This cylinder may contain Air, Nitrox, Heliox, Trimix or Helium

VOODOO GAS

If you don't know what gas is in the cylinder don't breath it -
Or prepare to meet the dark lord

Nitrox 2.0?

Text: Frank Lemke, pictures Krinner Drucklufttechnik GmbH

There is one aspect of diving that has always been particularly fascinating. No matter how far out one pushes their education or in which area of diving one is interested (engineering, biology, medicine, history, equipment, etc.), the new developments, findings and discoveries in the field of safety are always pleasantly surprising, and they offer new approaches, along with newly awoken interest, to deal with the subject at hand.

Of course, since the introduction of the first partially reliable equipment, there have been numerous oddities and flops. But this is what characterises our sport: with the exception of space exploration, there is essentially no other human activity with as much trial and error as diving (just think about the development of the decompression tables…).

It's that much more important to never assume there is nothing left to discover.

Against this backdrop, we would like to use this article to draw attention to a central diving question: "Can breathing gas for diving be made even better?"

All-purpose Agent: Oxygen

Basic knowledge learned in divers' training: oxygen is good for divers, nitrogen not so much. So what can you do to dive more healthily? Correct answer: add more oxygen to breathing gas to reduce the nitrogen content. Et voilà: we dive with 'Nitrox'.
As it relates to pressure-related application limits of this gas mixture, we won't delve much further here. Let's focus rather on the fact that Nitrox has become a de facto standard in recreational diving since its introduction, as it allows healthier, safer dives and longer dive times. The wide acceptance even goes so far that some divers now describe good old compressed air as 'Diesel'.

But how does this miracle substance make its way into divers' tanks?
Notwithstanding the fact that the existing standard for us divers is the use of Nitrox mixtures with up to 40% oxygen content which is difficult to make "artificially" ("…all breathing gas mixtures containing more than 21% oxygen are treated as pure oxygen"), there are basically three methods for producing a nitro-mixture:

1. The easiest answer: we buy ready-made mixtures from trusted breathing gas distributors ('Pre-mix'). "I don't get it – each different mixture has its own storage tank? How much does that cost?"

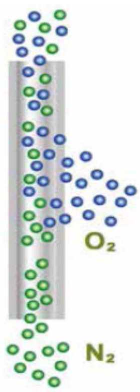
2. Exactly. The simplest solution is not always the most practical. We mix it ourselves. Whether in a partially compressed or a constant flow mixing system, this method is the most widely used at diving clubs, by private individuals and in many dive centres throughout Europe. Oxygen is either filled into a suitable diving tank and then 'diluted' to the desired nitrox mixture using compressed air, or oxygen (up to a proportion of 40%) is mixed directly with the intake air of a compressor in a mixing system so that the finished Nitrox gas is pumped directly into the tank.

3. We create Nitrox using a so-called 'membrane system'. This method is the first choice of dive centres with large numbers of scuba divers and in regions with limited gas production facilities. With this method, oxygen contained in the ambient air is craftily separated out and enriched at the molecular level. Scuba divers in particular benefit from this method, because the nitrox-mixture can be produced with an oxygen content of up to 40% with this technology – meaning for techies, no decompression gases.
It is this third method that we'd like to examine more closely.

**Creating Nitrox with a Membrane System –
"How does it work?"**

For the economical operation of a membrane system, what is first needed is a certain minimum operating pressure which is usually the region of 10 bar. For this purpose, a so-called 'screw compressor' is used, in which the intake air is compressed by interlocking screw elements.
The advantage: this compressor type has no valves or pistons and thus has a compact design, high flow rate, and is suitable for continuous operation.

The downside: the compression only works at low pressures. Luckily a membrane system doesn't need high pressure.



In the second step, the compressed air is dried, cleaned and filtered so that only highly purified air is used during the membrane separation process.

Using a so-called 'hollow fibre membrane', the oxygen and nitrogen are separated, since oxygen, due to its comparatively high degree of diffusion, travels faster through the membrane than the nitrogen which, thanks to its larger size, passes rather slowly through the membrane.

How much oxygen is concentrated during this process depends on the flow velocity, which is why a valve is present on the nitrogen side of the membrane, with which the air flow can be controlled. The physical condition of the membrane is also important as it becomes 'clogged' over time, meaning that the oxygen concentration decreases after a long time in service. Those who have ever wondered why they've only been able to achieve Nitrox 28 at a dive centre on holiday may now understand why – it may be because of the state of the membrane or poor preparation of the compressed air.
Therefore:

KrinnAir NITROX membrane systems offer only highly efficient compressed air preparation for the membrane separation process.

The oxygen-enriched air is then passed to a high pressure compressor and is compressed to 200 bar. The excess nitrogen is released into the environment.

So far so good, but…
Unfortunately, there's a catch to this method of Nitrox creation and it's called 'CO_2'.

Some of you are certainly wondering:
"Wait a second… the air we breathe contains 21% oxygen, 78% nitrogen and 1% 'other'. How did we get to CO_2?"
At first that seems right, but...

Yes, the air we breathe doesn't only contain noble gases in that 'other' category, it also contains ca. 0.03% CO_2. (This value, according to recent measurements from the US Weather Authority in July 2015, has already climbed to a worldwide average of 0.04%. Keyword: 'Fossil Fuels' …)

So what does this mean in practice?
Here is a brief overview, in which the values aren't listed as percentages, but rather as parts per million (ppm). 1 ppm corresponds to 1 ml per cubic metre:
(see table)…

Area	CO2-concentration
Our ambient air (currently):	0,04 % = 400 ppm
City air:	700 ppm
Level at which people begin to notice discomfort (Pettenkofer Study):	1000 ppm
Limit for residential areas in Germany:	1500 ppm
Unventilated bedroom or full classroom (also the limit for workplaces):	5000 ppm
Increased heart rate, shortness of breath:	from app. 5.000 ppm
Our exhaled breath:	app. 50.000 ppm
Symptoms of paralysis:	90.000 ppm
A candle being extinguished:	100.000 ppm
Death from short-term inhalation:	200.000 ppm

CO_2-Levels while Diving

In this country, the quality of breathing air is regulated for diving by the DIN standard EN 12021. This defines the allowable limits for water content, oil content, carbon dioxide and carbon monoxide.

For CO_2, the permissible limit is currently set at 500 ppm. That's where it gets tricky. Remember: the global CO_2 average is currently at 400 ppm. So if we use a conventional compressor and the partial pressure method, we are (on average) just below the limit. If our compressor were to be in an urban area, it would seem that due to the higher CO_2 concentration in the ambient air we would be in a different situation.

Unfortunately, oxygen and carbon dioxide molecules have a very similar size. Maybe you'll ask again with some surprise:

"Wait a minute, are you saying that a nitrox membrane system enriches more than just oxygen…?"

Bingo! This is unfortunately what happens with a 'normal' membrane system, and under certain circumstances up to three times!

A theoretical example: a membrane system is located in a densely populated urban area with a CO_2 concentration at 700 ppm. This means the concentration of CO_2 in the scuba tank could be over 2,000 ppm, more than four times the permitted limit!

When you consider the fuss (rightly so!) that is made about moisture and carbon monoxide in scuba tanks, why do you hear very little about CO_2?

Now, for the sake of fairness of course, it must be mentioned that any decent compressor, and also modern membrane systems, is equipped with sophisticated filter cartridges in which CO_2 binds to desiccants and is thus removed. Therefore, the above sample calculation shows a value that is not reached in practice.

Really? Clearly, any sensible compressor operator regularly conducts measurements with suitable equipment to check breathing gas quality. But what about those in the commercial sector, abroad, or under financial pressure due to high operating costs? The author is aware of cases where dive center operators felt embarrassed at the sight of home-bought air test supplies and asked if one could move the test to the next day for measurement… Filter life spans, as noted by manufacturers, are sometimes treated as just 'well-intentioned advice'. In addition: the manufacturer-specified life of filter cartridges for compressors is based on averages. Has the global rise in CO_2 concentration been accounted for?

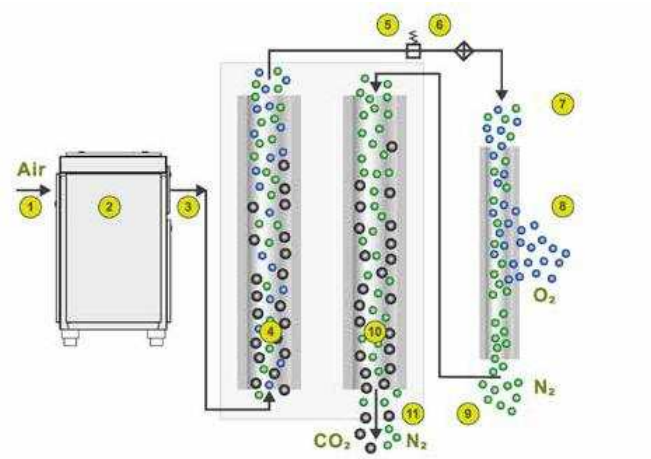
Control question: Who has ever investigated the following question: "How long before the CO2 filtering effect of a filter cartridge in a compressor begins to decrease?"

And anyway – would it not be great if you could eliminate the entire amount of CO_2 in the air completely, instead of relying on the compressor's filter cartridges?

station by krinnair
NITROX
www.nitrox-kompressor.com

WETNOTES became very aware of the solution to this situation at ‘boot 2015’.
The company Krinner Drucklufttechnik from Hohenbrunn has developed that solution: the “CO_2-separator” for Nitrox production. This is a module that reduces the amount of CO_2 significantly right after the compressed air preparation at low pressure (10 bar) and before the introduction of that prepared air into the membrane. The system can be used with intake air containing a CO_2 concentration of up to 2,000 ppm, and it can significantly reduce that amount to below 500 ppm. In a brief presentation at ‘boot’, the CO_2 level was even lowered to a staggering 18 ppm! The operation is as simple as it is genius:

The prepared air, which is first compressed in the screw compressor (1 and 2), is dried and filtered, so that oil residue and other impurities are removed (3).



So far nothing new. Now the CO_2 is absorbed using desiccants in one of two Cartridges (4), with the desiccants in the cartridges having a defined life span.

The cleaned air is then decompressed and heated (5 and 6).

Then the oxygen is separated in the membrane and fed into the high-pressure compressor (7 and 8).

Using the excess nitrogen (9), however, one of the two desiccant cartridges is ‘flushed’, meaning that the CO_2 is transported from the system (10 and 11) along with the expanded and heated nitrogen. After this regeneration, the desiccant is once again ready to bind the CO_2. It is a, so to speak, automatic, alternating cleaning the CO_2 filter without additives and energy expenditure. Only the built-in particle filter has to be changed after 500 hours.

Apparently, August Krinner, the owner of the company, really hit the bull’s-eye with this solution, as word of the effectiveness of his invention has spread not only to many dive centres around the world, but also throughout military circles. A number of these systems have already been ordered and are currently under construction; one was recently put into operation at a dive centre in Hyères France. The Royal Danish Navy Diving School in Copenhagen switched over to “CO_2-free” NITROX from KrinnAir since June 2015.

In our view, this is an excellent example of how the period of innovations for diving is far from over. The market will dictate the commercial success of this invention – and in terms of healthy diving, we wish August Krinner and his team the best of luck!

Technical Data:	
Electrical Supply Voltage / Hz	230 V / 50
Installed Capacity kW	1,2
Power Consumption kW	0,1 - 0,5
Sound Pressure Level dB(A)	68
Input Limits:	
Flow Rate max. litre/min	2500
NITROX Flow Rate max.litre/min	600
NITROX %	28 - 40
Positive OperatingPressure bar	7,0 – 10,0
Compressed Air Quality to ISO 8573-1	1.4.1.
Ambient Temperature ℃	+5 bis +40
CO2 Input max. < 2000 ppm	
CO2 Output max. < 500 ppm	
Dimensions:	
Depth/Width/Height	800 / 650 / 1450 mm
Weight	netto 170 kg
Compressed Air Input	Ermeto 18L
Compressed Air Output	Ermeto 18L
Nitrogen Input	Ermeto 18L
Nitrogen Output	Ermeto 18L
Control Air	8 mm

Krinner Drucklufttechnik GmbH was founded in 1995 as a technology company with a focus on compressors for industry and trade in Hohenbrunn near Munich.

Through the experience of August Krinner, the company's founder and Managing Director, medium-sized companies to large international corporations can be counted as customers of the company.

Krinner Drucklufttechnik GmbH plans and creates individual solutions tailored to customer needs and develops them for customers.
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