Hyper-Filtering Dive Air for Nitrox Preparation

Considerable confusion and misunderstanding presently pervades the diving community regarding the mixing of compressed air with pure oxygen to produce Nitrox. Due to the expense of the equipment, relatively few dive shops are making Nitrox by the NOAA Continuous Blending Procedure. Most are using partial-pressure mixing techniques because of the ease and relative economy of these methods. In addition, these shops want to utilize their supply of processed diving air for mixing purposes and thereby avoid the purchase of costly bottled nitrogen and scavenge booster pumps. Assuming this air has been properly prepared, it should be Grade E in quality and therefore contain only 5 mg/m^3 or less hydrocarbon materials. The next step is to further filter (Hyper-Filter) this air to remove the remaining organic contaminants, so that it can be safely mixed with pure O_2.

It is at this point that misunderstanding usually enters the picture. Many persons mistakenly believe that hyper-filtering simply means adding another air filter of the same type which was used to achieve Grade E. For example, it's assumed that merely adding another tower of molecular sieve or activated carbon will do the job. THIS IS COMPLETELY WRONG! Virtually no evidence exists that such procedures will routinely produce hydrocarbon-free air! Hyper-Filter cartridges are quite different from conventional standard models in both construction and chemical quality.

First, let's review what one is trying to achieve ... namely, the production of a modified Grade J air containing no more than 0.1 mg condensed hydrocarbons/m^3. Why? Because this level (or less) is known to be acceptable in air which to be mixed with pure O_2. Is a higher level ever permissible??? Probably, but it's difficult to quantify… GSMoT has consulted experts in NASA, AIRCO, and NOAA, and no one is willing to stipulate any "magic upper level." This is because too many ancillary factors exist in the mixing equation.

Above and beyond air quality itself, the cleanliness of pressure vessels, the presence of other non-compatible materials, the speed of filling, and the configuration of the transfilling apparatus are all factors in the "GO BOOM" scenario. Therefore, a specific level of air cleanliness might be acceptable under the set of conditions "A" and be unsafe with set "B." Until all of the mentioned parameters are researched and standardized, we must assume that virtually no hydrocarbons are tolerable. In many respects, Nitrox preparation in today's dive shop is about where regular air processing techniques were in the early 1960's ... very much in a state of infancy!

Hyper-Filter systems usually consist of two towers: the first contains a super dessicant which also removes both moisture and minute contaminants. The second tower is the main scrubber canister which absorbs any remaining trace hydrocarbons. For the filtration process to work properly, the flow rate and pressure within the Hyper-Filter towers must be closely controlled. When producing Grade E air, these parameters are seldom maintained with great precision; when processing for Grade J, precision is mandatory! In the normal production and storage of diving air, flow of the gas through the filter system is usually just a function of the compressor's rate of output. To consistently obtain Grade J, control of other physical parameters is also required. These additional prerequisites for controlled conditions partially explain why merely compounding Grade E filters cannot guarantee consistent creation of Grade J air. Unless flow rate, internal pressure, and even temperature within the filter system are controlled, one might succeed in getting Grade J during one compressing operation and fail on the next.

Another variation on this theme poses the question, "Just how many Grade E filters must be added to do the job?" Since no two compressor systems are probably totally identical in every physical characteristic, it's not logical to assume that adding a single Grade E filter to any existing system would always result in Grade J air production. Considerable trial, error, and expense could be required to determine the correct answer to the question.

To successfully get Grade J air, a rigorously low dewpoint must be maintained within the system because even small moisture levels can interfere with hydrocarbon removal. In fact, Grade J air has a dewpoint of about -100° F, or about twice as dry as most dive-shop air. Thus, true Hyper-Filters usually contain multi-chambered cartridges wherein the gas passes through an inner tube containing several high grade filtrants which both dry the air and remove trace organics. The gas exits this inner chamber through an outer conduit packed with a high powered dessicant which maintains a very low dewpoint within the entire tower. These super-dry conditions are difficult to achieve and maintain in most Grade E filters.

As a point of interest, most Hyper-Filters are designed to accept only special Hyper-Filter cartridges; normal disposable tubes will NOT mate to the towers. This precaution prevents the installation of incorrect filters and discourages unwise tinkering or experimenting by fly-by-night operators. It is also noteworthy that the gas flow pathway within Hyper-Filters is often dissimilar to that in normal Grade E towers!

Perhaps you have heard of dive shops which have successfully prepared Nitrox using scuba air which has NOT been hyper-filtered. How do they get away with it? The answer is complex but centers around the fact that many competent dive shops are producing air of far better quality than Grade E. Realistically, when your air is analyzed, you don't ask, "What grade air am I producing?" Instead you simply want to know it meets the normal scuba standard, i.e. Grade E. If extremely high grade air is being produced, and all other factors previously mentioned are proper, successful mixing with oxygen may be carried out!

However, there is a real dark side to doing this: As long as the high quality air is maintained (and this requires knowing WHAT purity you have), and all other factors stay the same (speed of filling, equipment configuration, equipment cleanliness, etc.), the mixing procedure may work. However, if one or more of these factors suddenly or unexpectedly changes, the process may fail violently! The Hyper-Filter guarantees that variation in air quality does not occur. It acts as a backup system to prevent a possible disaster if the primary filter system fails or becomes over-taxed.

Without hyper-filtration, no backup system exists for maintaining the extremely high quality air needed for mixing Nitrox safely. The only way to minimize that inherent risk is to verify air purity by very frequent analyses and to maintain scrupulous system cleanliness. Still, this is tantamount to diving deep alone without any backup equipment ... your primary system may be the best available, but if it fails, you're completely out of luck!

Even WITH hyper-filtering, the need to closely monitor the finished air quality is not eliminated. Air analyses must be routinely performed because even the cleanest air still has minute hydrocarbon material in it. Although the concentration may be below the limit of standard detection methods, the contaminants are steadily deposited within the system and, over time, slowly build up. Once they reach detectable limits (or 0.1 mg/m^3), it is time for the system to be dismantled, decontaminated, and renewed.

Occasionally, Hyper-Filters can get fouled up even after proper installation. For one example, operators may install conventional filling whips on the outlet of the system. This is unwise because the synthetic hose commonly sold for filling whips usually has plated steel fittings crimped to the ends. When these fittings are hydraulically pressed onto the hose, oil is used to lubricate the crimping process. Traces of this hydrocarbon can linger on these fittings or within the hose for extended periods and may recontaminate the processed air.

Steel-end fittings are used on air hoses because brass or stainless models are extremely expensive. Unfortunately, steel rusts and can introduce sparking metal particles into the air stream. A particle impingement in a valve or tank containing a high oxygen concentration could be most unfortunate. The bottom line here is that teflon-lined oxygen hose is preferable on the downstream end of the Hyper-Filters. Moreover, such filling whips should be equipped with a judiciously placed check valve to prevent back-flow of gases into the filter system.

Do other things go wrong? You bet! GSMoT has received several eye-witness reports of oxygen fires and hose explosions in Nitrox/oxygen fill stations and booster pumps. While the exact cause of each accident remains unclear, several could be related to incompatible air quality and inadequate maintenance. To date, no large explosions or serious personal injuries have occurred; nevertheless, having oxygen hoses and metal fittings burning like sparklers within your diving shop can be a very exciting and expensive event!

Any fires, explosions, or injuries, occurring as a result of improper specialty gas handling, could prove to be indefensible in a court of law or insurance investigation. The dive shop would have to PROVE to the court or investigator that its handling/mixing procedures were safe. This usually requires documentation on components and maintenance including scientific proof that all methodology was credible or approved by CGA, NOAA, NASA, or some recognized authority. Many dive shops would be hard pressed to come up with such evidence, especially if they were using a do-it-yourself, winged-together system.

In the sport diving community, widespread interest in specialty gas diving is barely five years old; the instructional organizations teaching these subjects are not that old. Relatively few standards have been set and agreed upon by all parties involved. In truth, specialty gas diving is still an infant discipline. The upshot of all this is that any prudent individual who is preparing and selling specialty gas formulations will do the utmost to play it safe. Playing Russian Roulette with unproven or substandard gas processing techniques makes very little sense.