D300/350/400 Overhaul: Theory and Practice

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The D300/350/400 second stage is one of Scubapro's premier designs. With its coaxial diaphragm and exhaust valve, it breathes the same in virtually any diving position, unlike regulators that get stiff when you roll on your back and look up (G260), or breathe wet when you go inverted (Scubapro Pilot, Air 1, and in fact, most standard case designs).

Its only shortcoming is an exhaust valve that is slightly smaller than Scubapro's newest designs, slightly increasing Work Of Breathing (WOB) at depths where air density begins to play a role (over 95'/air density >5 g/l). But its center-balanced poppet can be tuned to very low cracking effort, and the short air path from poppet to mouthpiece makes for huge air delivery.

Unlike the "gold standard" servo-assisted center-balanced poppet of the famous Scubapro Pilot here:

the D-series center balanced valve has only three moving parts, and performs almost as well.

In fact, the center-balanced design is so much better than other standard end-balanced barrel regulators that Scubapro reintroduced the center-balanced poppet this year with the D420. That regulator, discussed at great length here: D420! How about that?, simplified assembly and improved WOB even further, but eliminated one feature. Servicing became immeasurably easier, but the coaxial diaphragm was sacrificed in favor of a larger exhaust valve. Thus, total WOB decreased and breathing became even easier in the standard diving position, at the price of a return to slightly stiffer cracking when on your back.

But for some divers (photographers and others who like to peer under ledges), the superb breathing when inverted or on your back, plus near-effortless cracking effort all the time, makes the original D-series a regulator they don't want to let go. And that brings us to service. Service kits are still being made! But this regulator is HARD to disassemble, finicky to reassemble, and the rarity of a center-balanced design means that some of what you learned when tuning a G250 doesn't quite apply.

So let's tackle this regulator. There are three small and two **larger** challenges: **1) getting the cover off,** 2) removing the lever hex screw, **3) reattaching the Pre-Dive switch and lever spring,** 4) reattaching the diaphragm cover ring and 5) tuning the lever and poppet. We'll leave restoring a nicked knife edge to a D-series Restoration thread to follow.

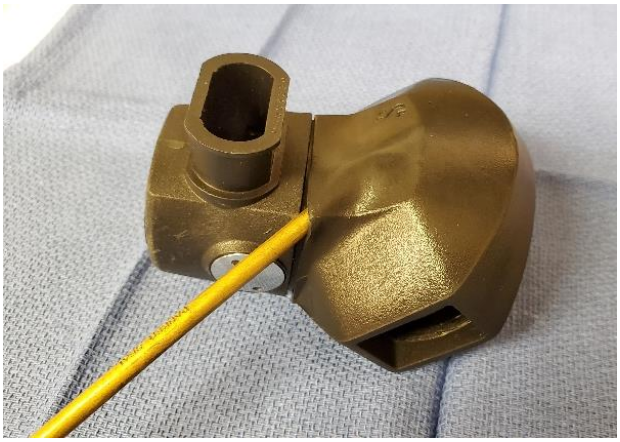
This discussion uses the attached schematic wherever possible. Numbers in parentheses are diagram numbers from that schematic. Any deviations (e.g. the final D-400 model with a new housing and polymer orifice) will be described separately.

Required Tools:

Forceps or surgical clamp
Small flat blade screwdriver
Brass spade
Brass pick
Pin wrench – custom tool Tool for Scubapro D-Series Second Stages, or
- Scubapro tool Scubapro Multi-Tool, Brass Chrome or
- small pin face spanner Face Spanner, replaceable pins (with 0.066" pins).
Wire claw small parts retriever – **critical** for PreDive switch ass'y (www.mcmaster.com PN 5681A22)
Three hex keys: 3.5mm, 3/32" and possibly 2.5mm
Spoon with smooth edged handle
Two needle-nosed pliers, if spring bending is required

Challenge #1: Cover removal

Removal of the cover was no big deal when the D300 was introduced. The rubber was soft and supple. Over the last 35 years however, the rubber has gotten harder and less pliable. It's amazing that it doesn't just crack and tear when you remove the cover, but that is a rare event. Cracking in the thin skirt at the back of the regulator is the worst that's usually seen.



First, slip a brass spade under the cover in back. Sliding it sideways will break any seal.

Now soak the whole reg in HOT water for 5 minutes. Use water as hot as you can stand with your hand; not boiling. Don't leave it in too long, or you'll fade the black color of the case.

Once the rubber cover softens, insert the spade in the front of the case at a 45 degree angle to the gap between the case at the bottom of the predive switch. Pry up the thick top of the cover front.

WARNING: It is very easy to jab a hole in the diaphragm if the probe is inserted too far!

After prying up the front corner of the cover, using your third hand, slip the flat blade of a cheap spoon handle, or the bowl of the spoon itself into the gap between the case and the thick cover. Make sure the PreDive switch is in "Pre" to be up and out of the way. Pry the spoon/handle back until you can see the top edge of the diaphragm cover ring. The smooth "shim" of a spoon handle keeps you from gouging the case.

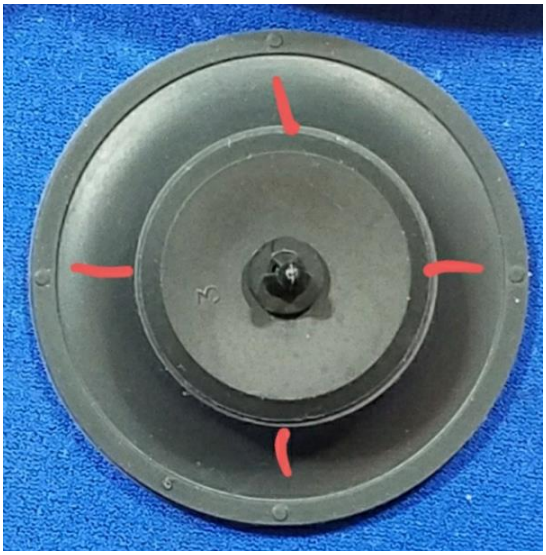
Here's the frustrating part: while holding the cover front pried up with the spoon/handle with one hand, grab the cover by both exhaust holes with your other hand and pull down from one side or the other until the cover comes off. A tool that fits in the exhaust holes would be easier, but anything longer than your fingertip will put a hole in the diaphragm. I'm open to ideas for DIY tools that will make this easier. Try not to swear when it takes four tries, as the pried-up front slips back down over the cover ring, and you have to start over. Now wipe off the sweat, have a beer, and come back later when your fingers stop aching.

Disassembly:

With the cover off, start by unscrewing the Diaphragm Cover Ring (32). It's relatively delicate and can be broken easily.

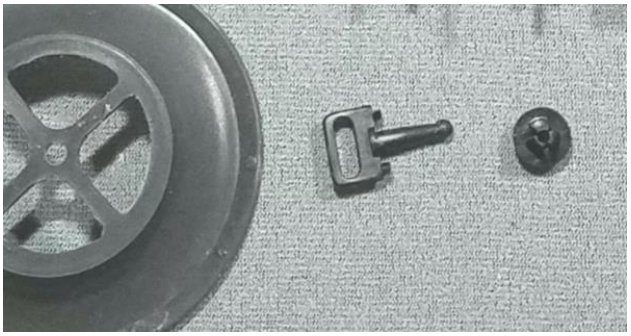
Set it and the underlying thrust washer (30) aside. If your cover ring is the short model (11.011.112), you are more prone to freeflow issues or wet breathing from a fluttering exhaust valve in current or when scootering. Taller redesigned rings (11.011.122) are occasionally available.

Before you remove the diaphragm (27), note the four tiny dots at 12, 3, 6 and 9 o'clock, on the very rim of the diaphragm. They orient the underlying lever linkage (26) in the correct position at reassembly. We'll look at that again.



Carefully lift one side of the diaphragm, and while watching the plastic linkage loop (26) that engages the lever underneath, slide the loop off the lever. The direction in which to slide the linkage differs between the D300/350 and the D400 (slide right with the 400; slide left with the 300/350).

Examine the diaphragm assembly, but do not attempt to disassemble it. The plastic cone of the exhaust retainer (28) that fastens the pieces together is essentially a single use item, and replacements are as rare as hens' teeth.



Check the diaphragm for holes,

examine the exhaust valve (29) for an even skirt, and the exhaust retainer for structural integrity. Replacement diaphragms and exhaust valves are occasionally available. If intact, set it aside.

Now inspect the lever in relation to the pre-dive spring. The D300/350 lever leg is on the right, near the end of the pre-dive spring.

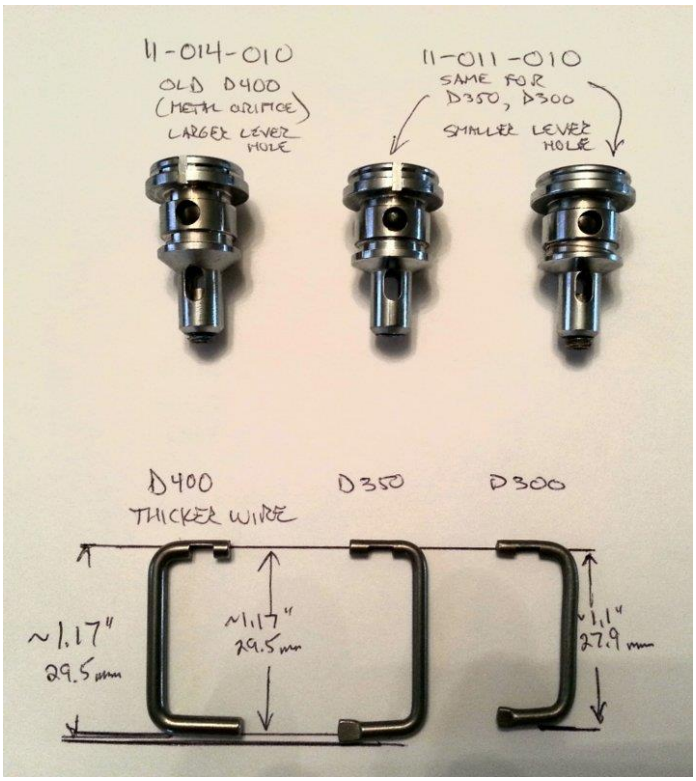
In rare cases, the lever can get caught behind the spring, and the regulator will freeflow when the switch is placed in the Dive position as the spring pulls the lever back with it.

If this has occurred with your D300/350, bend the long leg of the spring to the right, so the end of the spring is well past the leg of the lever. It may take several gentle passes to accomplish this without weakening the spring with a sharp bend.

Because of this problem, the D400 was redesigned, placing the leg of the lever on the left, where the spring end will not trap it.

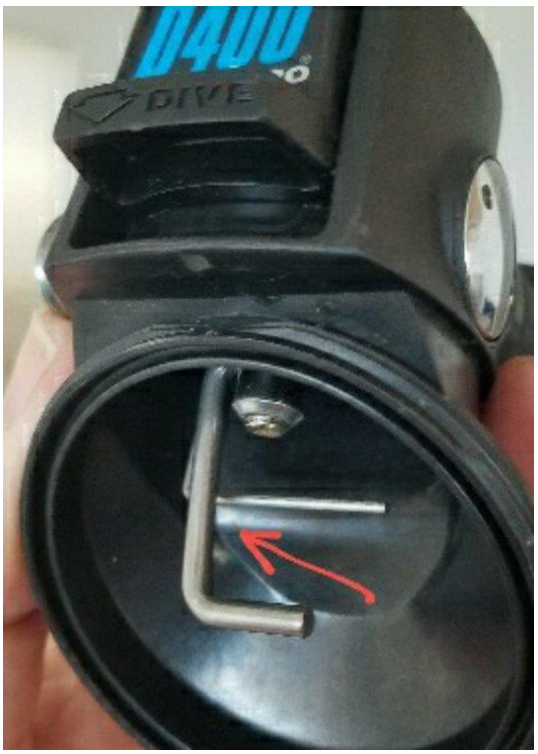
Additionally, the lever was lengthened (D350), and then thickened (D400) to improve mechanical advantage and smoothness of lever action. Unfortunately, because of the smaller lever hole, D350 housings are not interchangeable with the D400, despite being otherwise identical.

IMO, Scubapro then took a step back with their final modification of the D400 housing and lever, and that will be discussed below.

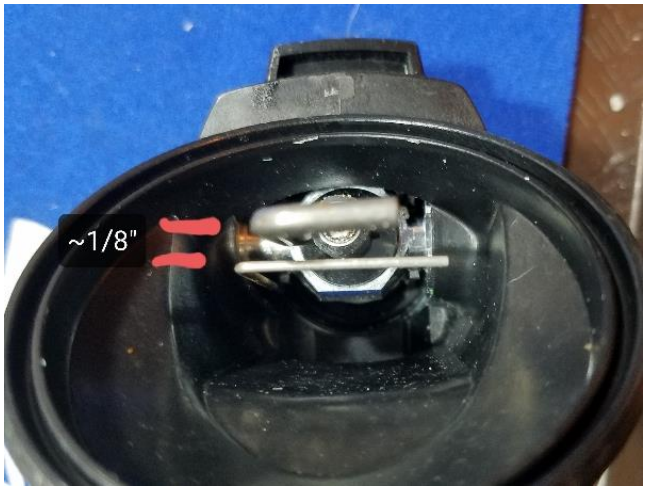


 Next, inspect the pre-dive spring position. With the predive switch in the up position, the long arm of the spring should have moved forward <u>against the lever</u>.

If that is not the case, the spring will need to be hand bent after the lever is removed, to make contact with the lever. See the pictures below in this regard. If the spring does not contact the lever with the switch in the up position, it will not retard the lever's initial movement, and cracking effort will be unchanged. Thus, a freeflow may be more likely.



To determine how much to bend the spring, sight along the axis of the housing and determine how much separation there is between spring and lever with the regulator positioned mouthpiece down. Note that with the mouthpiece up, normal lever slack will allow it to fall forward away from the spring and you will have an incorrect (excessive) estimate of spring shortfall. Write down the amount of bend the spring will require.



Next, using a custom tool, the pins in a Scubapro tool, or a small pin face spanner, unscrew the cap (1) on the top of the case. The Scubapro tool is by far the worst tool for the job, as it is easy to rock one pin up and out of the hole, scratching the cap as you rotate the tool. Using thumb pressure, it is easier to keep a face spanner seated.

Examine the case and cap to confirm which version you have.

The early D300 case had only three threads and a short cap, while later cases and caps were extended to 4 threads. If you have a shallow cap, you are at risk of having stripped threads and losing the housing capture provided by the cap, probably because of excessive force used in previous reassemblies over the years.

Take a small flat blade screwdriver and remove the spring pad (4) in the top of the aspirator (5). With the last D400 models, there may be a 2-part assembly with a white spring pad (11.015.306) under a new "adjustment pad" (11.015.206) in place of the single part #4. This is discussed further below. Set the piece(s) aside, and turning the reg upside down, allow the poppet spring (7) to fall into your hand. The poppet assembly (8) will probably remain in place. If so, reach in with forceps, grasp the nut at the top of the poppet and **carefully** remove the poppet assembly.
Do not ding the knife edge of the housing (10) with the metal end of the poppet during removal.

Challenge #2: Removing the hex set screw (16)

Temporarily replace the spring pad in the aspirator. Firmly pressing down on it, use a 3/32" hex key to loosen the set screw inside the diaphragm area that holds the lever.

NOTE: if heavily corroded with blue-green verdigris, this hex screw can be nearly impossible to remove. If the 3/32" hex key is a sloppy fit, you may strip the hex if significant force is applied. In this case, a 2.5mm metric hex may fit more tightly and grip the hex screw without stripping. But there is an additional problem: the housing tries to twist when you unscrew the hex, which is why pressure is applied to the housing while you unscrew.

Therefore, with a frozen set screw, you need a way to keep the tiny plastic legs on the aspirator from breaking from housing twist, as you unscrew the hex.

The way to do that is to insert a 3.5mm hex key in the hose inlet of the regulator, and manipulate it until the hex key passes into the inlet tube and <u>through **both** sides of the housing</u>.

This only works with D-series regs that do not have the techno-polymer knife edge, as that last model has side slots instead of holes in the housing, and will still twist.
If the hex screw loosens when braced in this fashion, unscrew it until the lever is just loose enough to remove. NOTE: Sometimes it is enough to merely remove the poppet, slide the lever to the top of the slot in the neck of the housing, and then slip it out to the left or right. You can then attack a frozen set screw using the method described below.

If you can't unscrew the hex, you have a problem. Because of lever size, you can't push a D400 or D300 housing out of the case with the lever still attached, although a D350 might fit due to a narrower lever contour. So, to remove the set screw, you can start by soaking the reg in warm vinegar to remove the verdigris. When that doesn't work, carefully prop the reg upright and place a drop of WD-40 inside the slot where the lever protrudes. The bore of the housing stem will trap the lubricant and gravity can do its thing. Leave it propped upright and come back a day later. Using the ultrasonic on the whole reg assembly will be hard on the plastic, and is not recommended unless nothing else works. But in most cases, WD-40 and time seems to do the trick. *As a final trick, it may be helpful to instead grasp the housing stem with pliers (padding the jaws with a bit of paper), using the lever as a fulcrum as you unscrew the hex. Y*ou do risk bending the top of the lever if bad corrosion necessitates a lot of force, but sometimes there's no alternative.
Work the screw back and forth with the hex key, until you are able to get a full turn counterclockwise. As noted above, there is no need to remove the hex screw entirely; just enough to remove the lever.

Once the lever has been removed, use your thumb to push up on the housing at the hex screw. The housing and set screw assembly will pop out of the top of the case. The assembly at this point will include six parts:
the tuning cap (spring pad),
the aspirator,
the VIVA flow director (aspirator gate),
the housing, and
the set screw.
The poppet spring and poppet should already have been removed.

First slide the VIVA flow director collar (aspirator gate) off the aspirator housing, by spreading the front arms of the collar slightly. Next is aspirator removal from the housing. The aspirator legs and the thin loop that comprises the front of the aspirator base are extremely delicate, and can be broken easily.

The aspirator is usually tightly fitted to a groove in the housing. Do NOT try to remove the aspirator by prying in this fashion:

Instead, it is easiest to pop the aspirator off the housing by pushing with your thumb against the side of the aspirator, while applying counterpressure against the stem of the housing where the hex key lives. Pushing from the back or front of the aspirator risks breaking the little loop of plastic that engages the housing at the front. The side of the aspirator is the strongest location for pressure.

If you break the aspirator, replacement parts are occasionally available.

Once the aspirator has been removed, take extreme care with the housing so that nothing contacts the knife edge.

Place a thin hex key through the housing stem holes where the lever originally rested, and use the hex key as a brace/fulcrum. Using a second hex key (3/32” or 2.5mm as determined previously), completely unscrew the set screw from the bottom of the housing.

Using a thin brass or plastic pick, remove the two o-rings from the side of the housing. Wrap the housing in a tissue and set it aside.

At this point, you've done enough disassembly for a simple service.

Removal of the inlet (32) and predive switch (34) is not necessary unless significantly corroded or leaking. If you do not intend to remove the inlet or Pre-Dive switch, skip to "Cleaning" below.

Inlet Tube Removal: The inlet is removed by <u>partially</u> unscrewing the inlet retainer (19) two turns on the side opposite the hose inlet. When the retainer cap stands proud by two threads, press firmly on it to break the inlet free of the case.

Then remove the retainer completely, along with the static o-ring (18) underneath. Carefully press on the visible end of the inlet, taking care not to pinch your finger on the sharp corners of the alignment ridges in the case (ask me how I know).

When the inlet is loose, carefully manipulate the spring so it does not catch on the inlet. Pull the inlet out of the case from the hose side. Remove the inlet tube o-ring (18) with a brass or plastic pick.

Pre-Dive Switch Assembly Service: Even Scubapro implies that assembling the Pre-Dive Switch can be a bear. First, they note that it is seldom removed. Then the manual describes a method of removing only the switch and o-ring while supposedly maintaining pressure on the switch retainer and screw. How one then finds enough hands to change out the switch o-ring while holding the switch retainer in the case is not at all clear. In fact, it's rarely that simple, especially if you're using an aftermarket 2-117 o-ring in place of the square switch o-ring in the service kit. We'll describe an alternate reassembly technique below.

If you decide to remove and service the Pre-Dive switch, then either before or after you remove the inlet tube, insert a small flat-bladed screwdriver in the mouthpiece tube, and unscrew the switch retaining screw (23).

The spring (24) may remain embedded in the retainer slot, which is okay. Remove the pieces from the case, along with the switch and o-ring from the front.

Cleaning

Plastic and rubber pieces can be washed in warm water with a gentle detergent like Dawn "Free and Gentle" or Simple Green "Crystal". Avoid scented detergents, as the odor may persist after cleaning. Do not soak the black rubber or plastic pieces for an extended period, as they will lose their finish and color and turn dark gray. After cleaning, rinse in clean water and allow to dry. Metal pieces can be cleaned of verdigris with a solution of warm 1/3 vinegar and a soft toothbrush, or a phosphoric acid solution like GSM's 43191 regulator cleaner. Keep in mind that areas of verdigris will reveal bare brass after corrosion is removed. Thin chrome plating in wear areas may also be removed with these acid solutions. Soak only as long as necessary to remove verdigris, then soak briefly in a solution of water with a little baking soda to neutralize the acid. Finally, rinse repeatedly in clean water and dry. The housing should be cleaned separately, so that no other metal part makes contact with the knife edge. It is my practice to use a plastic pill bottle with multiple holes drilled in the sides and bottom for this purpose. The housing is the only item in the bottle. A similar technique can be used with other small parts to reduce the risk of loss.

Ultrasonic cleaning can be used for heavy corrosion, with or without an acid bath and neutralizing rinse.

This completes disassembly.

Service, Reassembly and Tuning

The Scubapro service kit 11.012.045 is a disappointment, with only three items: a poppet ass'y (38) (11.014.014), a square predive switch o-ring (33) and a lever set screw (16).

There are NO replacement o-rings in the kit beyond that for the predive switch and the poppet stem. The required additional o-rings for a complete overhaul are as follows:

2-022 Duro 80 (Duro 70-80 okay) (top cap)
2-016 Duro 70 (Duro 70-80 okay), quantity (2) (inlet tube seals)
2-013 Duro 85 (Duro 75-90 can work), quantity (2) (housing seal - see discussion of duro below)
5-125 Duro **50** (poppet stem)
2-116 or 2-117 Duro 70 (substitute for square switch o-ring) (see discussion in post #6)
(5-179 or 1x7mm Duro 70 - quan 2; only for last model D400 with Delrin knife edge)
(see below for discussion re: this o-ring)

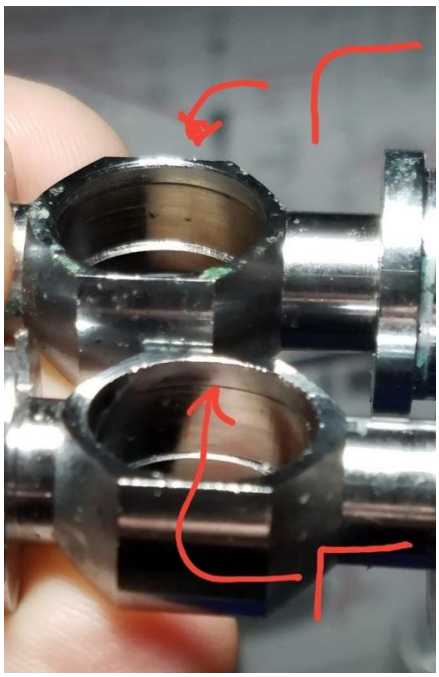
You can use nitrile, EPDM or Viton based upon your own preferences. Viton offers the longest shelf life, but nitrile is very inexpensive and widely available.
The correct aftermarket replacements for the static o-rings are also included on the annotated schematic diagram attached to this guide, along with service hints. Other DIY'ers have specified the 2-117 for the substitute square switch o-ring. In my experience, however, it does not seat as well in the land of the switch, and can be much more difficult to install.

The Scubapro D400 Service Manual is also attached. While it is helpful and accurate, it can be cryptic at certain points. I hope the following explanations flesh out the manual.

Inspection:

Inlet Tube – The inlet tube comes in two iterations, with a noteworthy consequence. It is critical that the housing is fully seated in the inlet tube before pressurization to avoid leaks.

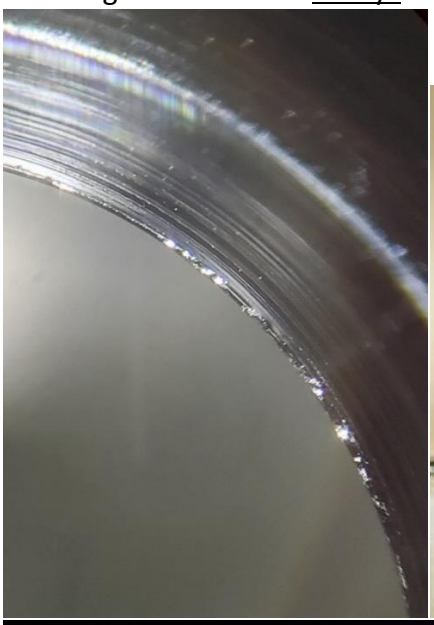
However, it is occasionally the case that the housing consistently wants to extrude from the top of the inlet. Careful inspection of the inlet reveals that some models have a slight radius at the top.

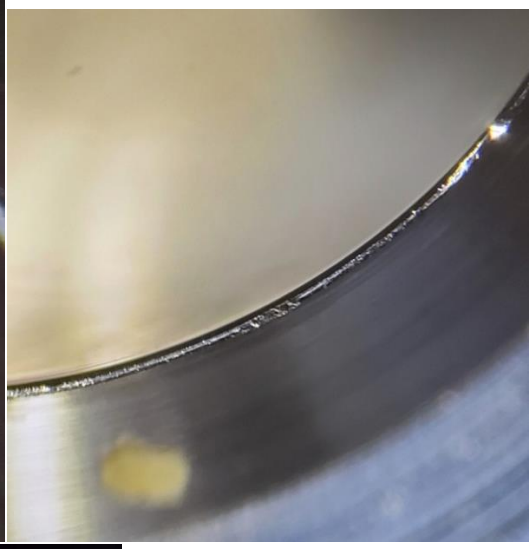


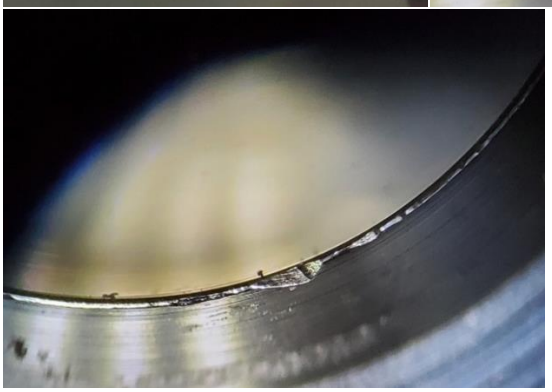
Thus, the use of a 75 Duro aftermarket o-ring may prompt it to extrude along the radius. As discussed below, a harder Durometer 90 o-ring does not seem to have this problem. Note that the original o-ring from Scubapro (01.050.147) was spec'ed at Shore A85. However, if your inlet has a sharp corner on the land, either a Duro 75 or 90 seems to work well in sealing the housing.

Housing – The housing (10, 11) has come with a variety of knife edge contours.

One consistent characteristic, however, is the fragility of that knife edge.
Used regulators almost <u>always</u> show damage, such as these examples:

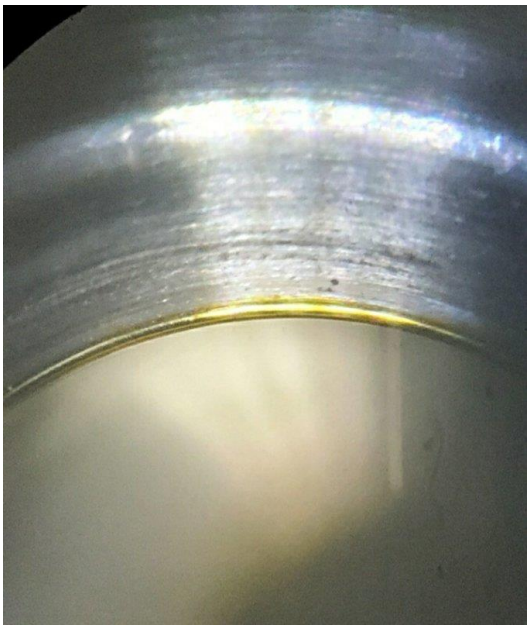






I have even seen flaws in new orifices in their original packaging!

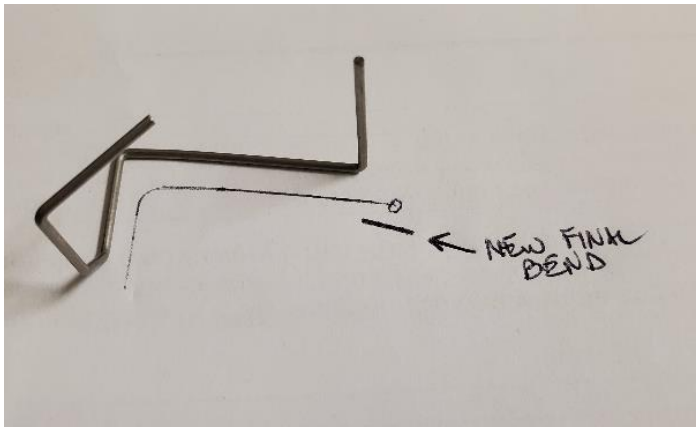
Thus, after inspection of your housing, a decision needs to be made. Will I accept the edge as seen, knowing that it will take greater pressure on the spring to seal the poppet? Will I accept the higher cracking effort that will result? Or will I try to find a new or restored knife edge, or try to restore the edge on my own? Note that any restoration effort will polish out a nick through the chrome finish.



With a restored knife edge, it will be essential to thoroughly rinse after every day of salt water diving, and perhaps repolish out any corrosion every 1-2 years. I will post on restoring a D-series knife edge in an upcoming thread.

Spring Contour - While it is not common, if evaluation of the spring revealed a gap between the lever and the spring's most forward position in the Pre-Dive position, you will have to re-bend the spring.

To start, with the spring laying on its side, trace the contour of the spring on a piece of paper. Then add a short line that shows the ideal final position of the crossbar once the spring is bent an amount that will bring it in contact with the back of the lever.



Taking a pair of needle nose pliers, grip the spring just below the 90° bend in the long arm, and then place the second set of pliers approximately 1/4" further away from the 90° bend.

This will allow a new slight curve to be added to the steel without stressing the spring at the sharp bend - brittle from when the spring was originally formed. It will take very little added curve to restore contact with the lever, and it is better to do repeated slight bends rather than attempt to undo an excessive new bend. By setting the lever against the tracing after each attempt, it is easy to return the spring to optimal shape in short order.

Reassembly:

If the Pre-Dive Switch was not removed for service, skip to page 27 below.

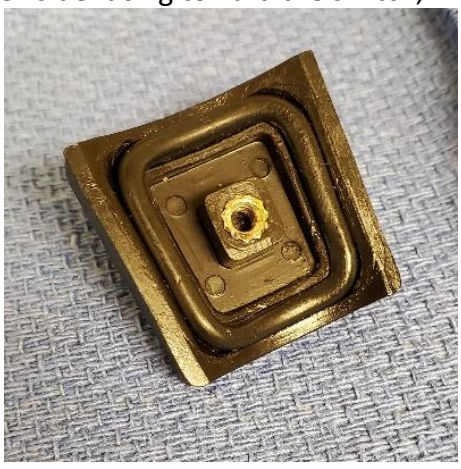
Challenge #3: Pre-dive Switch Reassembly

The reassembly of the Pre-Dive Switch is, after cover removal, the most frustrating thing about D-series service. Two tools are required: a small flat-bladed screwdriver and a wire-claw small parts grabber. The first step in reassembly is to insert the inlet tube at the same time as the pre-dive spring. While it is possible to thread the spring into place after the inlet has been installed, it is difficult, and risks permanently deforming the spring.

First, ensure that the top crossbar of the spring is inserted in what will be the lower slot of the switch retainer (22). The part is bidirectional, so either slot can be used. Next, grasp the head of the retaining ring screw with the claw grasper and set it aside.

Examine the pictures below to aid in orienting the spring. From the diaphragm side of the case, the left (long) side of the spring is on the hose side of the inlet tube, and passes over the tube. The short arm of the spring is on the right, and ends under the inlet.

Place the spring high in the case with the retainer clipped to the spring (in the lower slot), with the convex side facing forward. Then place a lightly lubricated 2-016 Duro 75 o-ring (18) in the land of the inlet tube (32). Insert the inlet tube retainer end first, with the spring high inside the housing and the inlet passing underneath the squared top of the spring. Take care that the sharp inlet flanges do not catch the spring as it is inserted. Before you seat the inlet in the far side of the case, cock the spring so the short arm of the spring passes under the other side of the inlet tube. Then seat the inlet tube fully. The spring will be dangling loosely over the inlet tube. Now place a second lubricated 2-016 o-ring in the recess for the inlet retainer (19). Place a little lube on the threads of the inlet retainer (to facilitate the next disassembly), and screw the inlet retainer into place, tightening hand tight with a Scubapro tool or a small pin face spanner. If the switch retainer has popped off the spring, press it back into place now, with the convex side facing toward the switch, and the spring in the lower slot.



Confirm that the spring is correctly (if loosely) oriented around the inlet tube. Confirm that you can position the retainer over the rectangular switch hole in the front of the case with the mouthpiece up. Set the case aside.

Take the switch (34, 35) and o-ring (33) and without lubricating the o-ring, place it in the land of the switch. If you are using the service kit's square o-ring, this is a straightforward matter.

If you are using a 2-116 o-ring, it will be a slight struggle to force the round o-ring into the square groove. Don't even try for all four sides. Not lubricating the o-ring provides just enough grip to fit the bottom and sides into place. The 2-117 recommended by other DIY'ers is even harder to install, and depending upon which switch molding you have, occasionally cannot be completely wedged under the switch edges into the land.

Here is the difficult part: with the switch capturing the o-ring on at least three sides, with your third hand carefully pick up the case and press the switch firmly against the front of the case. At this point, if you aren't using the square o-ring, you can use the forked end of a brass spade to push the bulging top of the 2-116 o-ring under the switch edge into the land, and with firm pressure on the switch, the o-ring will remain in place, trapped between the case and the switch.

With the square o-ring that fits the land perfectly, great pressure isn't necessary.
But you need to maintain pressure while you attach the spring, which is why the wire-claw grabber is so helpful.

Hold the case/oring/switch sandwich in one hand with the mouthpiece tube facing up, and the switch slid to its highest position in the slot. You may find it easier to push the sandwich against the edge of a padded table top. Use your other hand to position the spring/retainer assembly inside the case with the retainer (22) positioned precisely over the screw hole in the switch. With the retainer in position, insert the grabber holding the retainer screw through the mouthpiece tube, and partially thread the screw into the switch.

With the parts loosely connected (and with pressure maintained on the switch and o-ring), switch to your screwdriver for final tightening. As with the grabber, insert the screwdriver through the mouthpiece tube, with the switch maintained in the uppermost predive position. This brings the screw head into view from behind the inlet tube.

Trying to do the assembly with a screwdriver alone is an exercise in frustration. But however you got the screw into the switch, perform your final tightening with the small flat-blade screwdriver. Lube on the screw threads is probably not helpful here, as you need your switch retaining screw to remain where you set it. Firm tightening will bring the back of the retainer into contact with the switch mount for the screw, so that net tension is provided solely by the compressed o-ring, and not by additional tightness of the screw. If switch action is sloppy with your particular switch, consider reinstalling with a 2-117 oring, though this is only rarely needed.

If the o-ring pops out as you are installing the screw, all may not be lost. If the screw is in the switch at all, you may be able to use your spade to push the o-ring back into position and add more pressure to the switch to trap the o-ring while you complete tightening. If not, swear loudly and start over.

Your guide to proper screw tightness is the slight resistance with which the predive switch slides up and down. At this point, it is appropriate to add a small line of lube to the case above and below the switch. The o-ring will then pick up the lube as you slide it back and forth.

Reassembly if the Pre-Dive Switch was not removed: Place a lightly lubricated 2-016 Duro 75 o-ring (18) in the land of the inlet tube (32). Place the Pre-Dive Switch in the up (Pre-Dive) position, and lift the loose spring up high in the case. This will raise the long arm of the spring. Then, insert the inlet tube, passing the grooved end under the long arm of the spring, and cocking it slightly to pass over the short arm of the spring. With the narrow neck of the inlet tube now resting on the short arm of the spring, it should be possible to straighten the inlet tube and align its grooves with the case flanges and seat the inlet tube fully. Place a second lubricated 2-016 o-ring in the recess for the inlet retainer (19). Place a little lube on the threads of the inlet retainer (to facilitate the next disassembly), and screw the inlet retainer into place, tightening hand tight with a Scubapro tool or a small pin face spanner. Work the Pre-Dive switch and observe that the spring retracts fully against the rear of the case with the switch down, and that the long arm moves toward the diaphragm opening with the switch up. If needed, add a small line of lube to the case above and below the switch. The o-ring will pick up the lube as you slide the switch back and forth.

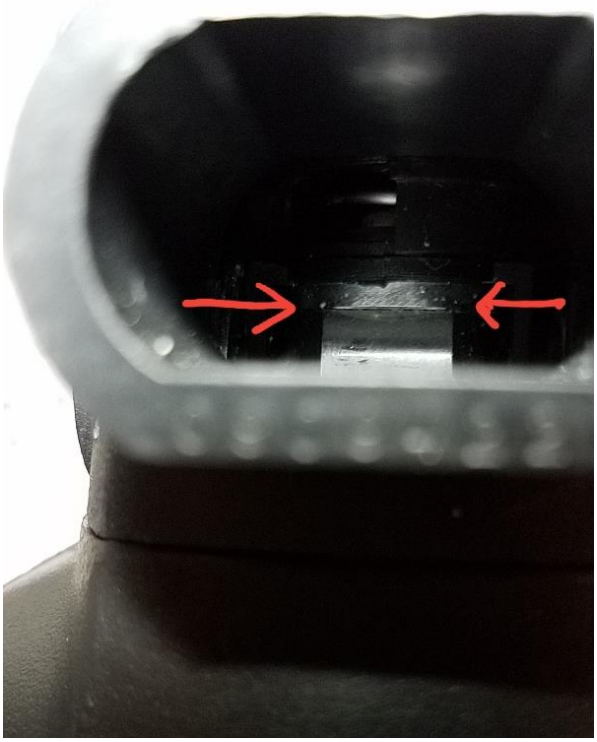
Housing Assembly Build and Insertion:
Slide two lightly lubricated 2-013 orings (75 or 90 Duro as discussed above) into the two lands in the walls of the housing. Insert the new hex set screw using two hex keys (one through the elongated holes in the housing stem, and one in the hex screw). Thread it clockwise until 2-3 threads are showing.

Attach the aspirator to the housing by aligning the tiny tab in the base of the aspirator with the slot in the housing's top radius. Resting the aspirator upside down on a firm surface, engage the housing in the thin loop at the front of the aspirator, and rock the housing against the back of the aspirator until the housing clicks into place. Note: putting pressure on the thin loop at the front of the aspirator base risks breaking the plastic.

Now add the VIVA collar (aspirator gate) to the aspirator, with the larger diameter toward the top of the assembly. Confirm correct orientation by feeling for clicking as the collar is rotated around the aspirator. Position the collar in the fully open position, with the space between the collar arms centered over the hole in the aspirator front.

To insert the housing assembly in the inlet tube, orient the housing with the notch that engaged the aspirator on the left when looking from the diaphragm side. This orients air flow toward the mouthpiece.
Ensure that the legs of the aspirator straddle the arms of the inlet tube symmetrically, to avoid breakage.
It is essential to avoid putting any pressure on the knife edge. The safest technique is to screw in the spring pad and press the assembly into place with thumb pressure on the spring pad, with the assembly perfectly vertical. Before pressing the housing o-rings fully into place in the inlet tube, ensure that the lower o-ring isn't pinched.

Confirm that the housing is fully seated:



Now, insert the lever into the hole in the stem of the housing. The D400 lever is inserted from the left, while the D300/350 levers are inserted from the right. This orientation is critical to ensure that the fulcrum of the lever (which is ground at an angle) is tilted in the correct direction. While maintaining pressure on the spring pad, screw in the hex screw one more turn. This is usually sufficient to snag the lever in the housing while manipulating the regulator for poppet insertion. Next, unscrew the spring pad for poppet and spring insertion. While inverting the reg body to remove the spring pad, the lever may fall out. Simply replace it, but note that if you forget until after you have added the poppet and spring, it is difficult to get the lever into place without damaging the low-friction nib on the end of the poppet.

Poppet placement:
Generously lubricate the oring at the bottom of the poppet stem. Holding the new poppet with forceps grasping the top nut of the poppet, carefully insert it fully into the housing, *ensuring that the metal base of the poppet stem does not nick the knife edge* as it passes into the housing. The final 4mm of insertion will be slightly firmer, as the o-ring at the base of the poppet stem engages the narrower diameter of the housing at its bottom. Feel carefully at that last 4mm of insertion for any grittiness. If this is noted, the mass-produced poppet stem is fractionally too large, and the base of the stem is rubbing against the housing. Your final cracking effort will be poor as a result. Remove and discard this poppet and try another.

Balance the poppet spring centered on the top of the poppet and add the spring pad (with or without an aftermarket graphite impregnated shim). When you are sure that the spring pad has engaged the spring in its center, screw the spring pad into the aspirator until it is flush with the top edge, and then 1/2 turn more. This is your preliminary tuning position.

Lever Adjustment:
Turning your attention to the lever with the reg lying diaphragm side up, you should be able to lift the lever and demonstrate slack. If you feel resistance when you first lift the lever, the hex screw is already too tight, and should be loosened until there is about 5mm of slack. Conversely, if the lever movement is sloppy enough that you can lift more than 5mm before feeling resistance, the hex should be screwed in further. Adjustments should be in 1/8 turn increments or less as you approach optimal lever position. The goal is to allow the poppet to seat fully against the knife edge, before any diaphragm movement engages the lever.

Typical starting lever position with the regulator unpressurized is per the picture below:

It is not optimal to eliminate all lever slack. When the diaphragm is attached and the cover ring screwed down, a lever that is too high will be displaced by the linkage loop even before a breath moves the diaphragm.
Freeflow of a pressurized valve before the diaphragm is even attached, despite several turns on the spring pad, indicates that your lever is already too high. The hex key is pushing the poppet off the knife edge, and no amount of spring pressure will seal it.

Therefore, the next step is to confirm an airtight valve. Pressurize the regulator with the IP of your first stage, and listen for a valve leak. Screw the spring pad in clockwise until the leak stops. If the leak doesn't stop, your lever is too high or you have a badly flawed poppet or knife edge.
Note that clockwise rotation “winds up” the spring, decreasing spring force until the spring settles after repeated valve action. Best practice, therefore, is to screw in the spring pad 1/12 turn past the point where the valve sealed, and then unscrew about 1/12 turn (one hour on the clock).

With a valve that seals, it is now time to add the diaphragm assembly. Examine the back side of the diaphragm and determine the position that keeps the linkage loop in a 12 o’clock/6 o’clock orientation. Turning the diaphragm over, one pair of rim dots should align with the top and bottom of the linkage loop.

Holding the diaphragm assembly by the center cone, slide the linkage loop over the end of the lever until the diaphragm is centered. Orient the correct pair of rim dots at the 12 o’clock and 6 o’clock positions on the case. Do not lubricate the rim of the diaphragm to “improve the seal”. This risks dislodging the diaphragm during a subsequent vacuum test for an airtight case.

Minor challenge #4: Adding the Diaphragm Cover

Ensure that the rim of the diaphragm is fully seated in the groove of the case. Center the thrust washer (30) on top of the diaphragm and lubricate the threads of the case to reduce plastic-to-plastic binding at later disassembly. Now add the cover ring (31). The majority of rings seem to sit slightly askew on the case, and they are difficult to screw on without crossthreading the thin plastic. I recommend that you unscrew the cover ring until you hear a tiny click indicating that the starting ring thread has just dropped off the first thread in the case. At that point, careful clockwise rotation will usually engage the threads symmetrically. If you feel any resistance, stop and unscrew, and try again. Crossthreading damage to the cover ring will make subsequent attempts very difficult, although threading can usually be accomplished, with the firmer case threads smoothing out most of the damage to the thin cover ring. Tighten the ring barely hand tight. Pressurize the regulator and ensure that the thrust washer has not compressed the diaphragm to the point of opening the valve. With the regulator pressurized, lift the exhaust valve leaflet and confirm that the lever is near the middle of the linkage loop.

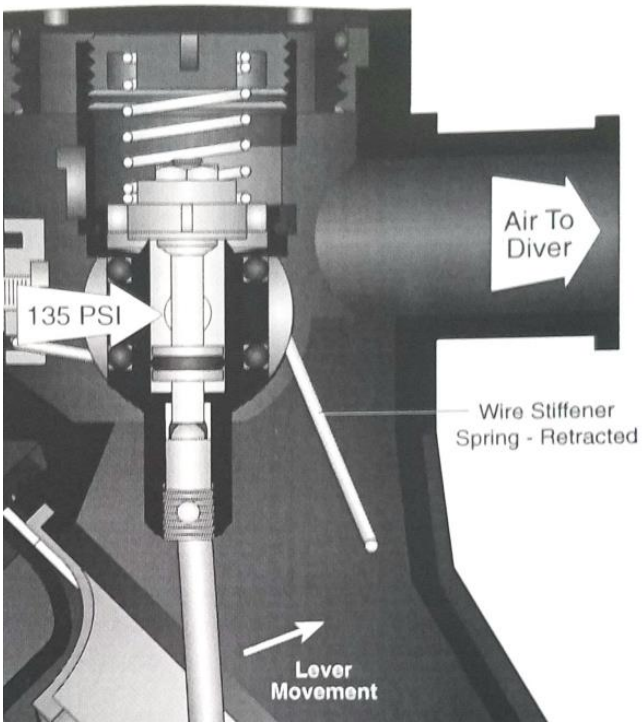
If lever adjustment needs to be fine tuned at this point, it is usually possible to adjust the lever without removing the diaphragm. A ball-end hex key is necessary to perform this adjustment, as the hex will be inserted in the set screw slightly off axis. With the exhaust valve lifted gently at the bottom, insert the 3/32” or 2.5mm hex at the 5 o’clock position of the diaphragm, adjacent to one of the bottom support spokes for the exhaust valve. Engage the ball of the hex key in the set screw and make an adjustment 1/12 turn at a time. Clockwise turns on the set screw will raise the lever; counterclockwise will lower it.

Challenge #5: Tuning the Regulator

Much like tuning a downstream second stage, correctly tuning the D-series is a balance of adequate lever height (to ensure maximum lever displacement and air flow) and proper poppet spring tension (to determine cracking effort). The sharpness of the knife edge is critical, and restored edges rarely get the thin rim that concentrates the spring force sufficiently to seal at low cracking efforts.

If lever height has been correctly adjusted per the section above, tuning cracking effort is a simple matter of screwing or unscrewing the spring pad. A lever that is too high will freeflow almost no matter how much spring pressure is applied to the poppet. A lever that is set too low will not freeflow despite a brisk purge with the VIVA gate fully open (see VIVA adjustment below). *Too low a lever may cause a dangerous degradation in performance*.

Because of the short flow path from poppet to mouthpiece, this reg delivers huge flows.



Spring fatigue is a factor in these old regs, and it is not uncommon to find a spring pad which is fully screwed in, and yet the valve still freeflows. After restoring the knife edge, it is usually possible to shim the poppet spring with a graphite impregnated washer from McMaster-Carr (PN 91545A270) and obtain enough spring pressure to seal.

Alternatively, if you have a late model D400 with a perforated spring adjuster and separate white spring pad, flipping the spring pad over reveals a thicker side that effectively shims the spring using the pad itself.

Finally, the Air1 regulator came with a poppet washer to decrease spring binding. If you have access to the rare SP part 01.060.100, that can be used to shim the poppet as well.

There is yet another workaround, however. You can use reduced Intermediate Pressure to get a seal. Higher IP will tend to creep around the knife edge/poppet seat interface due to the straightforward physics of spring pressure in pounds divided by knife edge area in sq. in.

Theoretically, for example, 1.4 lb maximum spring pressure applied to a 0.01 sq. in. area of the tiny rim of the knife edge implies the following: 1.4/0.01 equals 140; therefore any IP over 140 psi will leak, because increasing spring pressure on a sharp knife edge doesn't increase the area of seat impression significantly. Therefore, a valve that leaks at 140 psi might just seal if you decided to tune your first stage to 125 psi instead.

Conversely, a restored (blunter) knife edge with a larger contact area might overpower the ability of the spring to provide enough pressure to seal. Any polishing will blunt the existing knife edge unless the bore is thinned (technically difficult). Assume an increase in contact area from 0.01 to 0.015 sq. in. The resulting 1.4/0.015 is a 93 ratio. You can't drop your first stage IP that low, which means it can be very difficult to restore a sufficiently thin edge after polishing out a nick. And increasing the spring pressure on a blunt knife edge quickly increases the area of contact. If the spring force doesn't increase more than the increase in contact area, the problem gets worse. The alternative in trying for a seal at lower cracking effort with a blunter knife edge is to use a softer seat.

The problem of obtaining a better seal at low cracking effort has prompted attempts to create a DIY poppet replacement. After myriad failures with my own attempts, @Kupu came up with an ingenious solution using a Duro 50 2-104 o-ring in place of the seat. That workaround is discussed in this thread: solution for D-series poppet seat DIY? Time will tell if this proves to be a solution to aging components.

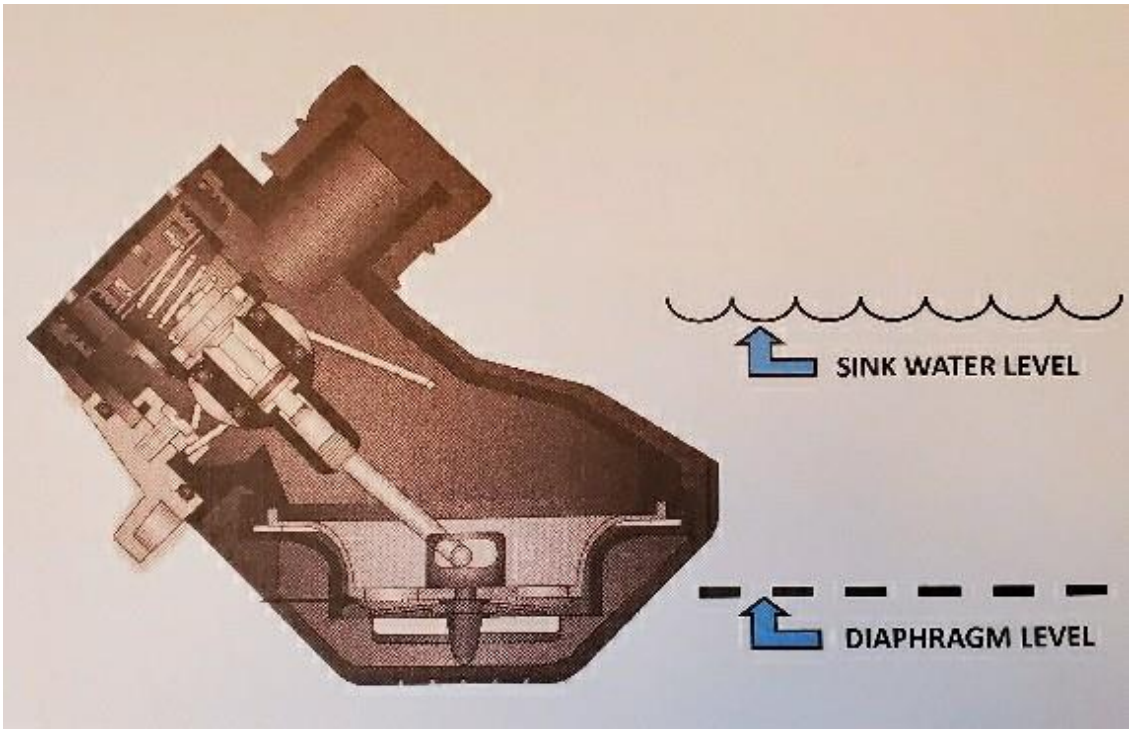
Tuning Technique:
With the lever set correctly, the ease of tuning will be a function of the equipment available. The best case would be having a magnehelic with mouthpiece, a slide on/off valve for your low pressure hose and a custom pin wrench for rapid cap assembly and removal. None of that is necessary, however. Given enough time, you can tune perfectly with a sink full of water and a screwdriver.

Cracking effort is specified by Scubapro at 1.0-1.4" water column. Avid D-series divers frequently set cracking effort lower than this, and 0.6" is occasionally possible with a perfect knife edge, without exceeding the case geometry fault of this design (the top edge of the exhaust valve is 0.6" above the center of the diaphragm in the least favorable diving position: looking up at a 45 degree angle). While 0.6" is possible, it makes the reg extremely twitchy, especially at depth, and prone to "crossover", or a freeflow that "blows" air at you during sharp inhalation at depth. A cracking effort of 0.8-0.9" is far more reliable, and still feels effortless during diving. The degree to which lower-than-specification cracking efforts are obtainable is a function of the poppet chosen.

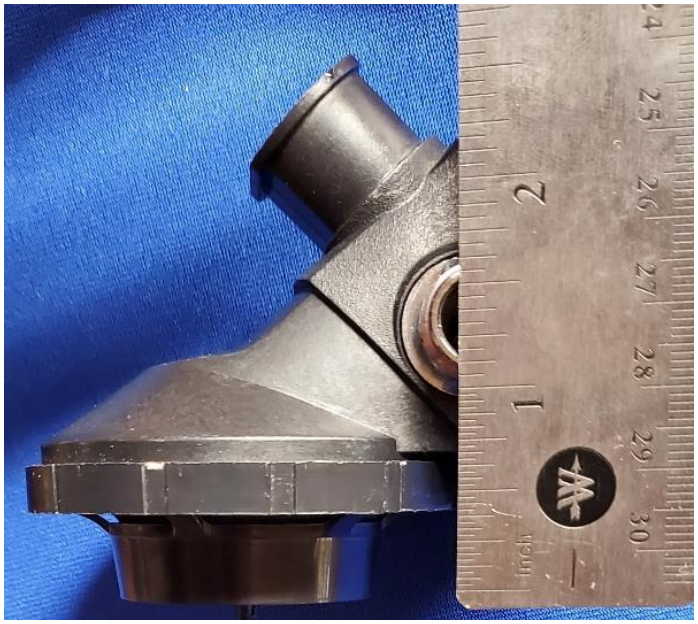
Scubapro has gone through at least five iterations of seat compound, with variable results. The current poppet, while more consistent, is not the best for obtaining below-specification cracking effort. Older poppets, notably the orange-top poppet with a translucent seat are better for low cracking effort. But they come at the price of added fragility due to component aging. The poppet alternative mentioned above may be a solution.

Assuming the valve seals at your first stage IP, you can quickly measure rough cracking effort without installing the top cap, by holding your hand over the top of the case (thus sealing the case and fully seating the housing) and inhaling as you read your magnehelic. Keep in mind, however, that the valve is fully pressurized, and you risk having the housing pop out of the inlet tube if you remove your hand and turn your attention away. Having a slide switch on your LP hose however, allows you to turn off gas pressure and purge the valve before removing your hand from the top of the case. Therefore, it is safer, albeit slower, to reattach the cap for each pressurization and measurement. A custom pin wrench makes repeated attachments much faster.

Without a magnehelic, you will need to attach the cap and submerge the pressurized regulator in a sink full of water. The physics are straightforward. The depth of the diaphragm below the surface of the water is the pressure in "inches of water" (just like the magnehelic) that is placed on the valve:



Cracking effort can be fairly precisely estimated by the depth to which the regulator is submerged when a slight hiss begins.



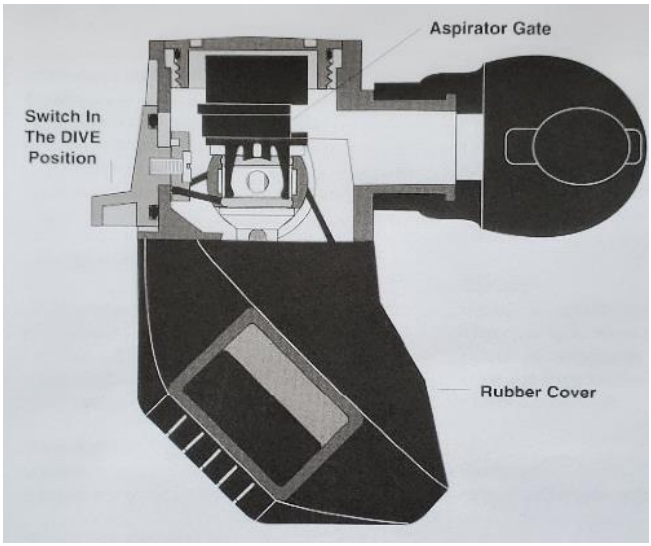
So, adjusting cracking effort is a straightforward (if slow) matter of repeatedly setting the spring pad position, attaching the top cap, pressurizing the reg and submerging it until you can just hear the reg begin to hiss. This regulator, tuned to 0.8"WC, has just begun to hiss as the water level in the sink rounds the back of the case.

A hiss that does not begin until water is at the middle of the hose inlet is approx 1.3"WC, and is poorer performance than this regulator is capable of. If that's the case, check your knife edge and poppet face for flaws.

FINAL TUNING AND ASSEMBLY

Tuning the Venturi Initiated Vacuum Assist (VIVA)

Like most high-performance second stages, the D400 makes use of the venturi principle to decrease inspiratory effort. The constriction of gas flow in the case generates a negative pressure which helps pull the diaphragm inward and decrease the effort required to maintain airflow during the inspiratory half of the breathing cycle. In the D400 this is accomplished by adjustment of the VIVA collar (aspirator gate, Part #6) after desired cracking effort has been obtained.



The gate is adjusted using the forked end of a brass spade, or similar long narrow tool, to engage one side or the other of the collar. Max flow is with the gate edges symmetrically at the edge of the oval airflow hole in the aspirator. The D400 will easily freeflow with the mouthpiece off and the aspirator centered.

Adjustment is accomplished with the mouthpiece mounted to the case, as the decreased opening size affects the venturi action in and of itself. With the mouthpiece attached, a brisk tap on the center purge area of the diaphragm should initiate a freeflow at most IPs. Using your tool in a fashion similar to the picture at right, nudge the collar of the aspirator gate to one side or another by "one click". The collar and aspirator are both notched, and it should be possible to feel, if not hear, as the gate pops over a notch to one side. Purge again. If freeflow has been eliminated, you're done. If not, keep adding a click at a time to disrupt smooth airflow until the reg will not freeflow. At that point, the VIVA is correctly adjusted.

Realize that as depth increases and air density rises, Venturi action is accentuated. Thus, the adjusted position is a minimum at the surface, and regulator assistance increases with depth. It is possible to occasionally feel a "crossover" into freeflow at greater depths. The reg may tend to "blow at you" during early inhalation. This stops by itself when you begin to exhale. But if you dive regularly at great depth, and this is uncomfortable, you can simply add another click of detuning to the VIVA collar, and it will no longer occur at depth. It is usually not possible to feel the difference in inspiratory flow between min and max VIVA positions, though it is measurable on an ANSTI machine.

Negative pressure check

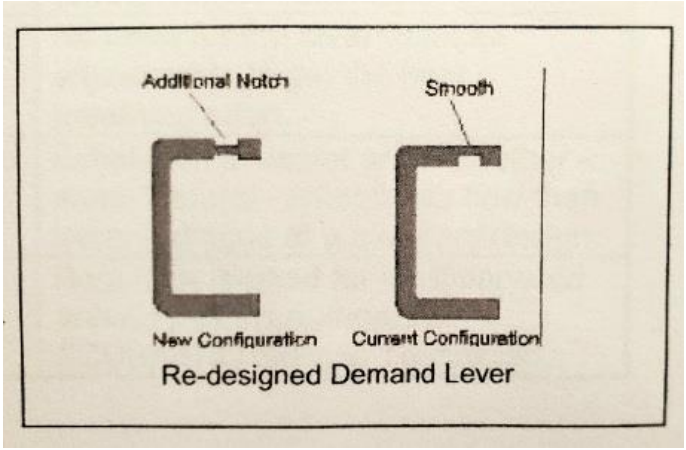
With the reg still attached to the tank after your VIVA adjustment, turn off the gas and purge the valve. Inhale lightly from the mouthpiece and hold the inhalation. Listen carefully for any air leak, and feel for a need to continue sucking to compensate for that leak. If a leak is noted, dunk the reg in a sink of water, to create a little surface tension along the skirt of the exhaust valve, and try again. If you still have a leak, the most likely causes are a poorly seated diaphragm (easy fix), an unnoticed hole in the diaphragm, a flaw in the skirt of the exhaust valve, or (worst case) a sheared o-ring in the inlet tube or housing, which will necessitate disassembly and replacement.

Attach the case and you're done!

You've reached the end of the road, and the only thing left is to attach the case and go diving.
It helps to wipe a thin layer of lube on the flat thin area at the back of the case. Then wiggle the case opening around the diaphragm cover ring. It's okay if the ring rotates a fraction of a turn as you fit the cover. The ring shouldn't be too tight with its delicate threads.
Work the front of the cover up and over the notch at the top, massaging it so that there's no gap below the Pre-Dive switch. Pressurize the reg to make sure that the cover hasn't somehow depressed the tip of the linkage loop that protrudes through the exhaust valve. If that has occurred, you'll need to remove the cover and drop the lever just a fraction, so it doesn't engage the valve when the cover squeezes on it.
Do a final check of cracking effort and attach a zip tie to the mouthpiece if you haven't done that already, and you're done!

Special Considerations: The Final D400 Model

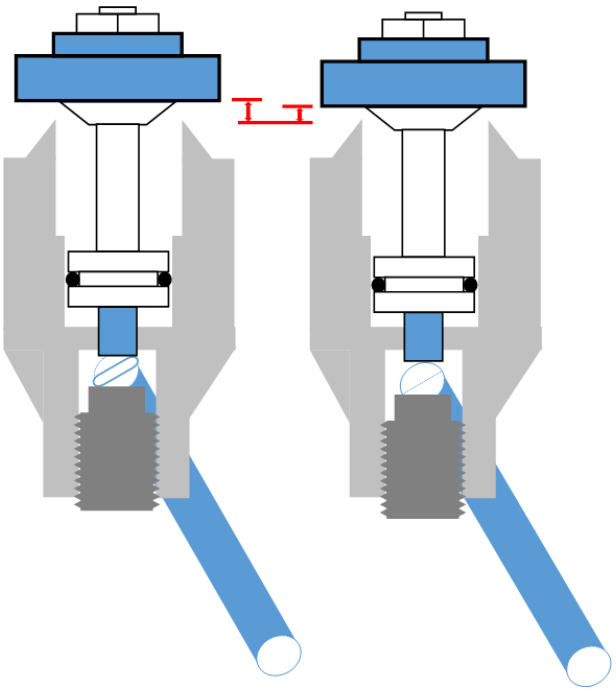
The very last model of the D400 included big changes, discussed in Service Bulletin #268 (attached below). The "improvements" included a redesign of the housing, eliminating the fragile metal knife edge in favor of a new housing with a replaceable "techno-polymer" orifice.



The lever was also changed to increase poppet opening and air flow by effectively doubling the mechanical advantage of the short arm of the lever.

Most significant was the change in knife edge. The "techno-polymer" edge was durable, no doubt about it. Only the new D420 plastic knife edge seems to be better. But its contour was decidedly rounded, and it was rare to be able to seal at less than 0.8"WC. The seat material in later poppets seems to have become harder, IMO. With a smooth but dull plastic orifice, that made for a better mating at lower cracking effort. The earlier, softer seats would better tolerate a nicked metal knife edge, but those same poppets would require too much spring tension to seal against a duller edge (with its larger total surface area). It became a Catch-22 to experiment with multiple seats to get best performance. As noted above, using @Kupu 's technique with the proper Duro 2-104 o-ring may be the solution to all this: solution for D-series poppet seat DIY?

With regard to the lever, the sharper contact point where the new style lever contacted the nib at the bottom of the poppet made for slightly increased friction, although total valve opening was improved. The mechanics are suggested by the diagram below:



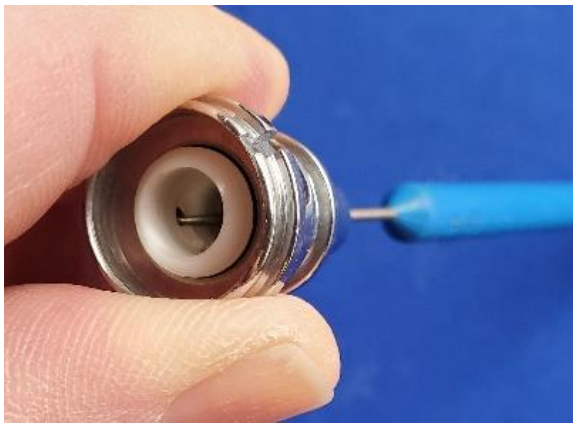
In any case, it is occasionally possible to "downgrade" to an older metal orifice, and lots of smooth D400 levers are around. It's worth experimenting to see if you can identify a difference in performance.

From a service standpoint with the very last D400 model, the only new challenge is getting the orifice out of the housing without damaging it, for there are no more available techno-polymer orifices on the market that I have seen.

To remove the orifice, use a small flat blade screwdriver to lever up on the two tabs in the oval holes in the side of the housing.

Then, using a straight blunt pick, carefully engage the side of the orifice from below through the stem of the housing, and carefully push up.

If the pick is engaged, the orifice will slide out. If not, it will slip and likely scratch your knife edge.



The static o-rings that seal the orifice to the housing are spec'ed by Scubapro as AS568 5-179 duro 70. However, this is roughly a 1x6mm oring, and the lands in the techno-polymer orifice measure 8.37mm diameter. A 1x6mm therefore requires significant stretch, and I am surprised at the specification. A 1mm x 7mm duro 70 fits quite well and is my choice, but as a static oring it probably makes little difference either way, as long as you can insert the orifice and it seals in the housing.
Replacing the orifice requires careful, symmetric downward pressure on the knife edge with nothing harder than your thumb. Resurfacing this knife edge will be discussed in an upcoming D-series restoration thread.

Well, that's about all I have to offer on this reg. I hope the tips above have been helpful. As always, this is just one guy's opinion, and with @Kupu 's poppet invention as an example, new ideas are always appearing for keeping this old beauty in service. I welcome any new ideas or differing opinions regarding service or performance of this regulator.

SCUBAPRO

Technical Service Schematic

D400/350/300 #11-01X-000

Date 12/97 Revision F

Annual Repair Parts Kit #11-014-041