(See most recent updates at the end of this document)

TECHNICAL BULLETIN 03

PRODUCT: Products with pre-installed potted penetrators

SUBJECT: Poor adhesion of potting on components and devices with pre-installed cable penetrator.

SUMMARY: On an undetermined number of pre-potted cable assemblies, there is poor adhesion between the aluminum in the penetrators and the epoxy.

We are currently testing the adhesion in production by pulling on the cable while have the penetrator secure and visually inspection for separation between the epoxy and the penetrator. However, this is not a robust test, and we do not have the capacity to do fully robust testing. We have still been receiving reports of the epoxy falling out of the penetrator as a solid mass upon arrival, as well as slow leaks developing after some pressure cycling.

IDENTIFICATION: Blue Robotics recommends conducting the early Optional Preliminary Vacuum Test in the BlueROV2 instructions to check for adhesion integrity.

Gently tug on all cables potted into cable penetrators and ensure they are well seated and adhere properly.

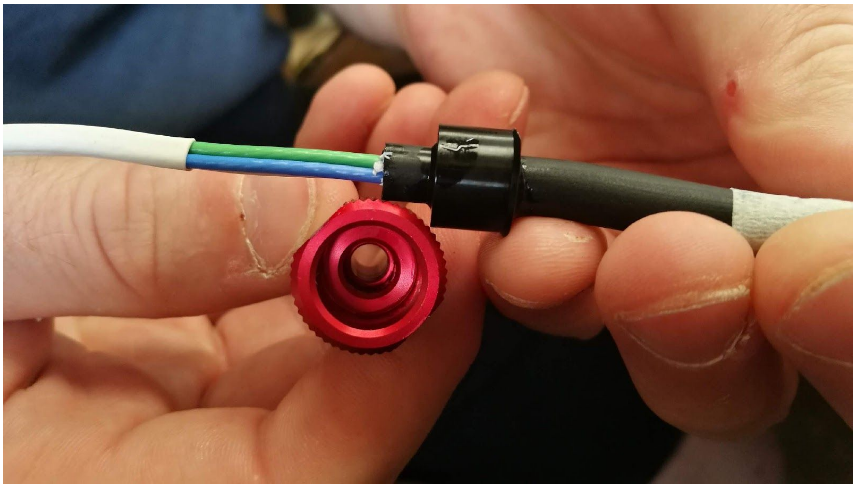


Figure 1. Cable Penetrator with poor adhesion to aluminum cable penetrator.

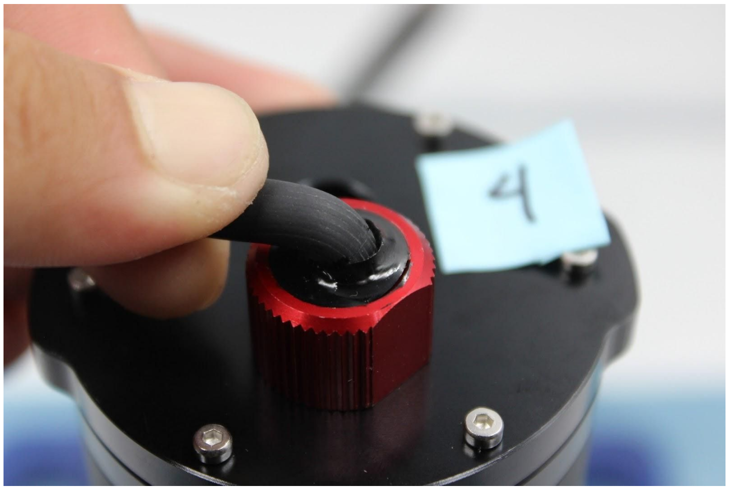


Figure 2. Cable Penetrator with poor adhesion to aluminum cable penetrator and cable jacket.

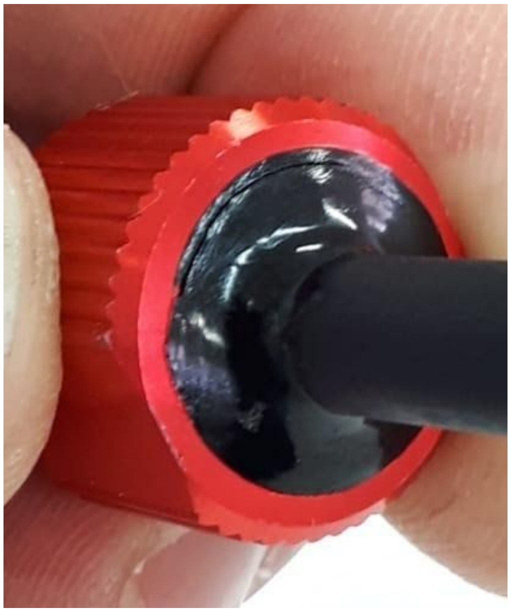


Figure 3. Cable Penetrator with poor adhesion to aluminum cable penetrator.

CUSTOMER ACTION: If you have an affected cable, please use the below contact information to begin the RMA process and receive a replacement component. Higher value products, such as the Ping360, will need to be returned before a replacement can be sent.

BLUE ROBOTICS ACTION: The cause of the delamination between the penetrator and the epoxy has been narrowed to either inconsistencies in the penetrator anodization process, atmospheric conditions, inconsistencies in the epoxy that we are using, or a combination of the three.

Since Technical Bulletin 02, issued on 29 March 2019, we have taken the following actions:

1. Requested that the anodizing facility ultrasonically cleans the penetrators after anodizing.
2. Fine grit bead blasting the penetrators prior to anodization.
3. Stored the epoxy cartridges upright.
4. Maintained consistent temperature throughout our manufacturing warehouse.
5. Added a step to the manufacturing process to pull test the cables and inspect for delamination.
6. Brought out a representative from the company that manufactures the epoxy to get their feedback on what we could be doing better.

Based on the feedback from the representative of the epoxy manufacturer, we will be doing the following:

1. Buying a potting machine to be used for all penetrator potting.
2. Installing desiccant on the air inlet of the epoxy hoppers to ensure that no atmospheric moisture gets added to the epoxy during storage.
3. Using epoxy that has come from the manufacturer in bulk only rather than using cartridges.
4. Updating the penetrator design so that none of the inside potted parts are anodized.
5. Adding the following steps to our potting process:
    a. Mechanically cleaning the bore of the penetrator.
    b. Chemically cleaning the bore of the penetrators.
    c. Removing the chemical residue from the bore of the penetrators.
    d. Potting immediately after cleaning.
6. Updating the penetrator design so that the corners are less sharp on the parts that are potted.
7. Updating the potting process so that the potting that is visible appears to be convex rather than concave.

Our progress on the above actions is as follows:

1. We have purchased the potting machine and expect it to arrive at our facility by 12.20.19.
2. We have purchased all necessary equipment to use the potting machine and have received most of it. We expect to receive the balance by 12.20.19.
3. We have built a humidity and temperature controlled chamber to test the effects of different atmospheric conditions on the potting process.
4. We have ordered epoxy in bulk, from the manufacturer, that we expect by 12.20.19.
5. We have received prototype quantities of penetrators with the design revisions mentioned above.
6. We are investigating different methods of mechanically cleaning the penetrators that will be effective and still allow for high throughput in production.
7. We are investigating different methods of chemically cleaning the penetrators that will be effective, safe, and still allow for high throughput in production.

Upon receipt of the potting machine we will begin testing in earnest. Our anticipated, but likely optimistic timeline is as follows:

- December
  - Acquire everything that we need in order to proceed and schedule testing.
- January
  - At the beginning of the month, begin building prototypes.
  - As soon as prototypes are built, begin testing prototypes.
  - Throughout the month, getting up our production facility to accommodate the new processes.
- February
  - Throughout the month, continue testing prototypes.
  - By mid-month, order high quantities of penetrators with updated design
- March.
  - Towards the end of the month, receive high quantities of penetrators and begin testing to ensure that nothing changed between low quantity processes and high quantity processes.
- April
  - Throughout the month, continue testing penetrators from high quantity order.
  - By the end of the month, move updated penetrator designs and processes into production.
- May
  - Begin shipping products with updated penetrator designs and processes.

This schedule relies on our diagnosis and solution for the problem being correct. We will keep you informed as we make progress or hit roadblocks throughout this whole process.

UPDATE TO TECHNICAL BULLETIN 03: 22 JAN 2020

(This update was shared in a Distributor Update email on 22 Jan 2020)

We have made progress according to the plan in Technical Bulletin 03. In January so far, we received new potting equipment, tested the first batch of prototypes with the changes recommended by the potting compound manufacturer, and tested those.

As a reminder, the changes included:

1. Updating the penetrator design so that none of the inside potted parts are anodized.
2. Adding the following steps to our potting process:
    a. Mechanically cleaning the bore of the penetrator.
    b. Chemically cleaning the bore of the penetrators.
    c. Removing the chemical residue from the bore of the penetrators.
    d. Potting immediately after cleaning.
3. Updating the penetrator design so that the corners are less sharp on the parts that are potted.
4. Updating the potting process so that the potting that is visible appears to be convex rather than concave.

The prototypes performed extremely well and we now have parts to make a higher quantity. We will be testing those parts for the next few weeks and then planning the next steps forward.

UPDATE TO TECHNICAL BULLETIN 03: 12 MARCH 2020

(This update was shared in a Distributor Update email on 12 March 2020)

We have learned many things in the past few weeks! We can now reliably make the penetrators fail in the same way as our customers. Our findings are summarized below:

- When the temperature of the epoxy increases, it starts to get weaker. Signs of weakness are observed between 20-45°C, but at 45°C, we see a dramatic decrease in reliability.
- We've used a data logger in some test shipments and we've observed the temperature of the packages to be around 40°C during shipment. This temperature can also be reached if the thrusters are sitting in the sun.
- From testing, we suspect that an assembled ROV will experience a higher fail rate. The pressure that is built up within the electronics enclosure paired with increased temperature during shipment can cause the potting to delaminate from the penetrator.
- **ACTION: Remove vent during shipment of assembled ROVs!**
- With our current penetrator geometry, when potted in a certain way, issues can still occur even in colder temperatures.

We are pursuing several options to fix this problem. This includes testing different epoxies, processes, and penetrator geometries. We expect to have more results in several weeks and we are hopeful that we will have a proposed solution soon.

We appreciate your patience as we work through this issue! If you have any feedback regarding our processes and what we've learned along the way, please let us know!

UPDATE TO TECHNICAL BULLETIN 03: 18 MAY 2020

(This update was shared in a Distributor Update email on 18 May 2020)

We last provided an update on March 12 after discovering how to repeatably cause penetrators to fail using a combination of elevated temperature and pressure. We completed experiments on several batches (32 penetrators in each batch) with the following variations:

- 1 batch with stock penetrators and an updated cleaning process
- 1 batch with stock penetrators, an updated cleaning process, and a priming process
- 1 batch with a new penetrator design with no inner anodizing and no sharp corners with primer applied to the penetrator
- 1 batch with a new penetrator design with no inner anodizing and no sharp corners with primer applied to the penetrator and cable

We were able to complete testing on these samples, using a test method that applied pressure in our Crushinator chamber while at an elevated temperature of 40-45°C. The results show that all of the above penetrators can experience failures in those conditions, however the new penetrator design experienced less failures. We also realized from this test that it may be too harsh since the combined application of pressure and 40-45°C temperatures is highly unlikely in operation.

We designed a follow-on test to evaluate the best performer under more realistic conditions including low pressures at elevated temperatures and high pressure under colder temperatures. We have a test plan laid out, however, this testing was cut short by the “Safer at Home” orders put in place for COVID-19 on March 19th. We have been unable to complete any further testing since that date.

Progress Since COVID-19

While we are halted on testing, we have continued to make good progress on this solution with our engineering team working remotely. We have separated our efforts into two paths:

1. A continued effort to improve the performance of the penetrator potting. We have our manufacturing department working on this effort including two engineers and a testing technician. We can’t continue this until we are able to return those team members to our office.
2. A separate effort to investigate radically different solutions that could replace the current penetrator while still being low-cost and high performing. We have redirected our remaining engineering effort to this project due to the urgency of solving this problem. There are three engineers working on this with full effort.

The first effort will continue when we are able to return our full team to our facility. Fortunately, we have also made tremendous progress with the second effort and we hope to have alternate solutions in testing within the next few weeks. One of our engineers has a small pressure chamber at home so we will be able to complete some testing. It's too early to share information on this effort but we will be happy to do so after some successful testing.

We fully realize the impact of these penetrator failures on our customers and we are treating this issue with the utmost urgency and attention. We have put all other product development on hold while we solve this problem and I'm confident that we will end up with a good solution that will be thoroughly tested and vetted.

In the meantime, we appreciate your effort to work through this and we recommend taking the following actions to minimize impact:

1. DO perform vacuum tests before each dive to reduce the chances of leaks and damage.
2. DO inspect cable penetrators before each dive for any obvious delamination or damage.
3. DO remove the vent plug during transportation to avoid any internal pressure build-up that might push outwards on the penetrators.
4. DON'T transport at high temperatures.
5. DON'T put excessive stresses on the cables especially when they are warm.
6. DON'T lift the ROV from the cables, except the tether, which is separately strain relieved.

Additionally, we have received a lot of anecdotal feedback from other customers about what they are doing to solve the problem. We haven't tested or validated these ideas, but we are happy to share them here in case they are helpful for anyone:

- It has been recommended to backfill the penetrator with marine epoxy or other potting compound to increase reliability.
- For new cable installations, various customers have suggested that alternate potting compounds such as E-90FL, JB Weld Plastic Welder, 3M DP-420, and 3M DP-620 may perform well.

We will continue putting our full effort into solving this problem as well as possible. Thank you for your continued patience. Please let us know if you have any questions, concerns, or thoughts.

Additional Note about the Wetlink Epoxy:

We have put sales of Wetlink Epoxy cartridges on hold. There are several reasons for this:

- As mentioned in the original bulletin, we have switched to a bulk epoxy dispensing machine in production so we no longer use cartridges, making the large minimum order quantities for cartridges hard to justify.
- The primary issues we have identified related to temperature are primarily issues with the epoxy and we would like to have conclusive results before we continue to recommend it.
- This compound is available from other vendors under the name Reltek B-45TH, including on here on Amazon.

Depending on the outcome of our continued testing, we may continue to sell this product or fully discontinue it.

UPDATE TO TECHNICAL BULLETIN 03: 08 JULY 2020

(This update was shared in a Technical Bulletin Update email on 8 July 2020)

Our last update was on May 18th and provided an update on our efforts to identify and correct failure modes on our potted penetrators. In that update we shared that we had identified a temperature-related failure mode that produces similar failures to those we see reported by our customers including epoxy delamination and leakage. Our testing of an improved design and potting process was cut short by the COVID-19 crisis and the "Safer at Home" orders in California.

We also noted that we have redirected our engineering resources to a separate effort to produce a radically different penetrator design that will eliminate these issues. That effort has been going very well and we are making rapid progress on a replacement for the potted penetrator! In this update we'll share a brief look at that design, which will eventually replace the potted penetrator.

Note, we're still in the development phase on this product and validating it in a variety of conditions. We don't have a timeline for release. We are sharing our progress to inform you and to request any feedback you may have.

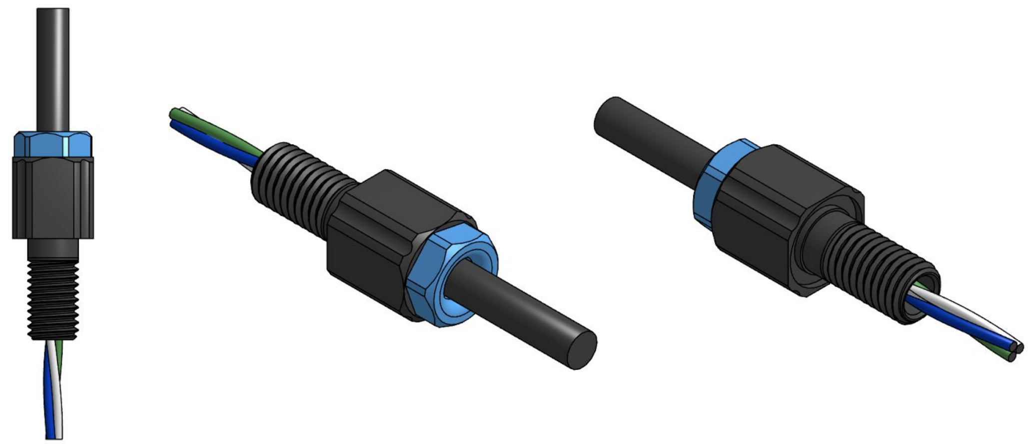
Introducing the Compression Gland Penetrator as a replacement for the Potted Penetrator

Note: The following has not been publicly released! Please keep this confidential.

After evaluating many different technology options for a revised penetrator, we decided to pursue a compression gland design. In a compression gland design, instead of epoxy potting compound, a rubber seal is compressed such that its internal pressure is greater than the surrounding water, sealing the cable from the water. With a screw compression design, it's possible to achieve high pressure ratings and there are commercially available glands available in other industries that are rated to 200-600 bar (2,000 – 6,000 water depth). There are a number of advantages to a compression gland design including the following:

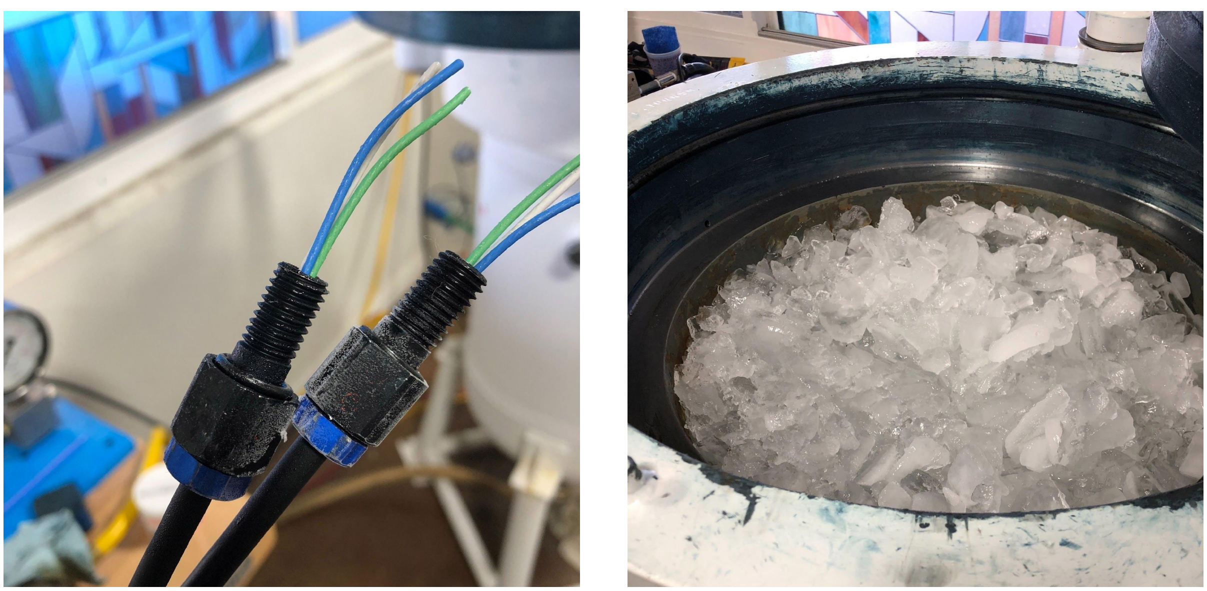
- No potting is required, making it much easier to assemble and, when provided as a kit, making it easier to ship worldwide
- It does not rely on potting adhesion, which is sensitive to surface finish, surface preparation, curing conditions, and epoxy variation
- It can be produced with much greater consistency
- It has inherent cable strain relief built in
- It is compact and not much larger or heavier than the current penetrators

We're not ready to show the internal details, but here is a preview of the outer appearance of the compression gland penetrator design:



Compression gland penetrator design for thruster cable. It is fast to assembly and does not require potting compound. (Confidential)

We've already tested several rounds of prototypes with excellent results including cycled pressure testing to 90 bar (the limit of our pressure chamber), high and low temperature exposure, strain on the cable, contaminated sealing surfaces, and with variations in cable diameter. In all cases this new design has performed well. We still have a lot of testing to perform to increase confidence further.



Compression gland penetrator prototypes after <0°C exposure (left) and our pressure test chamber cooled to < 5°C for cold water testing (right).

Due to the inherent challenges we found with the potted penetrator design and the numerous advantages of the compression gland penetrator design, we intend to make a complete shift to the compression gland design. We are working towards doing so as quickly as we can and with as much of our resources as possible. This is not a small undertaking due to the number of products that use penetrators and the number of penetrator sizes that must be designed and tested. We will be working to complete this effort for the rest of the year.

When completed, we hope to see substantial improvements in reliability and robustness across our product line! In the meantime, please continue to follow our recommendations on page 8 of this document to minimize the chances of failure on potted penetrators. If you have any questions or feedback about this change, please reach out to rusty@bluerobotics.com.

CONTACT:
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