IMPORTANT NOTICE

Please read this document before using the product as new features will require you to modify your operational techniques.

Prevention of Oxygen Fires

Study of past incidents:

The introduction of the Inspiration rebreathers in 1997 marked the start of a proliferation of the use of pure oxygen by divers.

All Nitrox trained divers know that operating equipment with pure oxygen requires special care, cleanliness, lubrication and replacement regimes but over time it has become clear that protocols for handling oxygen have to be reviewed and improved.

Oxygen fires are thankfully quite rare, but when they do occur, they can result in serious damage to people and possessions and every effort has to be made to avoid them.

From our research into oxygen fires, six important facts jump out:

1) Oxygen fires always occur when the valve is opened.
2) The diver's perception of what is slow opening is WRONG.
3) Rented or borrowed cylinders can represent a greater risk than the diver using his original cylinders.
4) 50% of oxygen fires start in the HP hose.
5) 50% of fires start in the 1st stage.
6) The oxygen HP hose always burns in an O_2 fire and is falsely seen as the culprit.

Type Testing:

To test oxygen compatibility of AP components and valves, testing is done by pressurising products within 20 milliseconds, with oxygen maintained at 70°C and at a pressure between 290 and 380 bar, multiple times. This exceeds the test requirements in the European standards.
This is far faster, at a higher pressure and at a higher temperature than divers do, so it is clear than when the product is new oxygen fires should not occur.

To ensure the assembly process is oxygen clean, all AP oxygen products are assembled in a dedicated positive pressure clean room using controlled systems.
This dedication ensures that new products are oxygen clean and ready for use to 232 bar.

Bearing in mind points (1) and (2) above, divers get away with fast pressurisation while there is no contamination present. The problem is, as the rebreathers get older there is more chance of contamination from liquids, solids and gases and greater care needs to be taken.
If you have a dedicated oxygen clean system, ensure you only ever use it with oxygen. Other gases bring added risk of contamination.

HP Hoses:

In our analysis there was one exception to the 50/50 occurrence when the fire didn't start in either the 1st stage or the HP hose; instead a HP hose bursting was the start of the problem. As the oxygen leaked out, the ignition was believed to be caused by "friction heat" caused by the oxygen flowing at great speed over metal components.

Burst hoses are very rare: AP Diving hoses (HP & MP) are extremely resistant to deterioration; the same hose and hose supplier has been used since the 1980s, so they are a known entity. AP HP hoses do not burst unless there is a fault in the crimping or the crimped component, or the hose has suffered external damage – they are

type tested to 20,000 psi (1,380 bar) and with that inherent resilience it is clear that using a HP hose at 250-300 bar, the hose is not going to burst without some other influencing factor.

It is possible to differentiate between a hose burst due to a fault or damage, and a hose burst due to a massive internal over-pressure during the examination after a fire, if a hose crimp is splayed open, it is clear that it has been subjected to an internal pressure way in excess of 1380 bar, which is only possible with a massive over-expansion of gas, i.e. an "explosion", occurring inside the hose.

AP Restricted HP Hoses

With half of the fires studied occurring inside the HP hoses, the decision was made to slow the HP hose pressurisation further. All HP hoses in diving have or should have restrictors. These are usually a simple small hole in the 7/16 UNF fitting that screws into the first stage.

The latest HP hoses from AP now incorporate a *super-restrictor*, a micro hole, drilled under a microscope, introducing a fluid dynamic condition known as *choked flow*. Typically, the maximum pressurisation rate that can now be achieved is 5-8 seconds by opening the cylinder valve as fast as possible which greatly helps to reduce the heat generated. However, this is *still way too fast* and the operator, you, need to modify the opening technique to slow down the pressurisation.

In point (5) above, half the fires start in the 1st stage, so this restrictor will not help prevent fires from starting in the 1st stage.

Oxygen fires in the 1st stage

When an AP 1st stage is new, oxygen fires do not occur. Fires start in the first stage due to contamination, which can be in the form of micro-solids in gases, solids or liquids. There is a fine sintered filter at the gas inlet of all the 1st stages to prevent large solids entering the 1st stage. The problem is that the 1st stage filter then collects any contaminants with the increasing risk of a fire starting in the filter, which is why the filter needs to be changed during the service. Every care must be taken to not allow dirt and liquid in through the 1st stage inlet.

Opening Cylinder Valves:

If a system is pressurised quickly the sudden gas compression results in high heat generation and if there is contamination present an ignition can occur.

Advising divers to "open valves slowly" has been the industry standard advice for generations of divers, but it is not 100% accurate advice. **What we mean is, "pressurise the system slowly", so it is very important to open a valve slightly and then wait,** allowing the pressure in the first stage and hoses to build slowly. **Allowing 1 to 2 minutes to reach full pressurisation, will greatly reduce the risk of a fire**, even if there is a degree of contamination present. Once it is up to full pressure, you can open the valve as fast as you like. If you think 1-2 mins is slow, remember the industrial standard is a pressurisation rate of just 10 bar/min!

With the experience of 40 years of manufacturing cylinder valves, it has always been obvious that divers over-tighten and mis-treat cylinder valves. Over-tightening a valve affects the sealing face, so the next time you need to close it you need to use a little more force than last time and it gets progressively worse. To help with this the AP cylinder knobs are shaped to provide a poor grip when closing the valve and a good grip when opening. Another issue is: some valve inserts are manufactured in brass and have plastic inserts in them to provide the open/close seal, with this design if water is allowed into the valve, the metal inserts start to corrode, and they often become very stiff to operate, which provides a solid contaminant and in turn makes it very difficult for the operator to open the cylinder valve slowly – adding to the risk of an oxygen fire. To prevent this AP cylinder valves are manufactured using a polymer threaded insert, so smooth finger-tip operation is ensured. Smooth cylinder valve operation is essential, particularly with oxygen, and any valves that you find are stiff to open should be set aside and serviced before further use – and that applies to all

valves: if a dive centre gives you a cylinder with a “difficult to operate” valve, the cylinder should not be used and returned to the dive centre.

AP Progressive-Opening Oxygen Cylinder Valves

Despite the above design features, it has become clear that we will never educate all divers to open the valves slowly or close them lightly, so the oxygen cylinder valve is now fitted with a new “needle valve” for the initial opening, which means for the first half turn, it appears that nothing is happening. Continue to open the valve just a fraction of a turn at a time until the HP gauge’s needle just starts to move, then stop and wait until it reaches full pressurisation, closing the valve slightly if the pressurisation rate is too fast.

Clearly, the advice regarding the opening of a rebreather cylinder just half a turn is now redundant information, the valve **must** be opened further.

The progressive opening also gives you progressive closing so in the event of a solenoid jamming open or the solenoid not securely connected to the lid fitting, you will be able to control the inflow of oxygen more easily. (We haven’t had many of those reported).

It would be sensible to advise anyone using your cylinder (such as a gas-station technician or another diver) that you have this progressive opening valve.

In Conclusion:

This combination of the new Restricted HP Hose and the Progressive-Opening Oxygen Cylinder Valve is without doubt a significant *safety-first* design improvement and a step-forward in helping to prevent oxygen fires. However, we also need to stress, the central importance of good diver practice in terms of care in handling, oxygen-cleanliness, i.e. no silicone grease or oils and above all, for the diver to adopt a different mind-set when pressurising oxygen systems.

ALWAYS PRESSURISE HP OXYGEN SYSTEMS EXTREMELY SLOWLY - TAKING BETWEEN 1-2 MINUTES TO REACH FULL PRESSURE using the method described above.