

replacement sensor before placing the rebreather in operation. Determining the accuracy of CO₂ sensors is necessary to enable employers to eliminate sensors that are unreliable or that cannot function under rugged diving conditions. Using a test or standard gas containing a CO₂ concentration of 0.005 ATA or less will ensure that the sensors can accurately detect CO₂ levels that can be harmful to the divers (see Ex. 3–12, p. 3–10). In view of the harmful effects that can result from high levels of CO₂, the sensors need to have a maximum error rate of no more than 10% of a CO₂ partial pressure of 0.005 ATA. This limit would provide an adequate safety margin to allow employees to detect CO₂ accumulation, make a preliminary effort to identify the cause and adjust breathing-system controls, and ascend to the surface if necessary.

(h) *CO₂-sorber materials.* This proposed condition allows employers to implement the manufacturers' schedules for replacing the canister of CO₂-sorber material in the rebreather as an alternative to using continuously functioning CO₂ sensors (see proposed Condition 1(e)). The proposed condition permits employers to use such a schedule only after the rebreather manufacturer develops the schedule according to the canister-testing protocol specified below in proposed Condition 11. This proposed requirement would ensure that the canister-replacement schedule meets quality-control criteria, including an assessment of the physical properties of the CO₂-sorber material and an evaluation of the canister's effectiveness using a standard canister-testing protocol (e.g., see proposed Condition 11 ("Testing Protocol for Determining the CO₂ Limits of Rebreather Canisters"). The protocol would permit the employer to make reliable estimates of canister duration, thereby allowing replacement of the canister before the CO₂-sorber material fails and the diver breathes excessive levels of CO₂.

(i) *Commercially pre-packed cartridges.* When the employer uses a CO₂-sorber replacement schedule, proposed Condition 1(i) requires the employer to ensure that each rebreather uses a manufactured (*i.e.*, commercially pre-packed), disposable scrubber cartridge. This cartridge must contain a CO₂-sorber material that is approved by the rebreather manufacturer and is capable of removing CO₂ from the divers' exhaled gas. In this regard, the canister must maintain the CO₂ level in the breathable gas (*i.e.*, the gas a diver is inhaling directly from the regulator)

below a partial pressure of 0.01 ATA.² The Agency believes that this proposed condition would ensure proper compression and uniform distribution of the sorber material in the cartridge, thereby preventing "channeling" in the material.³ By preventing channeling, the proposed condition would lower the diver's risk of rebreathing exhaled breathing gas that is high in CO₂.

(j) *Alternative to commercially pre-packed cartridges.* Under this proposed condition, employers may fill CO₂ scrubber cartridges manually instead of using commercially pre-packed cartridges. This practice would be acceptable if the employer meets all of the following conditions: The rebreather manufacturer permits employers to use this alternative method; the employer implements the alternative method according to the rebreather manufacturer's instructions; and the employer can demonstrate that the alternative method meets the performance requirements for commercially pre-packed cartridges specified by proposed Conditions 1(h) and 1(i). Therefore, the employer must be able to demonstrate to an OSHA compliance officer during an inspection that the manually filled cartridges are at least as effective as commercially pre-packed cartridges in removing CO₂ from the breathing loop. The Agency believes that employers can obtain information regarding the effectiveness of manually filled and pre-packed cartridges from the rebreather manufacturers.

(k) *Information module.* Condition 1(k) specifies that employers must ensure that their divers use an information module that provides them with critical dive information regarding electrical functions, gas pressures, and water temperature. For all rebreathers, the module must contain visual or auditory warning devices that would alert the diver to electrical weaknesses or failures (*e.g.*, solenoid failure, low battery levels). In addition, modules used in semi-closed circuit rebreathers must contain visual displays for the partial pressure of CO₂, or deviations above and below a preset CO₂ partial

pressure of 0.005 ATA. For closed-circuit rebreathers, the module also must have visual displays for the partial pressures of O₂ and CO₂, or deviations above and below a preset CO₂ partial pressure of 0.005 ATA and a preset O₂ partial pressure of 1.40 ATA, plus a visual display for both gas temperature in the breathing loop and water temperature (see the discussion of water- and gas-temperature sensors under proposed Condition (2)(a) below). Warning divers of electrical weaknesses and failures would alert them that they should stop relying on their electrically operated equipment, especially sensors, and take protective actions. Providing information about O₂ and CO₂ partial pressures will alert divers to toxic levels of these gases in time for them to prevent extended exposure.

While employers could provide recreational diving instructors and diving guides with dive-decompression computers for these purposes, OSHA believes that such computers are unnecessary because the divers would be diving within no-decompression limits, and the technical capability of dive-decompression computers far exceeds what is needed for no-decompression dives.

(l) *Checking electrical power and circuits.* As noted above for proposed Condition 1(k), the information module must warn divers of low battery voltage when they are operating either semi-closed-circuit and closed-circuit rebreathers. In this regard, a partial or total electronic failure could interfere with sensor and control systems and have serious safety consequences for the diver. Therefore, OSHA believes that the diver's safety depends on properly operating electrical power supplies and electrical and electronic circuits. Accordingly, the proposed alternative would require employers to ensure that the electrical power supplies and electrical and electronic circuits in each rebreather are operating as required by the rebreather manufacturer's instructions. The employer must check for proper operation prior to beginning diving operations each day, and more often when necessary.

2. Special Requirements for Closed-Circuit Rebreathers

(a) *Supply-pressure and temperature sensors.* This proposed condition requires employers to ensure that closed-circuit rebreathers use supply-pressure sensors for the O₂ and diluent gases (*i.e.*, air or nitrogen), as well as continuously functioning sensors for detecting temperature in the inhalation side of the breathing loop and in the ambient water. Supply-pressure sensors

² NOAA finds that physiological "strain" responses begin to develop with exposure to CO₂ concentrations over 0.03 ATA (Ex. 3–12, p. 3–10). Therefore, OSHA believes that a threshold limit for CO₂ of 0.01 ATA will provide divers with an adequate margin of protection from these effects.

³ "Channeling" describes open spaces (or channels) that form in the sorber material, and that permit exhaled breathing gas to pass through that part of the material to the inhalation side of the breathing apparatus with little or no absorption of the CO₂ contained in the exhaled breathing gas. This condition typically results from failing to compress the sorber material uniformly in the canister (*e.g.*, by shaking the canister vigorously).