OXYGEN FIRE IN A HOME MADE ADAPTOR

Des Walters

The following is recounted in the interests of diver safety and in the hope that others will be able to avoid errors associated with the careless use of oxygen apparatus.

A training exercise was being conducted by the New South Wales Volunteer Rescue Association involving 20 divers in a series of exercises over two days. Activities included simulated body recovery and responses to simulated diver emergencies. In keeping with current safety procedures a "D" size oxygen cylinder was available for use and was utilised in the training programme without incident on the first day when a commercially available Bendeez adaptor and a diving regulator were used to administer oxygen.

The cylinder's use on the second day produced a more dramatic effect. The Bendeez adaptor was not available so a home-made adaptor comprising a K valve with a standard CIG oxygen bullnose coupling attached was employed with the same regulator that had been used the previous day. When the cylinder and valve taps were turned on sparks erupted from the water sensing holes in the first stage. They started like a sparkler on bonfire night and got progressively stronger like a Mount Vesuvius fire cracker as the oxygen carved out the parent metal. I kicked the cylinder away and a small explosion occurred. The fire abated and the cylinder valve was turned off.

Within seconds the noise and fire had stopped and all I had to show for it was an accelerated heart beat, a case of "sunburn" on arms and face, and a T-shirt full of holes from the sparks.

The regulator was destroyed. The fire had been so hot that the brass surface of the valve was burned away where the regulator mated with it. The 1st stage filter and the "O" ring were consumed, as the fire had jetted into the regulator. The Delrim piston was melted, as was most of the teflon HP seat. The flame created a 5 mm diameter hole in the body of the 1st stage. The stainless steel stem of the piston was either ejected from this hole or consumed. The neoprene and fabric in the pressure gauge hose was burnt, and the hose was filled with soot. The hose leading to the 2nd stage was intact, but filled with soot. The downstream valves had been forced open and the 2nd stage mouthpiece was stained with soot. I have no doubt that if the regulator had been in a diver's mouth the result might have been fatal.

I was understandably alarmed by this potentially lethal accident and was keen to ascertain the cause. I made preliminary enquiries of Jim Agar (of Airdive), Dow Corning (who had supplied the lubricant in the regulator), CIG, CSIRO and Bob Sands (of Bendeez). The latter was contacted because of the research he had done in developing the Bendeez adaptor and his many industrial and technical contacts.

DISCUSSION

In considering why this fire occurred when using a home-made adaptor but not while using the commercially produced Bendeez adaptor the following points are important.

The regulator had just been serviced by the manufacturer, the octopus and tactile gauges were brand new, and the unit had not been used prior to the weekend. The fact that it was used the previous day indicates that it was unlikely to be the cause. It is doubtful whether any regulator, even one dedicated to oxygen, would have withstood this firey onslaught.

The lubricant used in the regulator was a Dow Corning Compound 7 or 14, which is widely used for regulator service. Dow Corning is adamant that this compound is unsuitable for use with high pressure oxygen or high pressure air! Cheaper lubricants are considered to be even more dangerous (eg. vaseline, petroleum jelly).

The adaptor valve was the difference between trouble free use on the first day and the potentially disastrous situation on the second day, and possibly the key to the problem.

The requirements for combustion are known to all who have done basic science. They are oxygen, heat and fuel. Oxygen was available in abundance. Heat could have been produced in two ways within the system used, either by a rapid pressure increase or by turbulent gas flow.

Oxygen delivery using the home-made adaptor required the turning on of <u>two</u> taps, one on the oxygen cylinder and one in the K valve. I turned on the oxygen cylinder first, <u>then</u> the K valve. This would produce a sudden pressure increase within the K valve and it is possible that sufficient heat was generated to cause a fire, which jetted into the regulator when the K valve was opened. That the source of the fire seems to have been the K valve seat supports this theory.

Heat can be produced by turbulent gas flow. Here the home made adaptor may be at fault when compared with the Bendeez adaptor which has been designed to reduce turbulent flow to a minimum. But heat produced by turbulent flow does not explain why the home-made adaptor had been used many times without any problems up to the incident described here.

The final requirement for combustion is fuel, and here the picture is not so clear. <u>Something</u> had to be fuel for the fire and my suspicion is that it was the silicone lubricant. All authorities contacted were quick to point out the unsuitability of the commonly used lubricants for high pressure oxygen, and that a regulator prepared for <u>air</u> is not suitable for oxygen. But this does not explain the many thousands of times the Bendeez adaptor has been used without any problems whatsoever! In fact on the recent "Pandora" expedition the Bendeez adaptor was used 647 times without incident.

So the explanation of the occurrence seems to be a combination of factors not present when using the Bendeez but occurring when the homemade adaptor was used.

First testing has now been completed by Bendeez engineers and by the CIG laboratory. While it is difficult after the fact to find the cause, both agree the fire started in the

adaptor and CIG believe the cause to be a contaminant. The view is supported by the fact that the fire abated when the fuel was consumed. When the oxygen cylinder was checked after the fire it still had over 1000 psi in it. However, the contamination theory does not explain how the adaptor had been used without incident previously. Was it a contaminant or was it the silicone? We may never know, however clear guidelines for the use of high pressure oxygen emerge.

GUIDELINES FOR THE SAFE USE OF OXYGEN

1. Never use oxygen near heat or flame, which includes people smoking.

2. Only use lubricants recommended as suitable for use with oxygen. This may not be as easy as it is to write, as Dow Corning say that they do not have a lubricant suitable for oxygen or high pressure air.

3. Turn oxygen cylinders on slowly. This reduces the heat caused by sudden compression of the gas inside whatever is attached to the oxygen cylinder.

4. Home-made adaptors should not be used.

5. Regulators used with oxygen should be scrupulously clean, and should be sealed until required for use as any contaminant, oil or grease, can be a source of fire. Remember that even using a prepared or new regulator on an ordinary scuba cylinder could contaminate the regulator with oil residue from a dirty compressor. Experts recommend that oxygen regulators be unlubricated and fitted with special "O" rings (as neoprene burns at a relatively low temperature). Consider using a regulator that has been designed specifically for oxygen use, eg. the Airdive Dedicated Oxygen Regulator or a CIG Oxygen Mini-Reg with flow meter, mask and reservoir bag to deliver 100% oxygen.

6. All divers should be trained to use oxygen and oxygen equipment as this is possibly the single most important life saving measure for all diving accidents. Remember, oxygen only becomes dangerous when mishandled. Perhaps this training should become mandatory as part of all basic diver training?

I will conclude by thanking all those who have assisted this investigation, in particular Bob Sands whose Bendeez was NOT responsible for the incident.

COMMENT

I congratulate Des Walters on his excellent paper.

This frightening demonstration of the fury of combustion in a pure oxygen atmosphere should not blind readers to the real value of post-dive oxygen (100%) in the management (and prevention, as on the Pandora expedition) of diving casualties.

Like the author, I have often used a made up adaptor similar to the one mentioned above. However I have ALWAYS had the adaptor tap fully open before turning on the oxygen cylinder.

This procedure means that instead of a ml or less of gas being rapidly compressed, as happened in the above incident, a much larger volume is compressed slightly more slowly so generating less heat, and as it is being compressed some gas is escaping into the low pressure side of the regulator so removing heat.

I think that Des Walter's guideline 5 could jeopardise the ready availability of oxygen for diving casualties. Murphy's Law suggests that when the equipment was needed either the oxygen or the dedicated regulator would not be available! Using a CIG Oxygen Mini-Reg with flow meter, mask and reservoir bag cannot be guaranteed to deliver 100% oxygen unless positioned by an anaesthetist or someone with a similar training in getting an airtight seal with a mask. Very few divers have had this training, and beards make the seal almost impossible to obtain.

For these reasons I prefer to continue to take a D size oxygen cylinder with a Bendeez adaptor already screwed into the outlet with me when going diving, and attaching any available regulator if the need arises. I believe the risk of a fire is low enough to be acceptable.

John Knight
Melbourne

Ed. This paper appears to have been submitted to more than one journal. It is printed here because of its interest and importance.

AIRLIFT SERIOUSLY INJURES DIVER'S ARM

JC Fine

Pirates, sharks and legendary curses are the least of a treasure diver's perils. The real danger of serious injury comes from the use of machinery and equipment on board ship and in the water.

While many stories about successful amateur and professional underwater treasure hunting ventures abound in popular dive magazines, there are far more unsuccessful ventures where one of the unfortunate divers is the victim of an accident.

It stands to reason that working with and around machinery that is designed to employ force on the surface or underwater requires special training and precautions. All too frequently, sport divers set about fabricating or buying treasure digging equipment without ever having professional training in its use.

Underwater demolition and blasting devices, hydraulic tools, welding and cutting equipment, airlifts, lift bags, water jets are all tools used in underwater treasure hunting work. All are potentially dangerous to a diver.

Recently a freak accident seriously injured a professional salvage diver. The piece of equipment he was using is often considered relatively harmless by most treasure