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Tech talk #6: "To VIP or not to VIP, that's a hell of a tricky question"

How often to inspect cylinders is one of the questions that most certainly troubles some of the cylinder owners. With the off-diving season kicking in let's have a look at cylinder inspections and why they are so important.

Ever since the industrial revolution and the invention of steam engines, pressure vessels have been in use. Unfortunately accidents happened and governments stepped in to regulate 'pressure vessels'. Nowadays I'd carefully say that most likely every country will have its own pressure vessel regulations or regulations that govern compressed gas cylinders. And guess, our beloved scuba cylinders are likely to fall within this category.

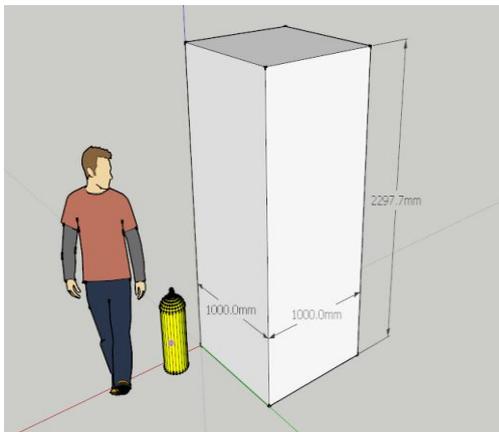
Fortunately, sudden catastrophic cylinder failures or explosions are not that common, however sadly enough yearly some incidents do occur. On the other hand, cylinder valves being ejected from the cylinders during the filling process caused by the cylinder valve thread not being compatible with the cylinder thread also occur too often; a type of accident that could have been completely prevented.

I'm not obsessed with numbers (that's my beliefs at least) but to put it in a little perspective, let's have a quick look at the energy contained in a scuba cylinder and the amount of force exerted on the cylinder valve.

1/ The amount of energy contained in any cylinder depend on the cylinder volume and pressure. It can be approximated by the following formula: $E = P_0 * V_0 * 450$. A S80 cylinder with a volume of 11.1 L and filled to 207 bar has 1,033,965 J of stored energy. Knowing that 1 gram of TNT exploding releases 4.184×10^3 J, our cylinder has an equivalent of 247.12 g TNT exploding. The good old MK2 grenade contained 2 oz or 56.7 g of TNT, so our filled scuba cylinder has an energy equivalent of 4.35 MK2 grenades, so some potential available for some serious damage.

2/ Modern cylinders in Europe have cylinder valves with a M25x2 thread. The surface area of the valve would in this case approximate 4.9 cm². From those good old days physic classes we remember that the force exerted on a surface would be equal to the surface area times the pressure. So the air inside our cylinder filled to 207 bar exerts a force of approximate 1,117 kg/cm² onto the cylinder valve, a force well over 1 ton. So we better be darn sure that that cylinder valve is correctly in place and the undamaged threads form a matching pair.

The graphic illustrates the relationship between the free volume of air in a S80 cylinder @ 207 bar (2297 L) versus the scuba cylinder and a human person to scale.



Appreciating some of the forces involved, what do some of the regulations stipulate for steel and aluminium scuba cylinders? In Europe, a visual inspection is mandatory every 2 ½ years; a hydrostatic test every 5 years. In the US the DOT requires a 5 yearly visual and hydrostatic test, however the CGA recommend in their pamphlet P-5 (2012) a yearly visual inspection of scuba cylinders. Down under the Australian government requires visual and hydrostatic test yearly. South Africa requires visual inspections annually and a hydrostatic test 4 yearly. The generally accepted 'rule in the diving industry' is to perform a visual inspection yearly. What do some of the manufacturers say? Luxfer recommends that their aluminium cylinders in normal service are to be visually inspected at least once every 12 months; however cylinders in heavy use (filled more than 5 times / week, rental cylinders, cylinders prone to damage) should be inspected every 4 months. Catalina recommends that all their scuba cylinders should be subjected to an annual visual inspection under normal use; a cylinder subjected to an average of one fill a day or more is considered a cylinder subjected to high use. Those cylinders subjected to high use should be visually inspected, both externally and internally, a minimum of every six months.

Let put some of the above blunt: not following the mandatory inspections schedule or filling cylinders which are not compliant herewith is not particularly law-abiding. It could get the operator or fill station operator into a legal mess with very little defence on his/hers behalf in case anything goes wrong. You will have no excuse. Ignoring some other aspects, filling cylinders that are out of date puts yourself and your customers at a potential risk. I'm sure you do not ignore the recommended oil changes for your car or the mandated car safety inspection, so why not have the same attitude towards your scuba cylinder and follow manufacturer's recommendations and the mandatory inspections? Wasn't that part of your open water course?

Understanding what happens during a visual inspection and hydrostatic test might help understanding the importance of those. Again there might be regional differences as far as the criteria are concerned, however the criteria and/or requirements will be similar.

A (annual) visual inspection is there to ensure that your cylinder is still in a good condition and is safe to use for another period of service by comparing its actual state to the relevant standard. In other words, a visual inspection is designed to find any mechanical or corrosion damage to the cylinder, both on the in and outside. The exterior of the cylinder is checked for many forms of damage, including: cuts, gouges, dents, and bulges, signs of heat damage, corrosion general abuse, current hydrostatic test date and tampering with the official markings. To the latter, I recently came across some cylinders which were stamped 24 97 and 13 97, this does raise some questions. The cylinder

wall thickness is measured. Finally the valve is removed and the interior inspected for debris, water, corrosion, pitting, thread integrity, and internal neck cracks. If corrosion is found, it may be necessary to clean the cylinder to remove the corrosion. The inspection also focuses on the cylinder valve (inspection of the valve is an integral part of the inspection process): the valve is checked for general damage and valve stem thread integrity. Finally great care is taken to ensure that both the cylinder and the cylinder valve have matching threads. When a visual inspection is completed and the cylinder meets the criteria, a sticker is applied to the cylinder indicating the test or next test date. To complete the job, the cylinder valve is torqued into the cylinder; the cylinder is filled and checked for leaks.

A hydrostatic test involves pressurising the cylinder to its test pressure (often 5/3 of the working pressure) and measuring its volume before and after the test. Although there are variations in the process, it typically involves filling the cylinder with water, placing it in a water-filled pressure chamber, and measuring the expansion of the cylinder as pressure is applied. A permanent increase in volume above the tolerated level means the cylinder fails the test due to metal fatigue and is permanently removed from service. A hydrostatic test is always accompanied by a visual inspection.

Having explained the visual inspection versus the hydrostatic test, it should be clear that both have their own purpose and that the majority of the defects that could be identified during a visual inspection will not be a reason for a cylinder to fail a hydrostatic test. If there is significant 'damage' to your cylinder most likely your cylinder will fail its visual inspection not its hydrostatic test. I hope you appreciate now the fact that visual inspections are crucial in cylinder safety. Scuba cylinders are in a way more often exposed to extreme conditions. Therefore I believe it is justifiable to have them inspected more frequently. Some of these exposures may make a cylinder unsafe long before it is due for its next hydrostatic test.

Some cylinder care and safety tips:

- Only fill your cylinders with air from a reputable source. Compressors pumping wet air will cause humid air to enter your cylinder. Over time and depending of the 'quantity' of water this will inevitably lead to internal corrosion and degradation of your cylinder. The wet air produced by the compressor can originate due to lack of filter maintenance (insufficient or improper filter changes), improper setting of or a faulty pressure maintaining valve. When quarterly air analyses are not performed it is as good as impossible to know if the compressor is pumping quality air or not. So if water is found into the cylinder, the compressor should be one of the prime suspects, especially if a batch of cylinders shows the same symptoms and/or are filled from the same air source. Sadly enough, we have witnessed brand new cylinders failing its first visual inspection due to internal corrosion courtesy of a faulty compressor. Don't let this happen to you.
- Rinse your cylinders with fresh water after use in order to remove salt, sand and dirt. Pay particular attention to the boot, backpack and cylinder bands... if fitted. This routine procedure will extend the life of your cylinder and significantly reduce the occurrence of corrosion.
- Store your cylinders upright: in the event moisture or water has penetrated the cylinder, the surface area exposed to potential corrosion will be less.
- Transport your filled cylinders upright and secured; if upright transport is impossible transport them horizontally with the valve facing the side of the vehicle.
- If your cylinders are not to be used for a while, either store them fully charged or with a couple of bars of air inside them and remove the accessories.
- Remove accessories once a month in order to thoroughly wash and dry both the cylinder and the accessories.

- Handle cylinders with care: don't drag, drop or roughly handle them. Although most scuba cylinders are made out of aluminium or steel, they are not indestructible, neither is the cylinder valve.
- If you suspect that your cylinders are internally contaminated with water, have them visually inspected and cleaned. Apart from compressor issues water also can find its way into the cylinder for instance due to improper filling techniques (for example the use of water baths for cooling the cylinder during the fill).
- Do not fill cylinders above their working pressure.

Next time you're out diving, maybe it's worth having a look at the cylinder markings, the last or current hydro test date and the presence of a visual inspection sticker. Your safety is important. Happy safe diving.

This article does not favour any brands nor claims performance comparisons between brands or condemns brands, it are merely some thoughts.



