NOAA EXPERIMENTAL DIVING UNIT
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APPLICATIONS of GAS SEPARATION TECHNOLOGY in the PREPARATION of DIVER'S BREATHING GASES and HYPERBARIC ATMOSPHERES

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DIVING PROGRAM

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ABSTRACT

Atmospheric gas concentrators are capable of producing high and low oxygen mixtures for use in diving and other hyperbaric activities. Both pressure swing adsorption and differential permeability concentrators produced usable nitrogen/oxygen (Nitrox) mixtures for diver breathing gas, saturation diving mixtures, and clinical hyperbaric treatment. In conjunction with the "NOAA Continuous Nitrox Mixer" exact mixtures can be produced at delivery pressures in excess of 3000 psi.

INTRODUCTION

The potential applications of atmospheric oxygen and nitrogen separators in the preparation of diver's breathing media were identified in Reference 1. This paper addresses the quantitative use of such devices, including working models of high pressure Nitrox preparation systems.

Two fundamentally different atmospheric gas separators are addressed. The molecular sieve based "pressure swing adsorption" (PSA) system depends on the selective adsorption-desorption of nitrogen on molecular sieve material during pressurization and depressurization with air. The "differential permeability" (DP) system depends on the differential rates of diffusion of gases through the walls of hollow fibers pressurized with air. Both systems utilize low pressure air as a gas source and produce product streams of high oxygen/low nitrogen and low oxygen/high nitrogen gases. Both of these product gases have applications in diving and hyperbaric activities. The high oxygen mixtures are used primarily with the NOAA Continuous Nitrox Mixer[2] to produce divers breathing gas and therapeutic Nitrox mixtures. The low oxygen mixtures can be used to produce Nitrox saturation breathing mixtures.

RESULTS

PSA System

The results of tests run on an AirSep Oxygen Generator, model AS-20, supplied with 100 psi of breathing quality air are shown in Figure 1. Although carbon monoxide is concentrated in the low-O2 product gas, its concentration is within acceptable limits. The "back pressure" shown on the horizontal axis is the pressure of the gas in the high-oxygen storage tank. The low-oxygen product gas is re-

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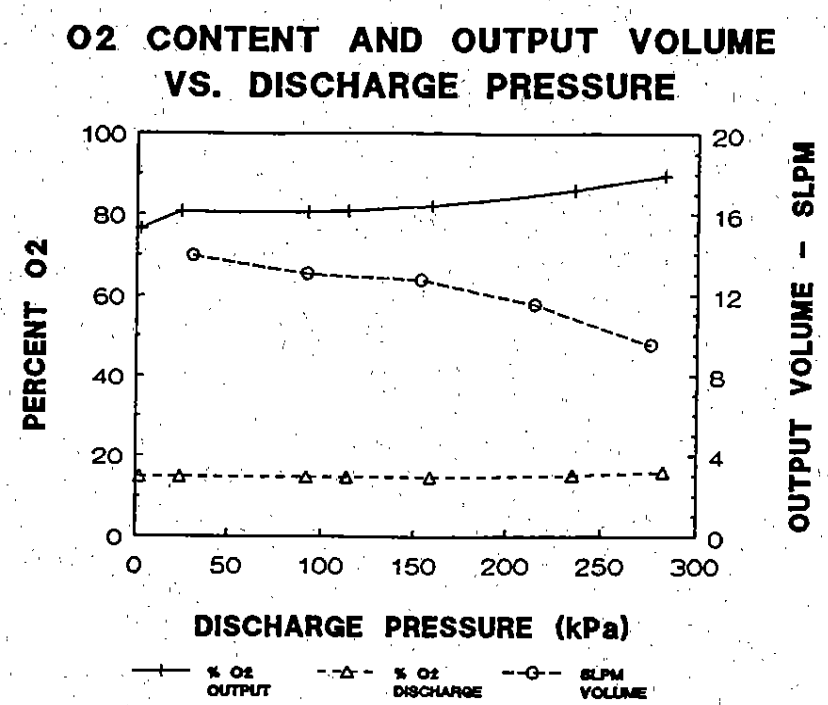

Figure 1

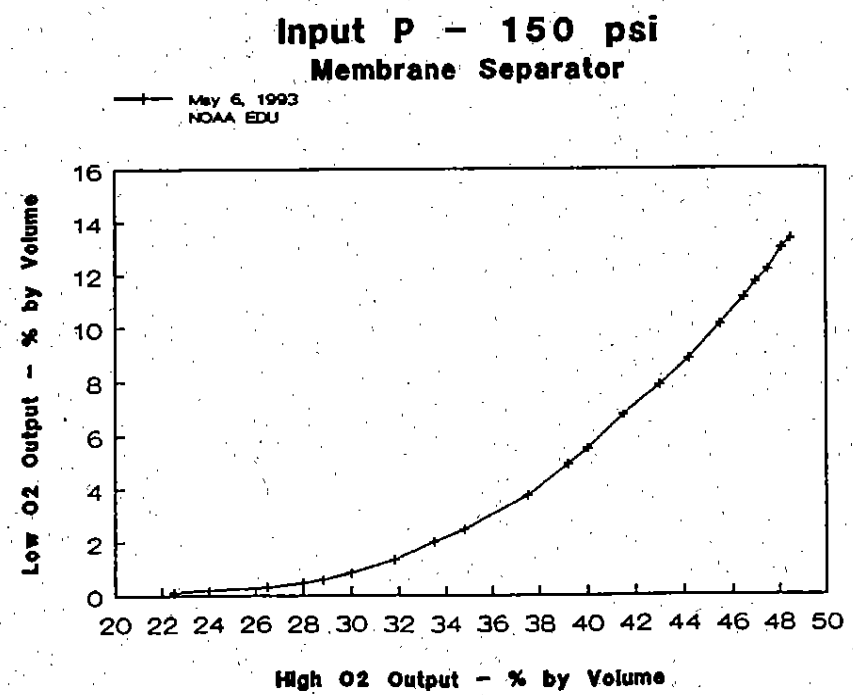

Figure 2

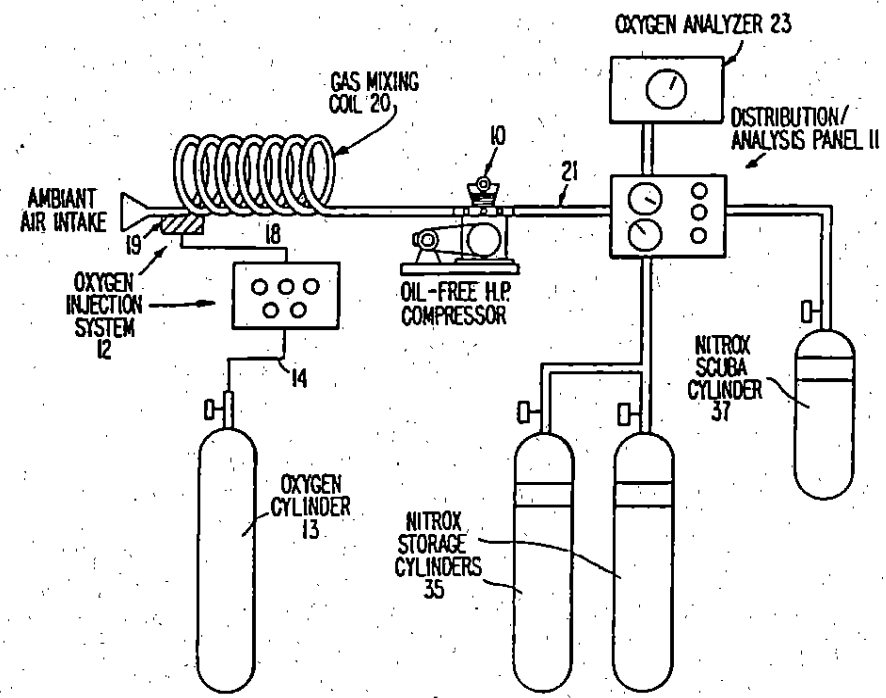

Figure 3

leased at atmospheric pressure, since a back pressure on this "desorbed" gas will significantly reduce the performance of the device.

DP System

The results of tests run on a Permea Model PPA-215A supplied with 150 psi of breathing quality air are shown in Fig. 2. The fractions of the respective gases in the high and low-O2 product streams are controlled by the back pressure or flow of the low-O2 product stream. This gas can be delivered at a pressure slightly less than the supply air. The high-O2 gas in these tests was delivered at atmospheric pressure. Slightly higher delivery pressures are possible.

Gas Mixing Systems

Figure 3 shows a generic "NOAA Continuous Nitrox Mixer" which can utilize either of the above atmospheric oxygen concentrators as a replacement for the oxygen source. Best performance of the PSA system is obtained by utilizing a high-oxygen "back pressure" in the range of 30 psi and adjusting mixer input rates to control the O2 content of the final high pressure mixture (conventional method). Best performance of the DP system can be obtained by adjusting the composition of the high-O2 product gas to the desired final high pressure mixer output, and compressing the entire output of the DP concentrator. Working models of both of the

above options have been constructed and tested at the NOAA Experimental Diving Unit (NOAA - EDU). Exact procedures for accomplishing the above will be described in NOAA EDU Reports 93-01 and 93-02, currently in preparation.

Nitrox saturation diving, at depths in excess of 50 feet of seawater, necessitates the use of gas mixtures lower in oxygen than air. While either of the systems can be used to supply such gases, the ability of the DP system to easily provide a wide range of mixtures, at working pressures, generally makes it the more appropriate method.

Philosophical Note - Many operational diving procedures and most therapeutic hyperbaric procedures call for the use of pure oxygen, which often results in logistic difficulties. In most cases the physiological intent of pure oxygen use can be obtained or improved upon with high-oxygen Nitrox mixtures and acceptable changes in equipment and/or procedures. A little innovation could result in significant benefit in these areas.

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REFERENCES

1. Wells, J.M., "Preparation of Divers Mixed Gas Breathing Media", Oceans '91, October 1-3, 1991, Proceedings, Vol.3, Honolulu, HI. 1991.

2. Wells, J.M., Continuous Nitrox Mixer, U.S. Patent Number 4,860,803, Aug 1989.