

Nitrox Production Methods

PROCEDURES AND SAFETY MATTER

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ENRICHED AIR, OR NITROX, HAS BECOME A TRUSTED WAY

for many recreational divers to extend no-decompression limits and reduce fatigue. By increasing the oxygen content and reducing nitrogen absorption, divers enjoy longer, more comfortable bottom times.

Producing nitrox starts with altering the composition of breathing gas by adding oxygen to or removing nitrogen from ambient air. Industrial gas plants rely on large-scale processes such as cryogenic liquid distillation or gas pressure swing adsorption, but dive operations typically use one of three more practical methods: membrane separation systems, partial pressure blending, or continuous blending. Each method has distinct characteristics, advantages, and safety considerations that influence how dive shops operate.

High-volume recreational operations often choose membrane systems because they provide a steady, reliable stream of enriched air. In this approach, ambient air is pulled through a semipermeable membrane that selectively removes some nitrogen. The resulting nitrox is then compressed using a high-pressure compressor rated for nitrox up to 40% oxygen.

One of the biggest attractions of membrane systems is their ability to produce consistent blends that can be banked for later use. Since these systems typically cannot exceed about 40% oxygen, they reduce some of the more significant hazards associated with handling highly concentrated oxygen. Maintenance tends to be manageable, consisting mainly of regular filter changes and routine compressor care.

The initial cost of a membrane system can be substantial, and shops needing oxygen-rich mixes for technical diving will require a supplemental blending method.

Partial pressure blending sits at the opposite end of the flexibility spectrum. Rather than generating a single stream of enriched air for storage, this technique allows



Gas blending requires care in managing high-pressure oxygen.

operators to create a custom mix inside each individual cylinder. A carefully calculated amount of pure oxygen is added first and then topped off with compressed oxygen compatible air (OCA) having condensable hydrocarbons less than 0.1 mg/m³ (ideally none). This method works for everything from standard recreational blends to technical diving mixes up to 100% oxygen.

The tradeoff for this versatility is the level of precision and care required. Because the process involves injecting pure oxygen directly into a cylinder, every component in the fill chain must be compatible with oxygen and kept rigorously oxygen-clean. The work is also more labor-intensive, requiring gas blenders to calculate each fill and remain attentive throughout the process.

Partial pressure blending is safe and highly adaptable when performed correctly. When done carelessly, it presents serious fire risks. One distinct advantage is that this method does not require a compressor to fill the cylinder.

Continuous blending, often referred to as the blending stick method, offers a middle ground. A device at the compressor intake continuously mixes pure oxygen with air before it enters the compressor intake. This allows operators to generate nitrox blends up to 40% without individually calculating each cylinder. It is an efficient and economical option for shops supplying large volumes of enriched air.

Continuous blending provides a safer, more controlled environment than partial pressure blending because the oxygen is diluted prior to compression, but it still requires constant monitoring to avoid oxygen concentrations above the intended level. It also requires a compressor suitable for use with enriched air up to 40% oxygen.

If gas exceeding 40% oxygen reaches the compressor, the risk of mechanical damage or a dangerous diesel-effect ignition increases dramatically. Although often perceived as low risk, continuous blending still involves pure oxygen handling and therefore requires proper equipment cleaning and clearly defined procedures.

Regardless of which method a shop chooses, operators must address the critical question of oxygen cleaning. A long-held misconception in the dive community is the so-called 40% rule, suggesting that equipment only needs oxygen cleaning when exposed to mixtures with more than 40% oxygen. This myth likely stems from misinterpretations of Occupational Safety and Health Administration (OSHA) guidelines that apply to low-pressure, surface-supplied systems — not to high-pressure scuba cylinders.

In the U.S., any gas mixture containing more than 23.5% oxygen is legally classified as an oxidizer under Department of Transportation hazardous materials regulations. Major cylinder manufacturers and standards set by the Compressed Gas Association, ASTM International, and the U.S. Navy reinforce similar thresholds, typically around 23.5% to 25% oxygen.

Even modest nitrox mixes behave very differently under pressure. Cotton burns twice as fast at ambient pressure in 40% nitrox as it does in 25% oxygen, and once compressed to 3,000 psi, burn rates rise exponentially. The result is clear: Any component exposed to nitrox mixtures containing more than 25% oxygen during normal operation

must be compatible with oxygen and oxygen-clean, regardless of the blending method used.

Because partial pressure blending introduces pure oxygen into the cylinder, oxygen cleaning is always required. Continuous blending and membrane systems introduce oxygen at low pressure, which leads some operators to incorrectly assume the 40% rule applies. But the enriched air produced by these systems is still compressed and stored at high pressure. That means every compressor part, storage bank, whip, and cylinder exposed to more than 25% oxygen must meet oxygen-clean standards. Cutting corners may not produce immediate consequences, but over time it contributes to a dangerous normalization of deviance.

Safe nitrox production ultimately depends on well-trained fill station operators who follow proper procedures every time. Gas blenders must maintain clean equipment, use OCA for all enriched air fills, and ensure that the gas entering the compressor never exceeds its maximum oxygen concentration rating.

Nitrox cylinders should be properly labeled and maintained with compatible O-rings, lubricants, and components. Safe fill rates must be observed to prevent excessive adiabatic heating, one of the primary causes of oxygen-related ignition.

In an environment where so many cylinders look alike, divers must also take responsibility. Every diver should analyze each cylinder and label it clearly with their name, the mix, the date, and the maximum operating depth.

The advantages of nitrox are well known but come with responsibilities for the dive shop and the diver. Enriched air is an oxidizer no matter how it is produced, and it behaves differently under pressure. Respecting that fact ensures that every nitrox dive begins and ends safely — with the right mix, the right procedures, and the right attention to detail. **AD**



From top: A final analysis by the diver is essential. • A tidy and clean blending station provides a much higher degree of confidence in the assurance of gas quality. • Cylinder color coding is not the same around the world. Oxygen labels can be green, white, or blue. • The only way to know what is in the cylinder is through individual analysis and marking. • Large volumes of nitrox can be produced using pressure swing absorption (PSA) generators.