

pressure of 1.40 ATA; and for open-circuit SCUBA, the O₂ fraction must never exceed 40% by volume or an O₂ partial pressure of 1.40 ATA, whichever exposes divers to less O₂. The proposed requirement that the fraction of O₂ be more than 22% is consistent with the definition of nitrox breathing-gas mixtures, *i.e.*, that they contain more O₂ than air. Specifying upper limits for the O₂ component in the nitrox breathing-gas mixture would prevent divers from developing O₂ toxicity.

The available evidence supports the Agency's conclusion that exposure to a maximum O₂ level of 1.40 ATA (or 40% by volume for open-circuit SCUBA) would prevent O₂ toxicity.⁵ Several previous studies found that no O₂ toxicity developed while breathing 1.40 ATA of O₂ for extended periods, but breathing 1.60 ATA of O₂ for the same periods resulted in a significant increase in O₂ toxicity (see Exs. 3–4 (pp. 3–5 through 3–16, P–15 and P–16, and P–37 through P–43), 3–9, and 3–10). OSHA could find no studies showing that O₂ toxicity developed when divers used O₂ at the partial pressures and for the durations proposed in this rulemaking, although in one study, two divers developed pulmonary toxicity when exposed to 1.40 ATA of O₂ for a total of 55 hours over a 3-day period (Ex. 3–4, p. 3–9). However, such an exposure is far in excess of the maximum time limit that recreational divers would experience, or that the O₂-exposure limits specified in the 2001 NOAA Diving Manual or 1995 DSAT⁶ report would permit (see discussion regarding proposed Condition 4(a) below).

4. Limiting O₂ Partial Pressure and Diving Depth

(a) *Limiting O₂ partial pressure.* Proposed Condition 4(a) identifies the procedures employers would use to prevent O₂ toxicity. Accordingly, employers must: (i) Determine a diver's O₂ exposure duration using the maximum partial-pressure O₂ exposure during the dive and the total dive time (*i.e.*, from the time the diver leaves the surface until the diver returns to the surface); and (ii) using the diver's exposure duration, ensure that a diver exposed to partial pressures of O₂ between 0.60 and 1.40 ATA does not exceed the 24-hour single-exposure O₂

limits specified by the 2001 NOAA Diving Manual (see Section III below, Reference (1), p. 3–23) or by the 1995 DSAT report entitled “Enriched Air Operations and Resources Guide” (see Section III below, Reference (2), p. 34).

The risk of O₂ toxicity increases with O₂ partial pressure (*i.e.*, dive depth) and dive duration. Therefore, as required by proposed Condition 4(a)(i), employers must use both of these factors to determine O₂ exposure durations.

Proposed Condition 4(a)(ii) refers to 24-hour single-exposure O₂ limits specified in the 2001 NOAA Diving Manual and the 1995 DSAT report entitled “Enriched Air Operations and Resources Guide.” Both NOAA and DSAT developed their O₂-exposure limits using models and theories extensively tested in the field for safety and efficacy. The recreational diving industry recognizes and uses both procedures, and, as OSHA noted in granting a permanent variance to Dixie, both procedures would afford divers adequate protection against O₂ toxicity.

Under proposed Condition 4(a), when the employer determines exposure durations and limits divers' exposures accordingly, the Agency believes that they will reduce the divers' risk of O₂ toxicity to the rate found among divers who breathe compressed air from open-circuit SCUBA during no-decompression dives.

(b) *Limiting diving depth.* This proposed condition requires that employers limit the divers covered by this proposed alternative to a maximum depth of 130 fsw or to a maximum O₂ partial pressure of 1.40 ATA, whichever exposes them to less O₂; this proposed condition would apply regardless of the diving equipment they use. This proposed condition would impose an additional constraint on O₂ exposure, further reducing the risk of O₂ toxicity. Moreover, the proposed condition would aid in preventing DCS by limiting the divers' nitrogen exposure; this limitation occurs because O₂ displaces nitrogen in the volume of breathing gas available for use. Therefore, limiting nitrogen exposure and restricting diving depth to 130 fsw would reduce the risk of DCS and, consequently, the need for decompression chambers.

Lowering the partial pressure of nitrogen in a diver's body fluids and tissues, especially in the central nervous system, also would decrease the risk of nitrogen narcosis. Nitrogen narcosis is an anesthetic condition that results when high partial pressures of nitrogen are present in central nervous system tissues; the condition can impair a diver's performance and, in severe cases

can result in injury or death (see Section III below, Reference (1), p. 3–20).

5. Mixing and Analyzing the Breathing Gas

(a) *Mixing of breathing gas by the employer.* Under this proposed condition, when employers prepare the breathing-gas mixture, they must: (i) Ensure that properly trained personnel mix nitrox breathing gases, and that nitrogen is the only inert gas used in the breathing-gas mixture; and (ii) ensure that they mix the appropriate breathing-gas mixture before delivering it to the breathing-gas cylinders, using the continuous-flow or partial-pressure mixing techniques specified in the 2001 NOAA Diving Manual, or using a filter-membrane system. This provision would provide quality control over the mixing process, so that the breathing-gas mixture contains the correct proportions of O₂ and diluent gas (*i.e.*, air or nitrogen). It also limits the diluent gas to air or nitrogen because OSHA believes that not enough information is available on other inert diluent gases (*e.g.*, helium, argon, neon, hydrogen) or on trimix (three gas) breathing-gas mixtures to ensure the health and safety of divers under the diving conditions specified by this proposal.

This proposed condition also states a general requirement that mixing processes produce the proper proportions of O₂ and diluent gas prior to filling the SCUBA cylinders; this requirement would provide assurance that the divers' breathing-gas mixtures are correct and safe for use. In addition, it specifies that employers must select from among several mixing techniques commonly used and accepted by the diving industry. These techniques include the use of a “filter-membrane system,” a recently developed mixing technique that de-nitrogenates air (*i.e.*, removes nitrogen from air using a filter membrane).⁷ After reviewing the technical literature available for this mixing system, the Agency believes that filter-membrane systems, which are commercially available from several manufacturers, would reduce the hazards associated with producing high-O₂ breathing-gas mixtures (*e.g.*, fire, explosion) because the proportion of O₂

⁵ Excessive O₂ can impair a diver's central nervous system, resulting in seizures (and, as a consequence, death by drowning); it also can damage to the lungs and compromised pulmonary function.

⁶ “DSAT” is an acronym for “Diving Science and Technology,” the research component of the International Professional Association of Diving Instructors, Inc., a trade association representing recreational diving instructors.

⁷ Filter-membrane systems produce nitrox breathing-gas mixtures in two steps: First, they route air through filters to remove hydrocarbons and other contaminants; then they pass the decontaminated air through membranes that transfer O₂ across the membrane fibers at higher rates than nitrogen (hence, “de-nitrogenating” the air). As the rate of air flow across the membrane fibers increases, the resulting ratio of O₂ to nitrogen also increases.