Ice on an Eskimos Arse!

Sometime the only clarity in life comes from watching South Park. For my friends who have asked me about freezing regulators, which is almost totally unheard of on a CCR, please watch the South Park episode on Royal Pudding. This explains some of the phenomenom of Ice on an Eskimos Arse. If you are interested in the concept of regulator freezing, please read the long drawn out article. If not do not bother and skip to the real interesting part about PIA orifices.

Apex Diaphragm regulator (as used on rEvo ccr)

The following bit is on care and maintenance of your rEvo 1st stages. It is important that a CCR diver has a higher degree of understanding for their life support unit, than does a casual sport divers regulator set. And it is my observations over the years that divers, specifically “Tech Divers”, to be self-sufficient and do their own regulator service. While this is a taboo subject for dive stores, with too tight panties, it is the norm and we will discuss it with open frankness.

It is also my observation over the years that divers make a few common mistakes by hurrying too fast. Let’s start with a couple

1. Pick the correct location to work - Always start with a clean “un-cluttered” work surface
2. Dont tear things apart until you have the start point identified - Make notes and always start by checking the I.P. first
3. Do not confuse a blown seat with a "Free Flow" this can be detected by checking the IP. Frozen Free Flow is an environmental condition where an Overpressure Free Flow is a result of mechanical failure.
4. It went this way... - No always take pictures with our phone to get the correct assembly
5. Do not remove OPV valves on 1st stage

Frozen Free Flow

This is a widely misunderstood concept that affects primarily cold water OC divers only. This discussion will address free flow of a standard scuba regulator in cold water use. There are two factors that cause a regulator to “freeze up” in cold water. The first is the cooling effect of high pressure gas when the pressure is reduced, it causes a cooling effect. The second is repeated immersions during freezing conditions such as ice diving or the ice that forms on an Eskimos Arse.

The first is more familiar to divers and this occurs when a diver is using high volumes of gas, especially at depth, in cool water. As the gas expands from the main cylinder and flows through the regulator a drop in pressure occurs. This causes a super cooling effect. The super cool gas can cause icing on second stage valve seats/mechanism which may cause them to seep or slightly free flow which adds to the flow and cooling to snowball into a stuck open second stage.

Back in early years of scuba most all of the second stages were made of brass and the metal immersed in water that was above freezing would cause a heat sink which would prevent the second stage regulators from freezing up. With the advent of plastic injection, plus the increase in higher performance regulators the plastic would not prevent the freeze up but actually insulate the cold gas from surrounding water and accelerate the freeze up. Some regulators have adjustable draw or tune to reduce this affect. Essentially its harder to free flow a hard breathing regulator than a highly tuned easy breathing regulator. If a diver is using the same regulator to inflate a BCD or Drysuit at the same time as breathing hard, the excessive gas flow will cause super cooling.

It starts with a slight hiss, crack, pop or flow of gas in the mouthpiece of the 2nd stage. It is caused by ice crystals forming on the 2nd stage seat surface and prevents the valve from shutting. This is very difficult to catch before it gets out of hand. A diver may if lucky be able to remove the mouthpiece, or switch second stages, shut off the leaking valve for a moment to allow thaw, then return....

A Secondary affect of the second stage free flow is a super rush of high pressure gas through the first stage, which then drops the pressure and super cools the first stage. The water inside an ambient chamber of a first stage would freeze. The expanding ice would press the diaphragm to then press the pin holding the first stage seat open, this results in the first stage free flow. The diver would exit the water with a solid block of ice surrounding the first stage regulator, and an empty tank.

A common misunderstanding was that the first stage of the regulator would freeze first causing the air to rush uncontrolled out of the second stage. This is easy mistake, as the incident starts at the second stage of O.C. regulators then proceeds to first stage.

In the 80-90’s it was common to see a silicone diaphragm sealing off the opening of the ambient chamber. The void was filled with messy silicone oil as the liquid silicone would not freeze, yet it would transmit the pressure to the main diaphragm. The first stage would be called “environmentally sealed” as the diaphragm with silicone would prevent water from entering and freezing the first stage. This did not prevent the second stage from freezing as this was a matter of engineering and design. One simple solution to the problem of super cool gas on second stage seats was the metal foil that was used in Sherwood Blizzard regulators. The metal foils were placed in the opening of the regulator to transmit warm exhaled gas along the foil to the valve seat, preventing 2nd stage free flows. Other regulators used external “radiators” or ribbed brass fittings outside the second stage that were all part of the second stage internal metal valve seating surfaces. These radiators would transmit external water temps that were above freezing to the area of low pressure cooling.

A good Diaphragm first stage regulator (as compared with piston) is by itself very difficult to free flow in cold water. Examples include Apex TX20 or TX50 are open environment. To increase the ability of a regulator to avoid environmental freeze up is to place a silicone diaphragm over the opening of the ambient chamber. A "**T**" shaped pressure transmitter is used in place of the messy silicone oil.

Now the first stages on a rebreather are not a serious consideration for freezing due to rapid flow of super cool gas as the oxygen only injects tiny amounts, so flow is not a consideration. The diluent side regulator could cause high flow of gas if the diver would breath via the ADV, or in combination with the BCD use excessive volumes of gas. So it is not critical for ccr divers to have “dry seal” first stages as the likelihood of high flow gas is not usual.

Frozen First Stage

This is the second possibility and could occur if a diver had allowed a regulator, attached to a scuba cylinder, to be left out on surface after an ice dive. The freezing surface temperatures would cause any water inside an ambient chamber to freeze and expand as described above. This should be self evident as it would free flow as soon as cylinder was turned on to dive again. Rebreathers should not be left in freezing environments before or after diving.

Mechanical Failure Free Flow

This is actually most common as most divers dive in warm climates where cold freeze flow is not possible, and where more regulators are poorly serviced. Repeated opening / closing of a high pressure seat can cause wear to occur or a delaminating of a high pressure sealing surface. It takes only a tiny fraction of a surface area to be compromised and a hiss of high pressure gas will flow past a seat. The leak of gas will no longer be maintained as an "intermediate pressure' and will become un-regulated as a leak of higher pressure gas. The reason modern second stages have a downstream opening valve (2nd stage) is to allow overpressure gas to Freely Flow out the mouthpiece. This prevents bursting of breathing hoses on regulators. *See OPV warning

The use of a simple Intermediate Pressure gauge or sometimes sold as "Divemaster Test Gauge" is a valuable tool for all technical divers. Knowing the correct operating pressure, or Intermediate Pressure (IP) for all regulators is part of your safety. A regulator manufacture will set IP on first stage at a recommended pressure to deliver adequate flow of gas. The second stage on conventional regulators will be then adjusted accordingly. The springs on a second stage regulator are manufactured to a spec that allows a technician to adjust the draw of a second stage to desired opening effort. A rebreather manufacture may adjust a common regulator to fit the rebreather so it delivers diluent or oxygen to devices at pressures other than factory design. An example is a oxygen solenoid which is an "Up Stream" valve (opening into flow) and the amount of voltage required to open a solenoid can be affected by pressure. Essentially the higher the pressure the more effort is required to open the solenoid. For this reason it is not uncommon for some rebreathers to have a lower oxygen IP. In contrast a manual only rebreather may have a higher than factory normal pressure to provide a constant mass flow of gas.

***OPV Warning**

Divers who add Isolation Valves to 2nd stage regulators on stage bottles. When a normally operating regulator goes to depth, the pressure in the hoses increases to maintain a set Intermediate Pressure 130-150 psi above surface pressure. When descending the ambient (surrounding) pressure increases, so the regulator increases pressure to keep the IP at 130-150 above surrounding. When a diver ascends, there is no relief valve or downstream 2nd stage to release excess pressure as the isolator valve shuts the flow of gas to 2nd stage off. This has caused hoses to rupture on O.C. stage regs that had isolators! In this case an OPV must be used on first stages. This is also the reason that OPV valves are necessary on rebreather first stages where the gas Oxygen / Diluent first stages do not have a "Down Stream" mechanism. A rEvo ccr for example has an ADV (auto diluent valve) in exhale lung that is the guts of a 2nd stage (downstream) mechanism. It is therefore prudent to use OPV's on all first stages on ccr, and imperative on stage bottles with isolators.

Servicing CCR First Stage Regulators

Be careful if a dive shop tech is adjusting your IP on a rebreather. Apex regulators are Apex regulators, with the exception to the Intermediate Pressure on the Oxygen side of a rEvo rebreather. The Dil regulator is just a stock Apex with standard IP as would be on open circuit use. The Oxygen side of an Apex is or may be a lower IP that is fixed to the orfice on the solenoid, or with recent change in rEvo solenoid orifice it is higher. You should always measure your oxygen flow rate out of the orifice with a Dwyer Flow Meter (.02 – 1.2 lpm range). The IP of the Oxygen side is set at the factory to match the orifice. I know there is a lot of information jammed in the week of ccr training, but I show divers the IP of each first stage, and I use a Dwyer flow meter to show the student the LPM of the orifice. You should measure each of these and record the readings on your own gauges, not just some guys random gauges as the type of scuba gauges on the market are +- 5 psi, where the Dwyer flow meter should always be consistent. By always measuring your IP's on your instruments, you stay consistent. I can send you the link to the Dwyer flow meter if you do not already have one. The value to regular measurement of the IP and the Orifice is that they are directly affecting one another. The lower the IP, the lower the Flow or the higher the IP the higher the Flow. You are also looking for contradictions such as if your IP is set correctly and your flow rate is low, this would indicate a blocked orifice, vice versa....

The concern on the Oxygen Apex regulator is that it is a "Fixed" IP regulator. The SS blank Plug would cover the "ambient" chamber on this diaphragm regulator. This prevents the regulator from sensing a change of surrounding pressure such as when you descend the water pressure increases with depth. This blanking is absolutely necessary with a rebreather that has a flowing orifice. If you remove the SS plate, the regulator would do just what a scuba regulator is supposed to do and sense that the pressure is increasing. On a traditional scuba regulator the IP at the surface would be 130-150 psi above ambient pressure measured as 0 gauge at surface. As you descend 15 psi per atmosphere means that the IP is 130-150 above the 15 surrounding ambient pressure. If the regulator did not increase above ambient, the regulator would slowly stop delivering gas to the diver, such as a blocked IP regulator at 10 atmospheres. Imagine if the diver had an IP of 150 psi and the pressure surrounding them was 150 psi, then there would be no flow of gas out of the hose.... it has equalized.

Below the blanking plug you will/may find a silicone diaphragm. This is a seal that prevents water from entering the ambient chamber. There is an important distinction between the Dil / O2 regulators in this respect. The Dil side has NO Blank Plug, but it does have the silicone diaphragm. This diaphragm can be called an Environmental Dry Sealed first stage. By preventing water from entering the ambient chamber, you will reduce the risk of freeze up on first stage (this is a discussion that I will post below). Underneath the silicone diaphragm environmental seal is a plastic T shaped piece that is a pressure transmitter. This is vital underneath the Dil side dry seal as the outside ambient pressure is transmitted down through the dry stage to the actual regulator "diaphragm". It is the first stage "rubber" (composite of some elastomer and fiber) diaphragm that makes the pressure adjustment to 130-150 above ambient. If you place the silicone dry seal over the first stage ambient chamber without the pressure transmitter, then you get a hydraulic lock and the first stage squeezes to seal, but prevents the pressure from transmitting to the main diaphragm and you basically have a fixed IP regulator. At depth you would find that you get diminishing to then no diluent flow to BCD, ADV, or MAV.

The Oxygen Side first stage does not have the plastic T shaped pressure transmitter as it has been removed by the factory. The oxygen side has the SS plate, with silicone seal underneath. These are held in place with a screw cap over the ambient chamber, thus blocking outside pressure and creating a Fixed IP first stage. Again the IP of the oxygen side is fixed to the specific orifice that Paul has changed. The IP has been lower than the Apex suggested IP range. When Paul changed the orifice size smaller, he increased the IP of the regulator which allowed HeCCR diver to dive to deeper depths while still utilizing the Hybrid orifice.

If an unsuspecting Apex service technician would simply adjust the IP to the standard IP in Apex literature, then they may impact your flow rate considerably. Too high of an IP would cause excess flow of oxygen, which would reduce the amount that the solenoid would fire, however you may experience spikes in Po2 while diving or certainly while at rest at deco/safety stops. Too high of an IP would also create greater work stress for the solenoid to open as it is an "upstream" valve, opening into the high pressure flow of gas. I'm sorry I can't immediately identify your model solenoid and give you the IP setting, however the flow rate for the orifice should in .5 – .6 LPM.

The only time it becomes useful, or necessary to install the T shaped pressure transmitter is if you choose to block the orifice on a hybrid HeCCR and turn the unit into strictly an eCCR. The orifice blank plug is a small o-ring sealed screw that fits the orifice opening and blocks any oxygen flow out of the orifice. The solenoid opening, where the solenoid ejects the oxygen is not the same opening as the orifice.

Now on a standard Apex regulator, or in regards to some stock models that do not have a "Dry Seal" first stage, there is an opening on the end of the regulator so water can enter and the surrounding increased pressure is directly applied to the main diaphragm where it increases the IP to above ambient.

Good Diving

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