don't have to waterproof them." Unfortunately, these motors are not waterproofed to MATE specifications, regardless being used in a commercial product. Simply put, if the brushless motors do not meet MATE specifications, they will not be allowed.

**Solution:** For brushless motors and stepper motors, sealing the motors with epoxy will rectify the situation. The electrical portion of the motor can be placed in a mold or other holder to allow all the wires to be sealed. Epoxy can be poured into the mold and seal the connections at the same time.

### Design Notes:

- The mold for the electrical portion of the motor should be as close fitting as possible.
- It is possible to make molds out of 3D Printer material, if water soluble material is used, water can be used to aid in removing the mold.
- For Stepper motors or motors where the electrical portion is on the outside of the motor, an armature replacement can be turned on a lathe to replace the rotating component during the sealing process.



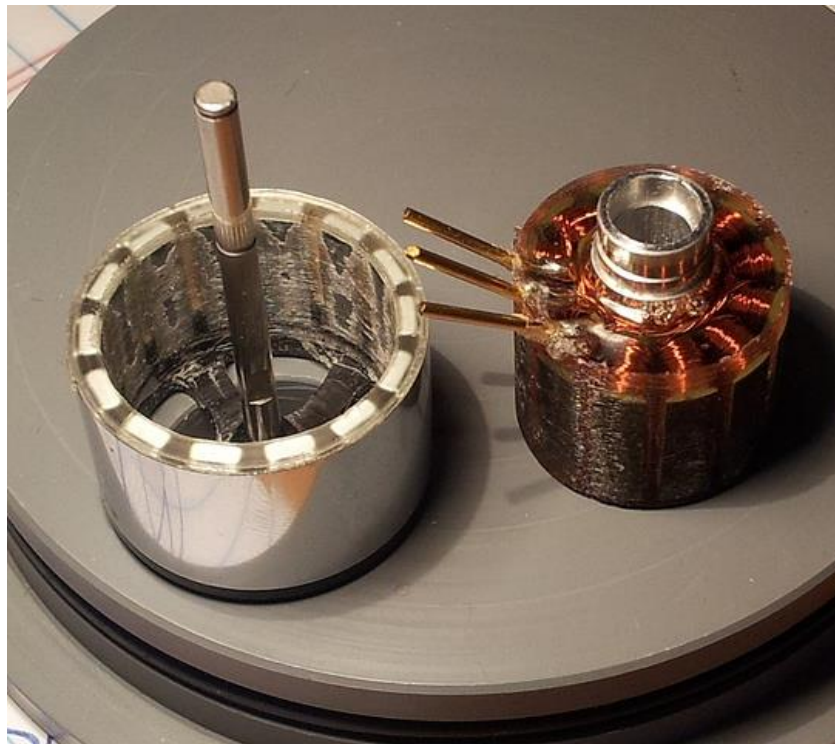
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- The lower the viscosity of the epoxy used the easier it is to flow into all the tight spaces in the area being sealed.
- Placing the motor into a vacuum chamber while the epoxy is being sealed will help pull the epoxy into all the crevices providing a better seal. A simple vacuum chamber can be made using a canning jar and a brake bleeding hand vacuum pump. It will take a while to evacuate the air but it will increase the sealing measurably.
- Epoxy selection: Any epoxy can be used, but for best chances at long motor life, an electrical insulating and thermally conductive epoxy should be used. Non-thermally conductive epoxies can cause a buildup of motor heat. This shouldn't be a problem operating underwater, but if operating in high ambient temperatures, it could cause a problem.

### Examples:

The following three figures show examples of the motor sealing process found on the OpenROV forum.



From: <https://forum.openrov.com/t/epoxy> Image - 1



From: <https://forum.openrov.com/t/epoxy> Image - 2



From: <https://forum.openrov.com/t/epoxy> Image - 3



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**Testing:** When sealing a motor, it is not enough to say “we sealed it, it’s good to go”. You need to test your results before putting the motor into operation. The best way to test is immersing the motor into a solution of conductive water and measuring the resistance between the water and the motor leads.

It is possible to seal the leads of a brushless motor stator (not rotor) in epoxy. The connection points between the motor leads (thick flexible and plastic insulated wires) and the motor windings (magnet wire) must be fully enclosed in the epoxy. To verify compliance, it is recommended that you photo document your process and include testing results.

One way to test this is to put the motor in a tub of typical water with the leads outside of the water. “Typical” meaning pool water, ocean water, etc. Typical conductive water that the ROV will be operating in, not distilled water.

Bring the leads out of the water while the motor is in the water. Make sure that the leads, don’t touch the water. Let the motor sit in the water over night to get “acclimated”.

When you return the next day, attach one lead of a meg-ohm meter (megger) to a copper plate and put into the water.

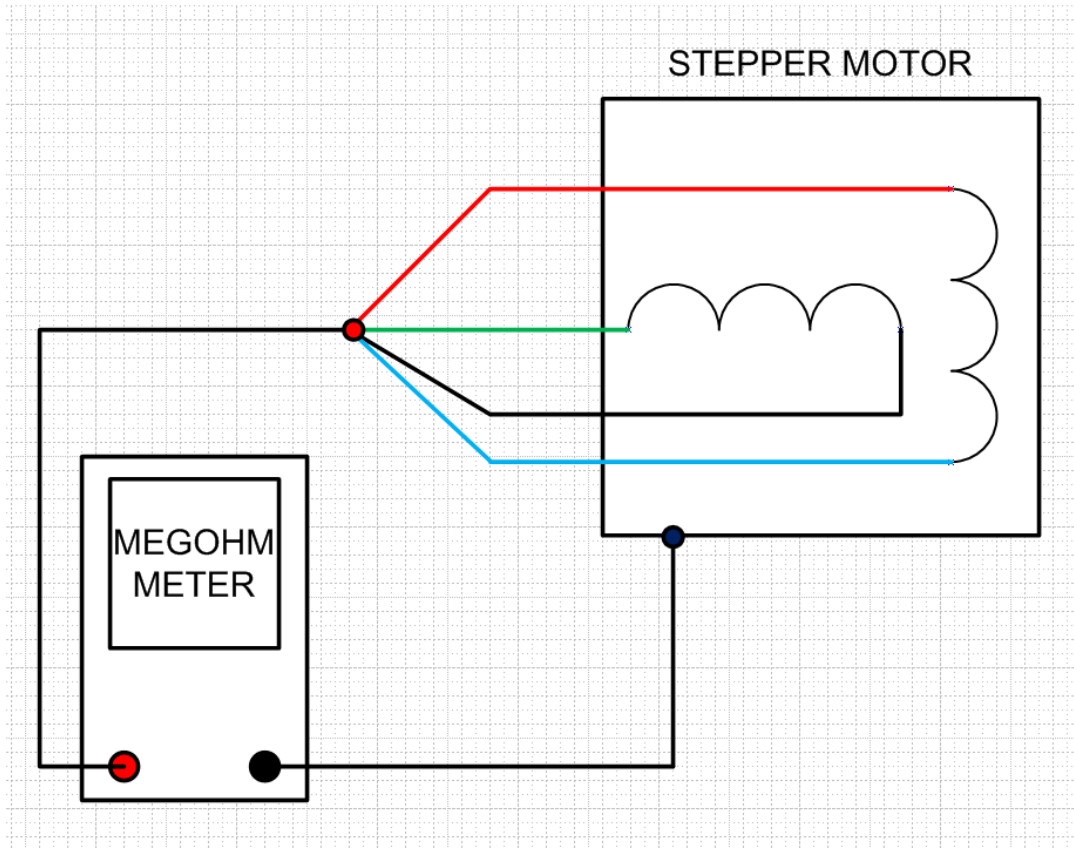
Attach the other lead of the megger to a motor lead and test. If you have more than 10Meg ohms of resistance you are good and sealed. Repeat the test for all three motor leads.

Conducting a megger test will fail for the stock brushless motor not sealed. The overnight soak allows maximized time for water to seep into the connection. Yet, this is sped up by placing the motor into a pressure vessel such as a paint pressure pot and subjecting it to pressures up to 40psi.

***SAFETY WARNING: If the motor is placed under pressure, the pressure vessel should be certified for the pressures used and equipped with a functioning high pressure relief valve. In cases for MATE related testing, pressures should be kept in the 25 to 40 psi range. Safety glasses must be worn at all times by anyone in the area and the system should never be left unattended.***

A megger is not a voltohm meter that reads into the megohms. It is a high voltage testing device used to locate faulty insulation and connections and unfortunately they are fairly expensive (\$500+ USD). The link below provides options to one that tests at 500VDC and is under \$100.

[http://www.amazon.com/s/ref=nb\\_sb\\_noss\\_1?url=search-alias%3Dindustrial&field-keywords=vc60b](http://www.amazon.com/s/ref=nb_sb_noss_1?url=search-alias%3Dindustrial&field-keywords=vc60b)



MEGOHM METER CONNECTIONS FIGURE - 5

**MegOhm Testing:** A megohm meter is a special type of high resistance tester that subjects the device under test to much higher voltages than what a multimeter utilizes. A typical multimeter might have a voltage as low as 1.5VDC while measuring ohms. This is not adequate for electrical sealing testing.

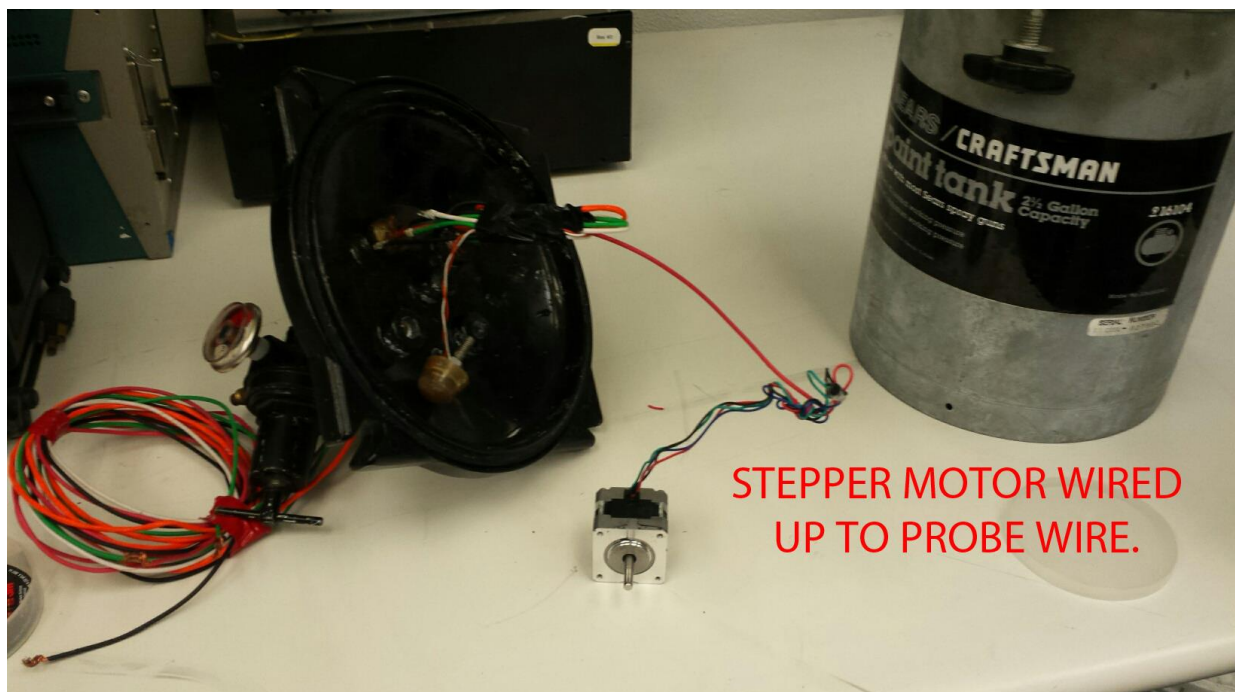
A MegOhm meter or “megger” typically has multiple voltage settings. 250VDC, 500VDC and 1000VDC and common test voltages.

**SAFETY WARNING:** *Due to the high voltages present during megger testing, care must be taken to ensure that no person becomes part of the electrical circuit. Safety glasses must be worn during all testing.*





Before using the megger, verify that it operates properly by using it to measure a resistor in the Meg Ohm range



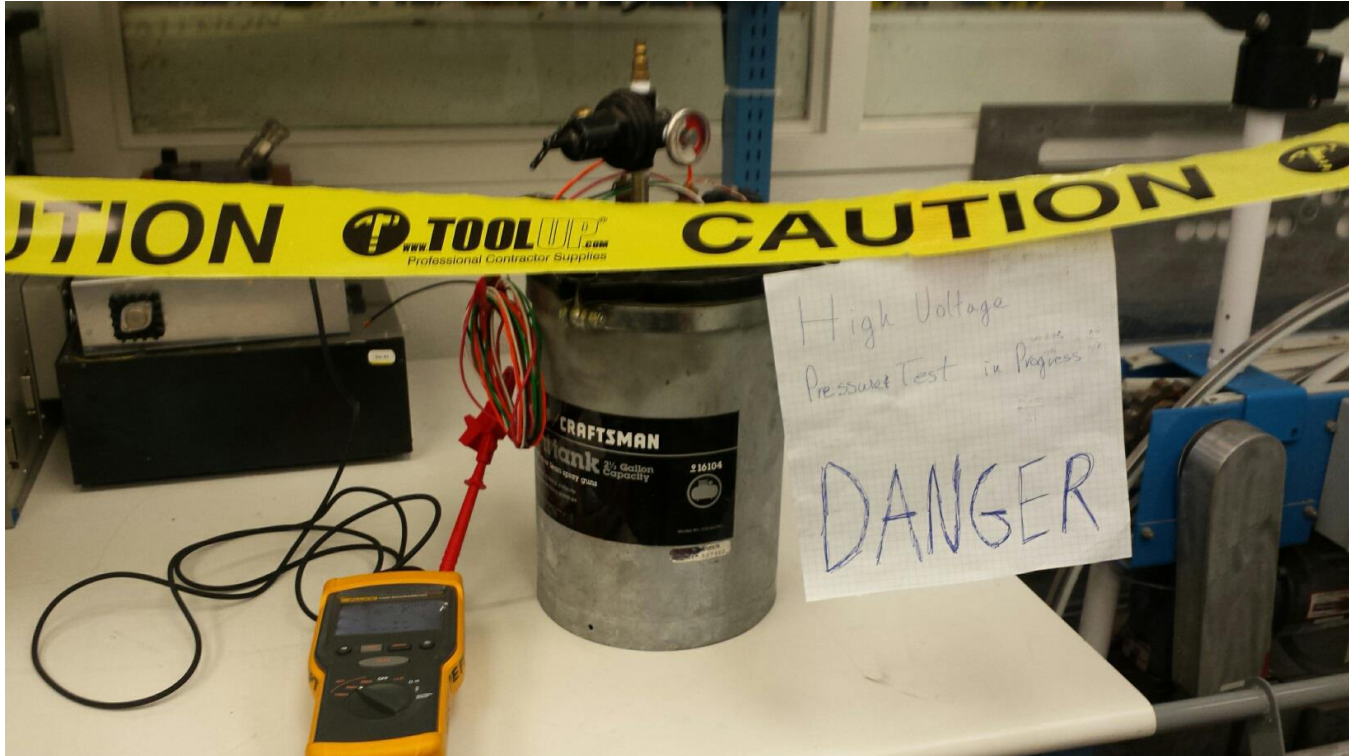


Be sure that all connections are out of the water and do not come in contact with the side of the vessel.



Testing of the motor showing greater than 2000M Ohms at 534VDC





Complete setup for MegOhm testing under pressure.

Maximum pressure used with this pressure vessel was 40PSI

### Below is an example testing data sheet

Test conducted by: Johnny Student

Megger Model: Samyo VC60B+

Time	Measured Ohms	PSI	Comments
1/1/16 12:00pm	>100 Mohms	Atmosphere	Testing Started
1/2/16 12:00pm	>100 Mohms	Atmosphere	End of 24 hour soak
1/2/16 12:01pm	>100 Mohms	40 psi	Started Pressure test at 12:00pm
1/2/16 12:30pm	>100 Mohms	40 psi	
1/2/16 1:00pm	>100 Mohms	40 psi	End of 1 hour pressure test