Double Hose Exhaust Valves

May 2011 im Vintage Scuba Diving Community Forum

SeaRat wrote:

There has been some discussion on other threads about the duckbill valve verses the mushroom valve on double hose regulators. For years I was not inclined toward duckbill valves because of their inherent problems of rotting on the inside of the regulator's exhaust horn. But I have been influenced by recently reviewed studies from the US Navy Experimental Diving Unit on double hose regulators. Because of these studies, I decided to visualize the fluid flow through these valves. Here's the results in a very easy-to-perform experiment with these valves. I used a water faucet to see water flow through the valves.

This photo shows water flow at high velocity through a duckbill valve on my DX Overpressure Breathing regulator. I took the box off because I have equipped it with a ring that makes it easy to get apart. Note that the flow is unimpeded. It goes out virtually as fast as it goes in, with no backup whatsoever.

This shows the water flow through a Healthways SCUBA regulator (Blue Label). Note how violent the change in is the flow. Note also the backup where the water flows into the tube.

This shows the flow through the original Healthways SCUBA regulator (without the duckbill valve, which virtually all had). Note that again the flow goes right through, although it is directed out the small holes there are enough of them that there is no backup in the flow. This valve had a problem, in that it allowed water into the exhalation hose in certain positions, and so cause an imbalance in the system when in a head-down position. This led Healthways to include an internal small duckbill valve in the chamber. But I have dove it without, and in a normal diving position it is a very easy exhalation valve.

The backup seen in the mushroom valve is due to the change in direction, along with the internal turbulence caused by the valve itself. This is inherent in the mushroom valve but not as apparent in single hose regulators as in double hose regulators, probably because of the nearness to the mouth of the single hose regulator. This would only occur at high flow rates, with dense gas (at depth--say 200 feet). But this is probably why few double hose regulators equipped with mushroom exhalation valves in the can passed the US Navy requirements for breathing resistance (the Nemrod Snark III is an exception, and probably the new regulator that Aqualung produced which is not available to the general public--the Mentor). There was speculation as to why USD never went to a mushroom valve--it is probably because they wanted to maintain their US Navy ratings, and the mushroom valve would have jeopardized that status.

SwimJim said:

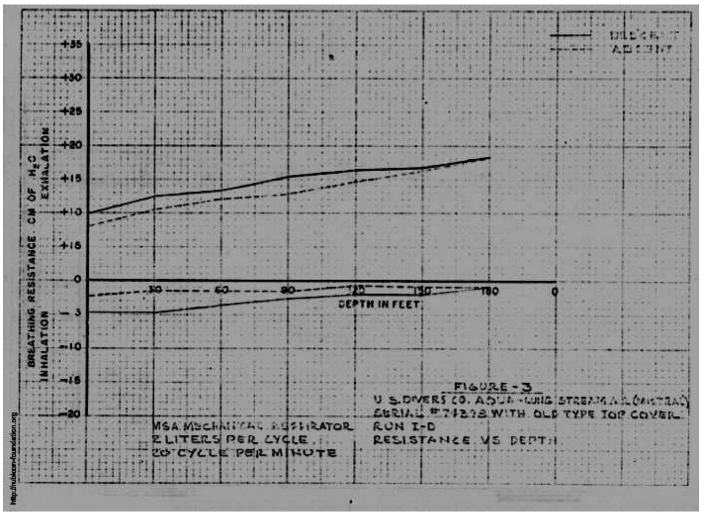
With the advent of readily available silicone duckbills, duckbills rotting in the cans is no longer really an issue. It wasn't with the originals, BUT, you had to really maintain them to get max life out of them. My Snark III Silver is an excellent breathing reg and has an exhaust mushroom in it. That mushroom is larger then the area of the original Heathways Scuba, Deluxe or Gold Label. (Yes, I own all three) Hence the flow rates are a little better with the Nemrod. The average shmo like myself will not notice much difference though. When diving Healthways, save the OEM hose sets and use a USD set. That makes a lot of difference.
Now, I have never taken any of these regs to 200. However, I was at Fortune pond in Upper Michigan and took my Phoenix for a spin down 140. As long as the hoses were clear, and a simple roll & clear will fix that, the reg, intake and exhaust breathed quite nicely. And thats in 39 degree water. A properly maintained duckbill will perform well enough that you won't really notice the difference. Now, if you put the reg on a flow bench you could quantify the difference. There would be one, but my guess is that it would be slight.

Michel said:

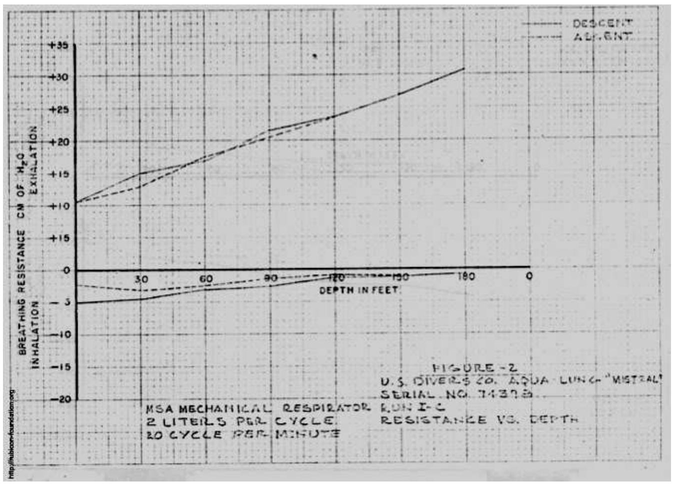
It is interesting to note that the duckbill you used for demonstration is the older type removable horn which enables the duckbill to attach to the exterior flange within the can with fishing line creating a clear path through to the slits whereas the silicone duckbills are not preformed like the more expensive neoprene ones and add a tiny folded restriction which, upon, my own experiments, as above, is negligible. I have a feeling that the duckbill is actually better suited to the double hose concept whereas the mushroom valve works best for single hose applications.

Searat again:

Michel, your powers of observation are great. This points out a very old U.S. Nave Experimental Diving Unit test of the USD Mistral regulator. They tested in 1959 both the new style top cover and the old style top cover. Here are the graphs from those tests:



This is the old top cover (top box, as we say now). Note the exhalation resistance curve.



You can download this study at:
http://archive.rubicon-foundation.org/dspace/handle/123456789/3818

Luis wrote:

I have tested the duckbill eliminator (mushroom valve, see picture below) with a Magnehelic and compared with a few different duckbills. The flow resistance of the duckbill eliminator is about the same or just a bit lower than any duckbill I tried.
I have replaced all my duckbills with duckbill eliminator on most of my metal can regulators. I have left a couple just to be original, but the truth is that from the outside no one can see. The duckbill eliminator is a

cleaner and neater installation. It doesn't roll when installing the exhaust hose or add bulk to the diameter of the horn.
In general I prefer a mushroom valve to duckbills for the following reasons:
- There is less maintenace and much longer durability with a mushroom valve than with a duckbill (but some of this depends on material and individual design).
- Duckbills make removing and installing the exhaust hose more difficult.
  I like to remove my hoses to dry.
- Duckbills sometimes move around and can cause a free flow on a highly tune regulator if they don't stay right on the center (John knows what I am referring to, See Note).

Dan's long duckbill work very well at staying at the center of the can, but they still have to be removed regularly or they will stick to the can. It is a minor inconvenience, but something to keep in mind. The preformed shape does help it stayed centered when used on the long geometry.
I still use duckbills on the reproduction plastic cans. The duckbill eliminator doesn't fit the round horn plus the horn comes closer to the center so the duckbill is locked closer to the center. Plus none of the duckbills will stick to the plastic cans. The size of the mushroom valve, materials, and geometry is going to make a big difference from one design to the next. As mentioned above, the Healthways valve is probably kind of small.
On the other hand using a mushroom valve that is larger than the mouthpiece valve is kind of a waist and can be counter productive. The materials and geometry can play as big of a factor in reducing flow resistance.
Note: the way I like to fine tune most of my regulators, I have to have the exhaust well centered on the can or I get a free flow. This is normally not an issue if the cracking suction of a regulator is over an inch.

They are glued in place. The recommended bonding is with silicone marine glue. It is very secure, but it can be removed without damaging the can or the duckbill eliminator. I used aquarium silicone boding/glue and have been diving for a while.
There have been test hanging weight to check how secure it is and it has not been a problem.
It is design to not interfere with the diaphragm.
It was design by another engineer using 3D CAD (SolidWorks) and as far as I know it was modeled in the can. He created some plastic models using a plastic depositing 3D sampler. It is a prototyping device that creates models similar to printing into 3D space.
There is a lip molded in place to guard against the possibility of the diaphragm ever interfering with the exhaust.
The flow cross sectional area at the smallest pint is about the same as a duckbill. The limiting factor (for the duckbill eliminator) is on the narrow spot of the horn, but the area is less restrictive that the duckbill itself. Again, I took instrumented data side by side of both devices. I don't run a precision lab, but I like to think it is reasonable engineering data.
I have used it to about 70 feet deep and it has always worked fine. I have also tested it side by side in a pool with two regulators on pony bottles. I tested on all possible positions and orientations.
Duckbills have been used for decades and they work.

Mushroom valves are just another design and there are always pro and cons to all designs. I do like the clean design this duckbill eliminator turn out to be. Let me point out that I was working with someone else on a similar concept fabricated in metal. But, it was another engineer that did this design and the prototyping. He did a great job (I did contribute only with some feedback toward the end of his project).

SeaRat answered:

Concerning mushroom valves in general for the double hose regulator, they involve a change in direction of the exhaled air. Usually that is a change of 90 degrees, and is very apparent in certain designs, specifically the Dacor R-4 and Dial-a-Breath regulators. Any time there is a change in direction in the flow of air, there is a loss coefficient associated with that directional change. Each design is different too. The Healthways mushroom is not a 90 degree offset, but matches the diaphragm at about a 30 degree offset.

The duckbill eliminator may have overcome this by not having a space at the end, and may act much like a duckbill by allowing the air to exhaust out the bottom with no directional change. However, not all of the surface area would be available from a mushroom, even with the duckbill eliminator. This is what inhibited many mushroom valve designs until USD made the third generation Calypso second stage, and designed it so that the mushroom valve opened inside an air pocket so that there was no pressure differential from water head across the mushroom. But the duckbill eliminator does introduce a narrower opening into the exhaust horn (by the insertion method) that is not present in the original duckbill. Also, the original duckbill has no turbulence, whereas the duckbill eliminator would have a raised area which would cause some turbulence in front of the mushroom valve.

Luis discussed the diameter of the mushroom as being less than an inch (so that the effective radius is about 0.5 inch), which allows fine tuning of the second stage without leaking. My Nemrod Snark III has a very large diameter mushroom valve, and it does leak air in some positions. So having the duckbill eliminator the size that it is would be an advantage. But the duckbill itself, as long as it extends to the center of the diaphragm, would have the same advantage.

Now, about duckbills verses mushroom valves in most diving positions and in the US Navy EDU testing. The testing is conducted under pressure through a dive to a simulated 198 feet. I have a diagram of their experimental setup, which is much more complex than a simple Magnehelic. Measuring on a Magnehelic at one atmosphere does not tell much about performance at depth, and at higher ventilation rates. I'll provide some graphs of that later in another entry. But I do have other observations from my own diving too. The exhalation valve is usually about six to twelve inches above the lungs in normal diving--this is not accounted for in the US Navy EDU tests. But when I dove my Healthways Gold Label in high current spring melt river water, it seemed that the exhaled air was almost being sucked out of my lungs during a very strenuous dive. The differential in pressure makes the differences between the duckbill and the mushroom almost a non-factor in a horizontal dive position. It does count when in a vertical position with the demand valve (regulator) at the same height as the lungs. But for overall efficiency, it is very difficult to beat the duckbill design.