Regulator Maintenance 101

The following subject of servicing a regulator on a rebreather must be taken seriously as this single item of life support is critical to operation of delivering gas safely to your rebreather. For divers who are already proficient with service of regulators, there may be one or two new tricks you can put in your hat. For divers who are not proficient with regulator service, then use this as a tool for greater understanding of how your regulator works, and how you can diagnose a potential issue in future.

Here is a few wise words from an icon of our rebreather industry:
With that said, I'll add this pearl of wisdom:
THERE IS NO BETTER WAY TO LEARN ABOUT THESE MACHINES THAN BY ACTUALLY DOING THE WORK ON THEM YOURSELF.
By developing a "ritual" of maintenance of your unit, you will increase your knowledge of it, and continue to enjoy successful dives with it.
FAILURE TO ADHERE TO A STRICT MAINTENANCE PROGRAM ON THESE UNITS COULD CAUSE A FAILURE THAT COULD KILL YOU.
I can't say it any simpler than that. (excerpt from Kevin Juergensen)

Now I will make a statement that appears to contradict what most people believe as a sacred fact. *"The quality of the regulator on a rebreather has very - very little difference to the quality of the life support the rebreather provides"*. What I am saying is that you do NOT need a high performance, high quality, high priced regulator to make a good rebreather. Boom! Well its a fact, and all you need to do is look at a few of the military / commercial rebreathers that we hold in high esteem, such as the Mk 15, BMR 500 , etc, etc. and you will often find a very small piston regulator like Sherwood Selpac, or SEAMCO piston with both being A clamp yoke style and not DIN. So if you happen to have a nice quality Apeks regulator then feel good, but understand weak or strong a regulator has simple failure points that you need to watch for.

The following tips are good to keep tract of whether you do your own service or not.

- Know the Intermediate Pressure (IP) of each regulator; Dluent / Oxygen as designed by rebreather manufacture as this may be different from the recommended factory setting.
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- Test the I.P regularly which means you need a DM pressure test gauge
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- Keep Tract of Regulator Service Dates
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- Travel with a regulator 1st stage service kit regardless of whether you service your own or not
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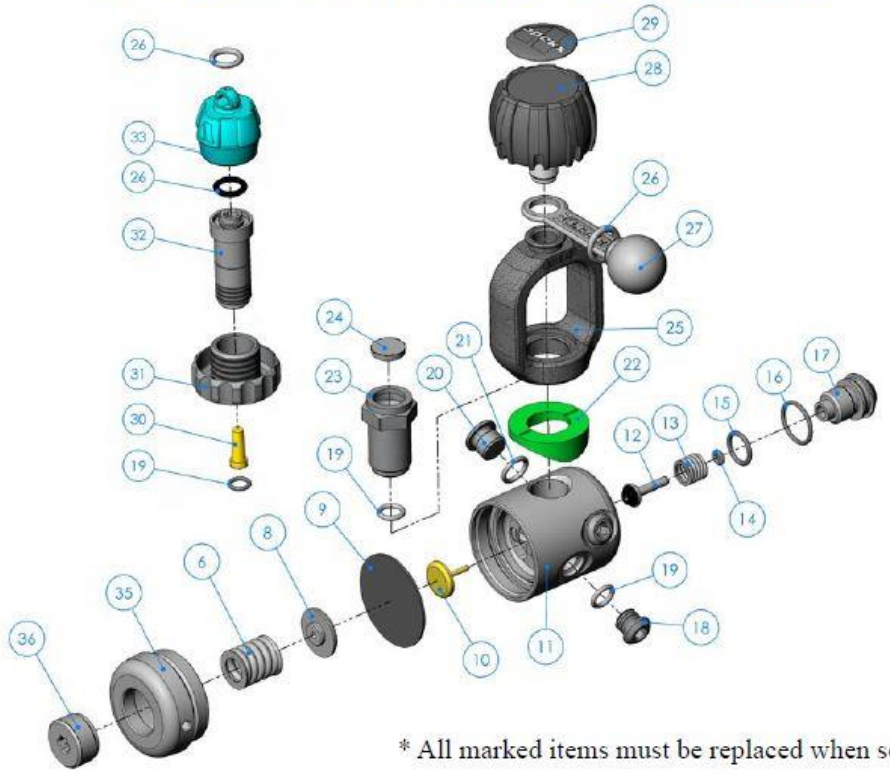
- Install OPV on both the oxygen an diluent regulators

The intermediate pressure on the regulator pictured is factory set for 150 psi +- 5 psi for standard scuba use. This pressure is set by turning part #5 clockwise which puts pressure on #6 - to the #8 spring pad - #9 diaphragm - #10 valve lifter. The tip of #10 valve lifter fits into the center of the sealing surface #12 High Pressure (HP) valve. What you do not see is the "volcano shaped" valve seat (inside part #11) which #12 rests against in the closed position. The IP is the pressure of cylinder gas that comes out of the Low Pressure (LP) port holes. On a balanced regulator as shown above, the tank pressure from 3500 to 500 would deliver a set 150 psi. If this were an unbalanced regulator, as the cylinder pressure drops, then so does the IP drop.

US4 & US1 Exploded Parts Diagram



Now if you look at this regulator also made by Apeks is almost identical. But if you look from part #11 - #9 going to left the parts now change. Part # 7 is now #35 which both do same thing. There is the large spring #6 and the spring adjuster #5 is now #36. The difference in these two designs is that in the new diagram, water enters through hex hole in part #36 and floods the diaphragm holder #35. The point is that surrounding pressure "ambient" will increase as you descend and decrease as you ascend. You have to imagine that when diaphragm #9 is in place that there is a small air space (air chamber) below it on #11 body. Since air / gas is compressible, this space is compressed and once it presses in then the regulator responds by equalizing to new surrounding pressure. It is essential for the regulator to sense changing ambient pressure so it can maintain 150 psi over ambient. This new diagram is typical of Diluent regulator and "Solenoid driven Oxygen regulators.

To contrast these two regulators by the addition of parts #1.2.3.4 is to say that the regulator 1st stage is now a dry "environmentally sealed" first stage. The part #2 is a soft flexible silicone diaphragm. When tightly sealed together this soft diaphragm presses in (squeeze) as water pressure increases. Part #4 is essential as it is a "hydrostatic" transmitter. It feels the pressure applied to the soft silicone diaphragm and presses on part #8 pad to adjust ambient pressure.

Now a variation of the first diagram regulator DS4 is commonly used on "orifice" driven rebreathers like KISS or rEvo mCCR. Part #2 is replaced with a solid metal/plastic plate that locks the IP to the surface pre set pressure that accommodates the flow desired. Part #4 hydrostatic transmitter is then removed. The second regulator US1 / US4 cannot be blocked or fixed IP so its not found on orifice rebreathers.

So is there any benefit to an "environmentally sealed" first stage verse a first stage that allows water to enter the diaphragm / spring chamber. NO there is not, and in cases where you need a blank plug for fixed IP then the only choice is a DS4 style. But back to the US1 style where water enters to the diaphragm. No water gets past the diaphragm to enter the breathing gas, so salt, dirt, mud, sea guck is external and you rinse it off if you ever clean your ccr. The only exception to this would be Arctic diving, or Ice diving here in MN where the rebreather is removed from dive, freezes, and returns to a dive. Water expands as it freezes and would press the diaphragm open for a "free flow". Now free flows do not occur on a rebreather dive as they might occur on an O.C. ice dive as there is no high flow of gas (high to low pressure expanding gas cools) to super cool the first stage causing a freeze up free flow underwater. This is same reason that an economy piston regulator can deliver sufficient gas to operate a ccr, is same reason that an eCCR can operate with either a US1 or a DS4 no difference.

Now let me get back to orifice flow rebreathers like KISS and go one step further with the rEvo hCCR or hybrid ccr with an orifice and a solenoid. The manufacture will set an IP based on a size of orifice selected, and it is up to the diver to tune in the oxygen flow with a Dwyer flow meter. The IP may be higher than Apeks factory set point and to a point this is still ok. And beware in cases like the rEvo hCCR where the IP has changed over time as the orifice size has reduced. Know your unit! These units require the DS4 style oxygen regulator with a blank plug for fixed IP.

This next bit is a stretch so go slow here as its tricky. There are divers who wish to alter their stock rEvo hCCR to eliminate the orifice and go strictly solenoid eCCR. The unit comes with a plug to seal the orifice hole, but it also requires two more steps. First the blank plug must be removed, to be replaced by the environmental diaphragm. Second the hydrostatic transmitter must be installed or the silicone environmental diaphragm would squeeze, seal shut and now you have a blocked IP = no bueno! Note that the rEvo ships with an "orifice plug" but not a hydrostatic transmitter?

At some depth which is equal to the IP, then a fixed IP regulator would have equal surrounding pressure to the IP setting on the first stage. With no pressure above ambient, then there is no flow. This means that fixed IP ccr's have depth limits, and one reason that an hCCR diver may wish to block orifice and go straight eCCR.

Now lets recap as all we have done is discuss the operation of two styles of Apeks 1st stages, how the IP is set, how the IP changes on standard 1st stages, and how a fixed IP or blanked 1st stage does not change. Knowing how your regulator responds to your rebreather is essential to go on. If you are unsure, please ask. Read the CCR manufacturers opp manual to see what the mfg recommends. If you need PDF files on Apeks regulator service manuals please ask. First bullet to know the IP of your first stages is covered.

Next is to discuss the actual testing of IP on each of your oxygen and diluent first stages, and what is the recommended equipment to do this. First you will want to acquire one of the test gauges sometimes marketed as "Divemaster test gauge" . These are not high quality as they are knocked out "economically" in some Asian factory, but not to worry. Its not the precision, but the relative consistency as you test over and over..... This also means that "your" gauge is consistent, but you cant borrow three peoples test guage as they all may be +- 5 psi? By using your own gauge, you get consistent readings. This gauge plugs into a low pressure BCD nipple, which is not present on all ccr regulators, so pull a LP port plug off and screw in a BCD hose for this test. Write down the diluent and oxygen reading in your ccr service log book. No Shite, I actually had a small pocket size spiral notebook that I kept for years with data.... Compare the data to the CCR manufacture recommended setting.

The old school thought was that on eCCR like Inspiration, the diluent IP was 150 - 155 psi or same as factory Apex, whereas the oxygen IP was 140 - 145 psi. The reason why was the oxygen solenoid is an upstream valve, and it worked better "opened" under lesser pressure. The current rEvo hCCR seems to deify this as the IP is much higher to support deeper diving on a fixed IP.

Story time as this is instructive. Recently I made a rookie blunder, "screwed the pooch" and use this as it can happen to anyone. So the deal here is that rule #1 when diagnosing are trouble regulator is to check the IP. And the reason why is this example: Say a standard scuba regulator is slowly hissing from the 2nd stage. The "Jump to Conclusion" ASSumption is that the 2nd stage seat is worn, or out of adjustment and its leaking. And here I am doing a ccr build before pool demo and the Over Pressure relief Valve "OPV" was hissing. So I jump to conclusion that the spring screw needs to be tightened down. NOPE you DOPE! That didn't fix the leak, then 25 years of regulator service hit me in the head, Dooh! I checked the IP and it was 200 psi plus..... The OPV is just like a little 2nd stage regulator as it is a downstream mechanism, and in event of blown seat or high pressure creep, then the spring pressure holding the seat is exceeded and it leaks! I've seen countless scuba 2nd stage regulators cranked down to impossible breathing to solve wrong problem. Now look at diagram DS1 for #17 Balance Plug (balance chamber) and I unscrewed this and removed #12 the High Pressure Valve to see if it was deformed. A normal valve will have an even thin circle embedded into the plastic surface. A damaged Valve may have an un-even circle, a ding, or delamination of surface. In this case it looked normal, so I looked at the corresponding "volcano" seat surface and it looked clean. Any bit of the tiniest grit sand, etc will prevent seal and HP creeping pressure occurs. This seat must be perfect, hence reason NO sharp object is inserted as you can permanently damage the volcano seat. The other reason (s) could include dry sticky, or damaged O-Ring #14. In this case the regulator did not require a complete rebuild, but clean "volcano" seat with soft Q-tip, and surface of valve, re-lube O-Ring and presto! No more leaks from OPV, and IP locked in at 150 psi.

So moral to story is don't assume, always check the IP and know what can cause High IP or Low IP.

High or Creeping IP

- HP Valve Seat is worn or damaged
- Spring Adjust Screw is set too far
- O-ring in Balance Plug - Balance Chamber dry or damaged

Low IP or no flow

- Cylinder Valve not open or blocked
- Conical Filter Plugged
- Spring Screw set too low
- No Flow at depth - * not a surface test diver removed blank plug, did not install hydrostatic transmitter

External Leaks (gas)

- Blank Plugs "port plugs" 3/8 or 7/16 UNF O-rings are damaged or plug is loose
- Din Connector Tube O-ring worn or loose
- Diaphram Clamp is loose
- Diaphram is worn or damaged
- Diaphramg seating surface damaged - see note on never using pick to remove main diaphragm

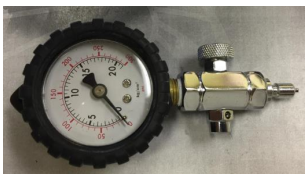
Tools

- Divemaster IP test Gauge - this is low pressure economy gauge with BCD nipple
- Pin C - Spanner for Diaphram Cap / Environmental End Cap - sometimes 2 are required
- Regulator Holder Tool with 3/8 UNF thread - 7/16 UNF or an expired Co2 cartridge with 3/8 unf thread works too
- Clean Table with NO clutter and good lighting, a service mat or neoprene mat helps
- Imperial and Metric Crescent Wrench, 11/16 spanner wrench, Metric Allen Key tools 5,6 mm , O-Ring pick, Toothbrush
- Oxygen Compatible 111 lube such as Christolube or Crytox, White Household Vinegar, Dawn Dish Soap
- Apeks First Stage Kit (s) #AP0241/AA
- Cell Phone Camera to take pictures, Note Pad, PDF Regulator Service Manual

Tools

IP Test Gauges come in many styles from simple BCD nipple-gauge to complete test benches

Simple DM Test Gauge



My favorite is the Deluxe Test Gauge - it has a screw knob to release pressure. You don't have a 2nd stage to purge n "pop" the pressure, or "cycle" the IP to make sure it holds and that the valve seats on the orifice.

Test Bench is nice but $$$$

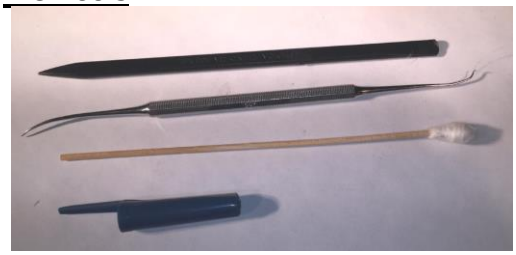
Regulator Holder

My go-to holder is an old "used" Co2 cartridge as it has 3/8 UNF thread and you can add a 7/16 port adaptor

C Pin Spanner Wrench

The C spanner must be the adjustable "hook" to fit the diameter tightly, with the correct size indent pin.

Pic Tools



1st Tool - Black Plastic pointer - good choice

2nd Tool - Dental Pick - hard to avoid and tempting, but very bad in many cases

3rd Tool - Medical swab on wooden post - if you are ever going to use a swab, the medical are tightly wound

4th Tool - Cap for a ball point stick pen - Best tool any day of the week as you can't damage brass with nylon tip

Lubricant

Ok, I'm sure by now that you have heard me harping on, on, on about how much I prefer good old fashioned Silicone Grease verse the "Oxygen Compatible" lubricants.... well **this is NOT the time to use silicone**. This is HIGH PRESSURE and this is the right place to only use an oxygen compatible lube. Only use silicone on low pressure gas like MAV, BOV. For oxygen compatible I may prefer Triolube, but both brands work well. Don't use too much.

This next section is a **NO - NO DONT DO THIS!!!**

#1 NO- NO

NEVER remove a diaphragm with a dental or metal pic! **NO-NO** If the pic punctures through or slips, you scratch the surface that the diaphragm seals on and you will get a leak! Try this smart trick by first removing the diaphragm cap, and spring, the attach regulator to a scuba tank. Simply press down on the spring pad and the air will burp up the diaphragm. Slip finger or plastic tool under the lip of the diaphragm and remove.

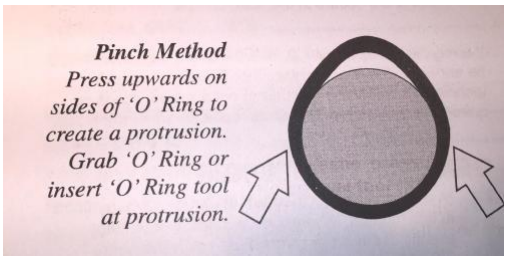
This is the safe and preferred method

#2 NO - NO

NEVER put any metal pic, or probe into the valve chamber as there is a high pressure "volcano" shaped seat at the bottom. It only takes one tiny nick, or scratch to this critical / \ shaped orifice and you will never get the regulator to maintain stable IP as it will creep. If you have to clean, start by soaking in dawn / vinegar solution, then rinse. If there is some foreign grit, dirt,or other you may take a cotton medical swab and wipe the surface only. A dab of tooth past may be used to polish if necessary.

#3 NO - NO (ok this pictures is actually a YES YES)

This is actually the correct picture, but the "POINT" is that you **NEVER** use a metal dental type pick to remove an O-ring. The sharp metal is likely to always scratch and cause leaks! This picture shows how you can use a soft nylon plastic tool like a pen cap to slip the o-ring out of place.

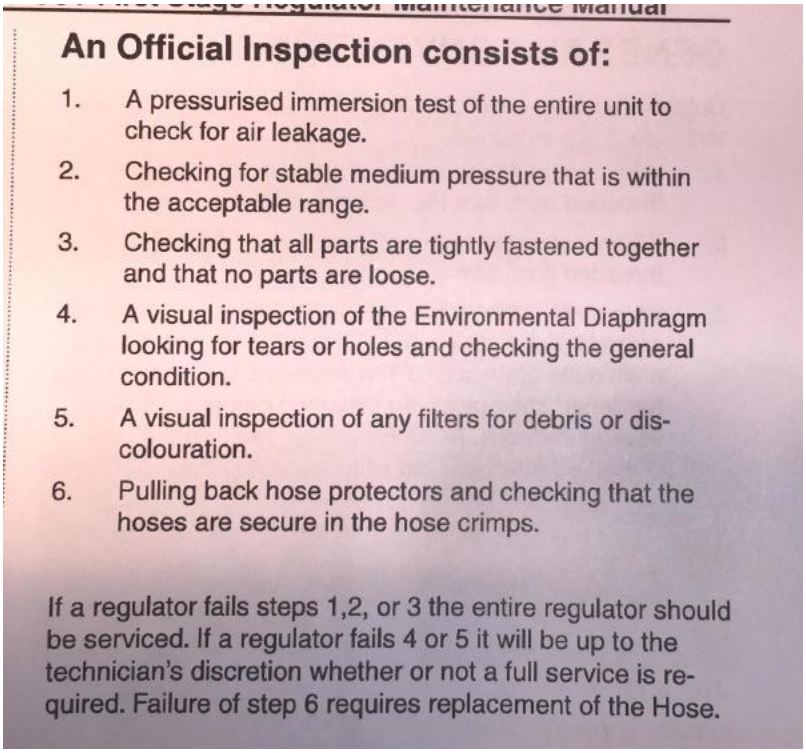


Well the pinch technique is good, but doesn't work if its inside, or very small diameter parts. For this you need a nylon probe like the pen cap that works inside and outside.

If you are getting ready for a dive trip this winter, or just in mood for servicing your rebreather regulators then consider these steps.

1. Regulator manufactures "recommend" annual service on standard scuba regulators. This is overcautious for the casual diver, and may even be overkill for an active divers such as instructors who use their regulators constantly. This timeline can easily be skewed by the casual diver dipping the first stage in salt water on their biennial dive trip, which would benefit from immediate service. Some manufactures will give service techs a guide to "look" at the regulator, or essentially doing a visual service and wait for second service year to replace parts. This entails looking at key components for telltale signs of salt intrusion, as well as an IP test. The point is that the industry standard on service is cautious for the novice, and gives the service center leeway for parts and overhaul. Since rebreather divers should be beyond newbie diver and not flooding seawater into their regulators, then they should be less prone to require annual service kits. The second point is that rebreather regulators only do a fraction of the work (opening / closing of valve seats) as compared with a scuba diver that breaths several times a minute, while the rebreathers only injects a few squirts of gas as needed by volume or consumption of oxygen. So if you take care of your regulators then you should expect them to at least give you two years or more of worry free service.

- look for white residue inside DIN inlet, port plugs that indicate salt reside - bad
- monitor IP with IP test gauge - turn cylinder on and measure IP, then puge on / off / on / off a couple times to see that the IP is steady. You are working the valve and seat. IP should be at the rebreather manufactures set point and remember this may deviate from the regulator manufacture suggested
- Any indications of external gas leaks from port plugs, DIN tube, Diaphragm - bad indicates service or parts or whole



An Official Inspection consists of:

1. A pressurised immersion test of the entire unit to check for air leakage.
2. Checking for stable medium pressure that is within the acceptable range.
3. Checking that all parts are tightly fastened together and that no parts are loose.
4. A visual inspection of the Environmental Diaphragm looking for tears or holes and checking the general condition.
5. A visual inspection of any filters for debris or discolouration.
6. Pulling back hose protectors and checking that the hoses are secure in the hose crimps.

If a regulator fails steps 1,2, or 3 the entire regulator should be serviced. If a regulator fails 4 or 5 it will be up to the technician's discretion whether or not a full service is required. Failure of step 6 requires replacement of the Hose.

2. If you are considering doing this service yourself; then have the manufactures service manual on hand, have a completely clean / un cluttered work area that is well lighted, have the proper tools and service kits
3.

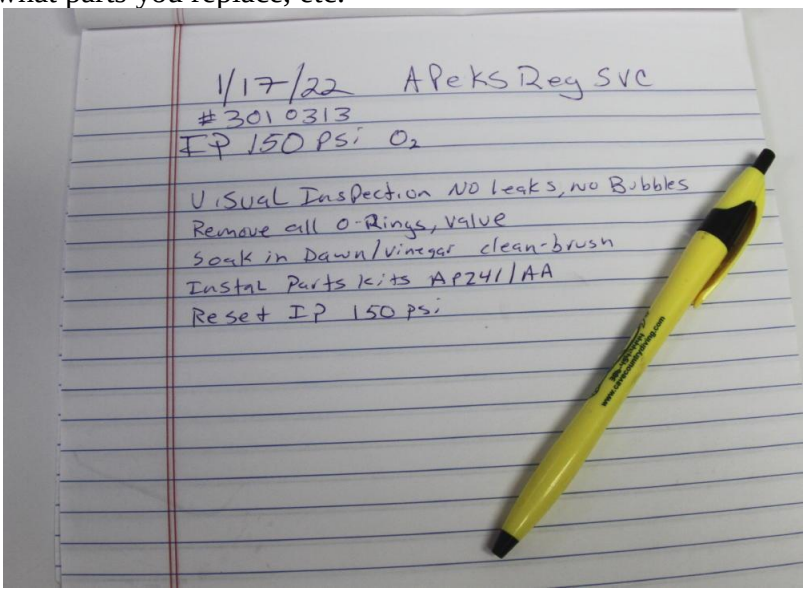
3. Go step by step from the service guide and do yourself a favor and take the parts out as they appear in the "exploded diagram" Leave the parts in this order so you can compare o-rings to the new o-rings in parts kit.
4.

4. Lay the parts from the new service kit out in order as shown on back parts list. Note parts kits may contain extra parts that are not required for your specific model as these parts kits may be generic to fit several models. Keep new o-ring away from old, do not mix and always throw away old parts. Buy a spare kit if you want spares!
5.

5. Take pictures and notes as you are working. Start by recording the pressure settings so you know what it was, then compare it to what it should be. Pictures of how it looks assembled on the rebreather so you orient the ports, hoses on the same way when re-assembly occurs.

Ask your local regulator service tech to give you assistance if you have any questions on how to, or to check your work. This is an irony in the business as dive centers can be high brow and obstinate about a diver servicing their own regulator, and the irony is that rebreather divers must have this understanding to ensure their unit is operating correctly. If you encounter belligerent minds, do not despair. Ask your instructor to help you find the right person to help guide you through, or ask them to provide you with a "regulator service clinic" to be taught to you and your dive buddies.

Keep notes on each regulators, writing details of date, serial number, IP or intermediate pressure start / finish, what parts you replace, etc.



Have the Factory Service Manual on your workbench to compare parts on disassembly and reassembly

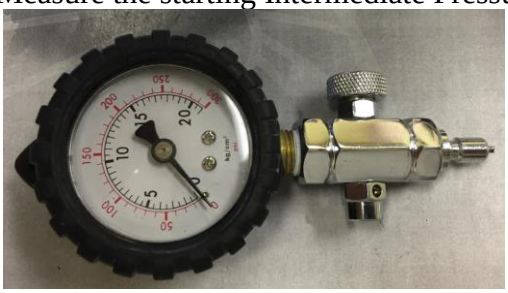
Next is to get a Tupperware to fit the regulator parts into and make the cleaning solution. Use Dawn dish soap and household white vinegar in 50% - 50% and stir well. Find and old toothbrush with decent bristles for scrubbing.

Most Excellent Solution for cleaning scuba bits, regulators, etc... But do not leave un-attended as vinegar is a weak acid, yet will still strip plating on metal parts! Rinse well with copious amounts of hot/warm water.

To Start

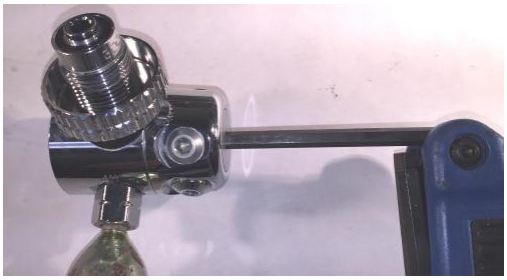
Remove regulator from CCR, assemble tools, BCD whip, and clean working area.

Measure the starting Intermediate Pressure with BCD whip attached to low pressure port. Record pressure.



Use C Spanner and regulator holder tool to remove the diaphragm cap, spring, spring pad, then attach to scuba tank to pop up the diaphragm.

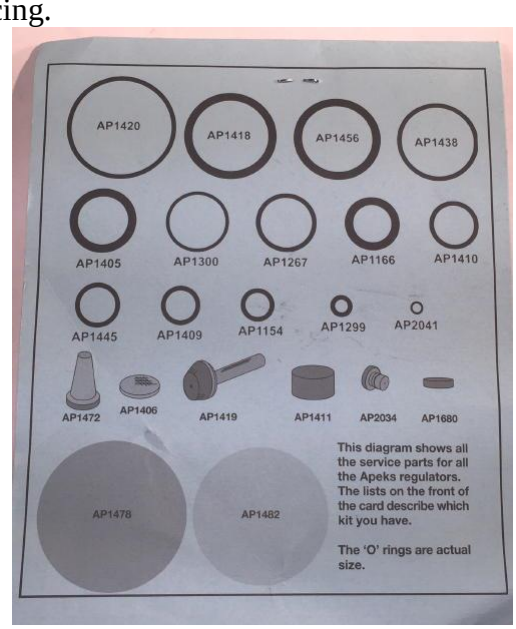
Remove the turret shown here or balance plug (part # 17 DS4) depending on version of regulator.



Remove DIN Spin Tube

Lay the parts out in order as shown on the diagram and identify O-rings, diaphragm, filter, valve from the Apeks AP0241/AA Service Kit

Lay the O-rings and parts out in order, actual size chart to compare. There may be extra parts in the kit that do not fit the style of regulator you are servicing.



Once you have removed the old O-rings and laid the parts out, soak the metal parts in tub of cleaning solution and use tooth brush for light scrubbing. Rinse with warm water, and let dry. Lubricate new o-rings with oxygen compatible lube and re-assemble.

When assembly is complete you will need to re-set the Intermediate Pressure by turning in / out the diaphragm adjusting screw. Attach the regulator to a cylinder, with BCD hose and IP test gauge attached, turn cylinder on and pressurize regulator. Note the pressure and adjust as needed to 9-10 bar (140 - 150 psi) based on ccr manufacture not the Apeks guide. You will need to pressurize and depressurize the regulator several times to get the high pressure valve "seated" on the orifice. Basically you are bumping it up/down/up/down or opening/closing valve several times to seat the valve under pressure. The IP should lock in and not creep up (internal leak) or creep down (external leak).

Use the Apeks Service Manual and also remember to take pictures with your cell phone camera so you can get the port plugs and orientation of the regulator as it came off the rebreather.

For Apeks parts kit see www.silentexplorers.com for web shopping cart

For Tools: Trident Diving Accessories, www.ScubaTools.com "Peterbuilt" special built regulator service tools, also recommend the book "Regulator Savy"

Learn as much as you can about your rebreather inside and out. Remember the idiom of "If its not broken, don't fix it" , but also do not be afraid to take little steps to test, clean and when you are ready, learned and confident to service your regulator then do so with great caution.

This is simple stuff that you should feel comfortable to do on a regular basis. If you have any questions, do not hesitate to ask your instructor to show you, or better yet watch you as you do the job for the first time. You can also email questions and I will try to answer them in timely fashion.

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