

employers may use schedules for replacing CO<sub>2</sub>-sorbent material provided by the rebreather manufacturer. When doing so, employers must use:

(i) A CO<sub>2</sub>-sorbent replacement schedule only when the rebreather manufacturer has developed the replacement schedule according to the canister-testing protocol specified below in Condition 11; and

(ii) A rebreather at a water temperature that is lower than the minimum, or higher than the maximum, water temperature used in the canister-testing protocol specified below in Condition 11 only when the rebreather manufacturer adds that lower or higher temperature to the protocol.

(i) When using CO<sub>2</sub>-sorbent replacement schedules, employers must ensure that each rebreather uses a manufactured (*i.e.*, commercially pre-packed), disposable scrubber cartridge containing a CO<sub>2</sub>-sorbent material that:

(i) Is approved by the rebreather manufacturer;

(ii) Removes CO<sub>2</sub> from the diver's exhaled gas; and

(iii) Maintains the CO<sub>2</sub> level in the breathable gas (*i.e.*, the gas that a diver inhales directly from the regulator) below a partial pressure of 0.01 atmospheres absolute ("ATA").

(j) As an alternative to manufactured, disposable scrubber cartridges, employers may fill CO<sub>2</sub> scrubber cartridges manually with CO<sub>2</sub>-sorbent material when:

(i) The rebreather manufacturer permits manual filling of scrubber cartridges;

(ii) The employer fills the scrubber cartridges according to the rebreather manufacturer's instructions;

(iii) The employer replaces the CO<sub>2</sub>-sorbent material using a replacement schedule developed under paragraph 1(h) above; and

(iv) The employer demonstrates that manual filling meets the requirements specified above in paragraph 1(i).

(k) Employers must ensure that each rebreather has an information module that provides:

(i) Visual (*e.g.*, digital, graphic, analog) or auditory (*e.g.*, voice, pure tone) displays that effectively warn their divers of solenoid failure (when the rebreather uses solenoids) and other electrical weaknesses or failures (*e.g.*, low battery voltage);

(ii) For semi-closed circuit rebreathers, visual displays for the partial pressure of CO<sub>2</sub>, or deviations above and below a preset CO<sub>2</sub> partial pressure of 0.005 ATA; and

(iii) For closed-circuit rebreathers, visual displays for: Partial pressures of O<sub>2</sub> and CO<sub>2</sub>, or deviations above and below a preset CO<sub>2</sub> partial pressure of 0.005 ATA and a preset O<sub>2</sub> partial pressure of 1.40 ATA; gas temperature in the breathing loop; and water temperature.

(l) Before each day's diving operations, and more often when necessary, employers must ensure that the electrical power supplies and electrical and electronic circuits in each rebreather are operating as required by the rebreather manufacturer's instructions.

## 2. Special Requirements for Closed-Circuit Rebreathers

(a) Employers must ensure that closed-circuit rebreathers use supply-pressure sensors for the O<sub>2</sub> and diluent (*i.e.*, air or nitrogen) gases and continuously functioning

sensors for detecting temperature in the inhalation side of the gas-loop and the ambient water.

(b) Employers are to ensure that:

(i) At least two O<sub>2</sub> sensors are located in the inhalation side of the breathing loop; and

(ii) The O<sub>2</sub> sensors are: Functioning continuously; temperature-compensated; and approved by the rebreather manufacturer.

(c) Before each day's diving operations, and more often when necessary, employers must calibrate O<sub>2</sub> sensors as required by the sensor manufacturer's instructions. In doing so, they must:

(i) Ensure that the equipment and procedures used to perform the calibration are accurate to within 1% of the O<sub>2</sub> fraction by volume;

(ii) Maintain this accuracy as required by the manufacturer of the calibration equipment;

(iii) Ensure that the sensors are accurate to within 1% of the O<sub>2</sub> fraction by volume;

(iv) Replace O<sub>2</sub> sensors when they fail to meet the accuracy requirements specified above in paragraph 2(c)(iii); and

(v) Ensure that the replacement O<sub>2</sub> sensors meet the accuracy requirements specified above in paragraph 2(c)(iii) before they place a rebreather in operation.

(d) Employers must ensure that closed-circuit rebreathers have:

(i) A gas-controller package with electrically-operated solenoid O<sub>2</sub>-supply valves;

(ii) A pressure-activated regulator with a second-stage diluent-gas addition valve;

(iii) A manually operated gas-supply bypass valve to add O<sub>2</sub> or diluent gas to the breathing loop; and

(iv) Separate O<sub>2</sub> and diluent-gas cylinders to supply the breathing-gas mixture.

## 3. O<sub>2</sub> Concentration in the Breathing Gas

Employers must ensure that the fraction of O<sub>2</sub> in the nitrox breathing-gas mixture:

(a) Is greater than the fraction of O<sub>2</sub> in compressed air (*i.e.*, exceeds 22% by volume);

(b) For open-circuit SCUBA, never exceeds a maximum fraction of breathable O<sub>2</sub> of 40% by volume or a maximum O partial pressure of 1.40 ATA, whichever exposes divers to less O<sub>2</sub>; and

(c) For rebreathers, never exceeds a maximum O<sub>2</sub> partial pressure of 1.40 ATA.

## 4. Limiting O<sub>2</sub> Partial Pressure and Diving Depth

(a) Regarding O<sub>2</sub> exposure, employers must:

(i) Ensure that the exposure of their divers to partial pressures of O<sub>2</sub> between 0.60 and 1.40 ATA does not exceed the 24-hour single-exposure time limits specified either by the 2001 National Oceanic and Atmospheric Administration Diving Manual (the "2001 NOAA Diving Manual") or by the report entitled "Enriched Air Operations and Resources Guide," published in 1995 by the Professional Association of Diving Instructors (known commonly as the "1995 DSAT Oxygen Exposure Table") (see References (1) and (2) at the end of this appendix for complete information regarding these references); and

(ii) Determine a diver's O<sub>2</sub>-exposure duration using the diver's maximum O<sub>2</sub>

exposure (partial pressure of O<sub>2</sub>) 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).

(b) Regardless of the diving equipment used, employers must ensure that their divers do not exceed a depth of 130 feet of sea water ("fsw") or to a maximum O<sub>2</sub> partial pressure of 1.40 ATA, whichever exposes them to less O<sub>2</sub>.

## 5. Mixing and Analyzing the Breathing Gas

(a) Employers must ensure that:

(i) Properly trained personnel mix nitrox-breathing gases, and that nitrogen is the only inert gas used in the breathing-gas mixture; and

(ii) When mixing nitrox-breathing gases, they mix the appropriate breathing gas before delivering the mixture 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.

(b) Before the start of each day's diving operations, employers must determine the O<sub>2</sub> fraction of the breathing-gas mixture using an O<sub>2</sub> analyzer. In doing so, they must:

(i) Ensure that the O<sub>2</sub> analyzer is accurate to within 1% of the O<sub>2</sub> fraction by volume; and

(ii) Maintain this accuracy as required by the manufacturer of the analyzer.

(c) When the breathing gas is a commercially supplied nitrox breathing-gas mixture, employers must ensure that the O<sub>2</sub> is Grade A (also known as "aviator's oxygen") or Grade B (referred to as "industrial-medical oxygen"), and meets the specifications, including the purity requirements, found in the ANSI-Compressed Gas Association Commodity Specification for Air, G-7.1-1997. In addition, employers are to ensure that the commercial suppliers:

(i) Determine the O<sub>2</sub> fraction in the breathing-gas mixture using an analytic method that is accurate to within 1% of the O<sub>2</sub> fraction by volume;

(ii) Make this determination when the mixture is in the charged tank and after disconnecting the charged tank from the charging apparatus;

(iii) Document the O<sub>2</sub> fraction in the mixture; and

(iv) Provide the employer with a written certification of the O<sub>2</sub> analysis.

(d) Before producing nitrox breathing-gas mixtures using a compressor in which the gas pressure in any system component exceeds 125 pounds per square inch (psi), employers must:

(i) Have the compressor manufacturer certify in writing that the compressor is suitable for mixing high-pressure air with the highest O<sub>2</sub> fraction used in the nitrox breathing-gas mixture;

(ii) Ensure that the compressor is oil-less or oil-free and rated for O<sub>2</sub> service, unless they comply with the requirements of paragraph 5(e) below; and

(iii) Ensure that the compressor meets the requirements specified in paragraphs (i)(1) and (i)(2) of § 1910.430 whenever the highest O<sub>2</sub> fraction used in the mixing process exceeds 40%.