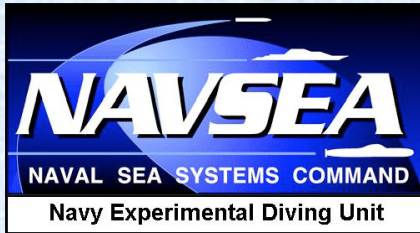


Development of a Scrubber Gauge for Closed-Circuit Diving

Dan E. Warkander

Annual UHMS meeting, June 2007



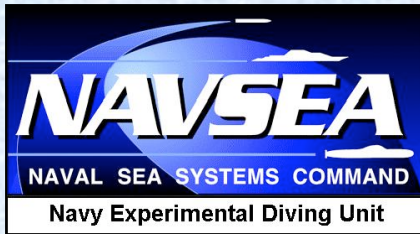
CO₂ scrubber gauge

Currently, the scrubber is not monitored during dives.

Stated endurance times rely on worst case testing at assumed diver workloads.

Therefore, the full capacity of the UBA is unlikely to be used.

If the scrubber could be monitored, dives could be safely extended, or shortened as dictated by actual events.



CO₂ scrubber gauge

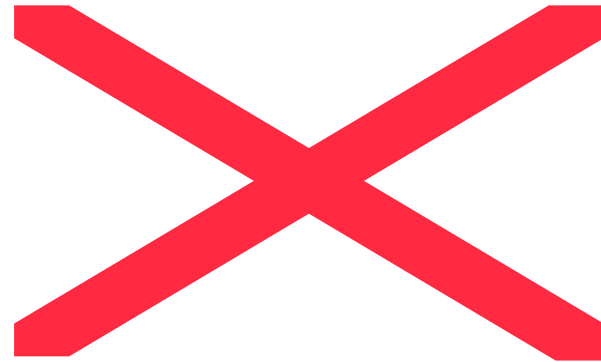
Why not CO₂ sensors in the outlet?

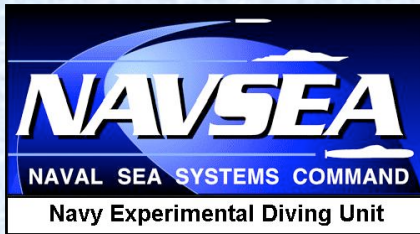
1: Not yet available for the diving environment.

2: Typically, no CO₂ to sense until 60 to 80% of the absorbent is spent;

A CO₂ sensor does not allow for any planning –

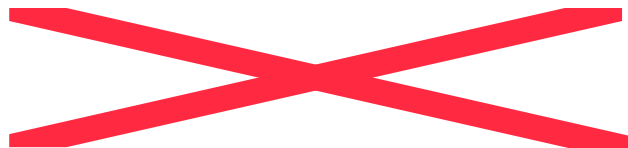
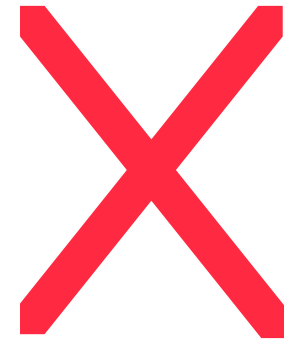
Can only be a warning!



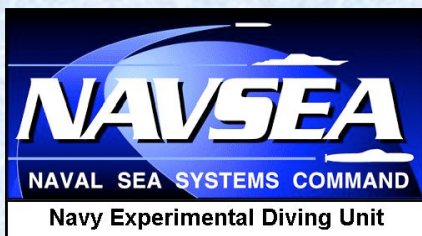


CO₂ scrubber gauge

The absorption of CO₂ is an exothermic reaction. This project takes advantage of temperature changes inside the scrubber to provide a readout like a fuel gauge (U.S. patent 6,618,687).

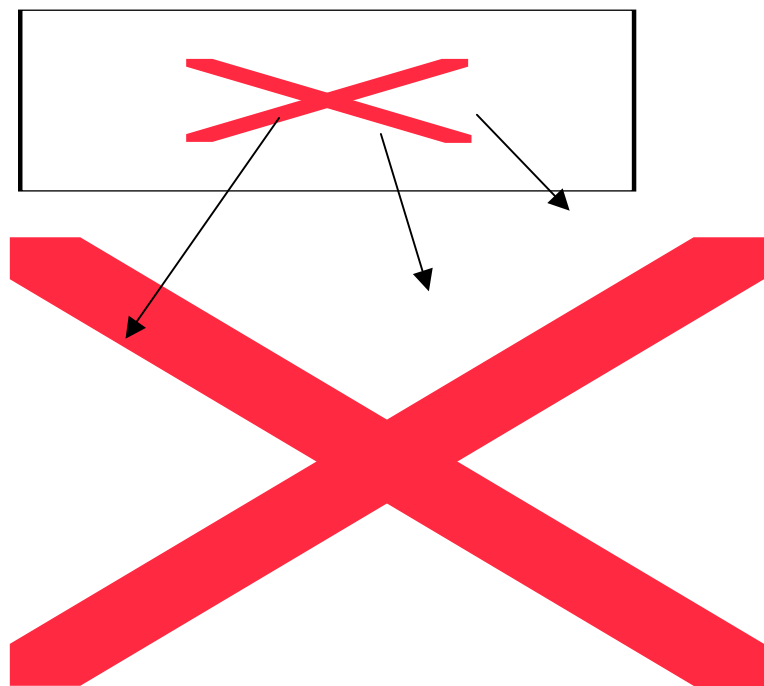


U.S. Patent 6,618,687:
Title: Temperature-based estimation of remaining absorptive capacity of a gas absorber.
Inventor: Dan E. Warkander.
Assigned to: The United States of America as represented by the Secretary of the Navy, Washington, DC.

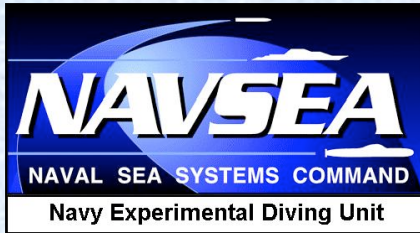


CO₂ scrubber gauge

Example of recorded temperatures & CO₂ level



CO₂ level

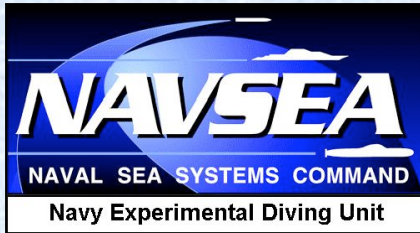


CO₂ scrubber gauge



The method makes gauge readings essentially independent of:

- depth
- ambient temperature,
- ventilation (workload).



CO₂ scrubber gauge



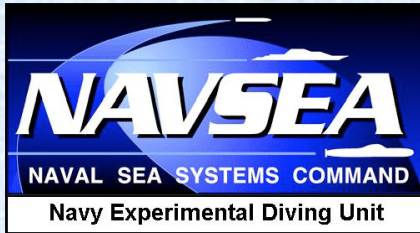
No field calibration needed.

Simple design.

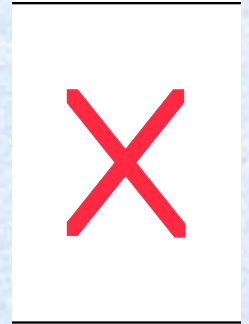
Can be switched on as desired - minimum power consumption.

Can be made very small.

Minimal training because readings are easy to interpret (compare to fuel and pressure gauges).



CO₂ scrubber gauge

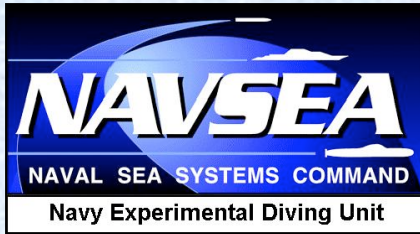


Test conditions:

Full range of temperatures, diver workloads and depth and three absorbents.

Standards endurance as well as mission-like profiles.

A total of about 1,000 scrubber hours.

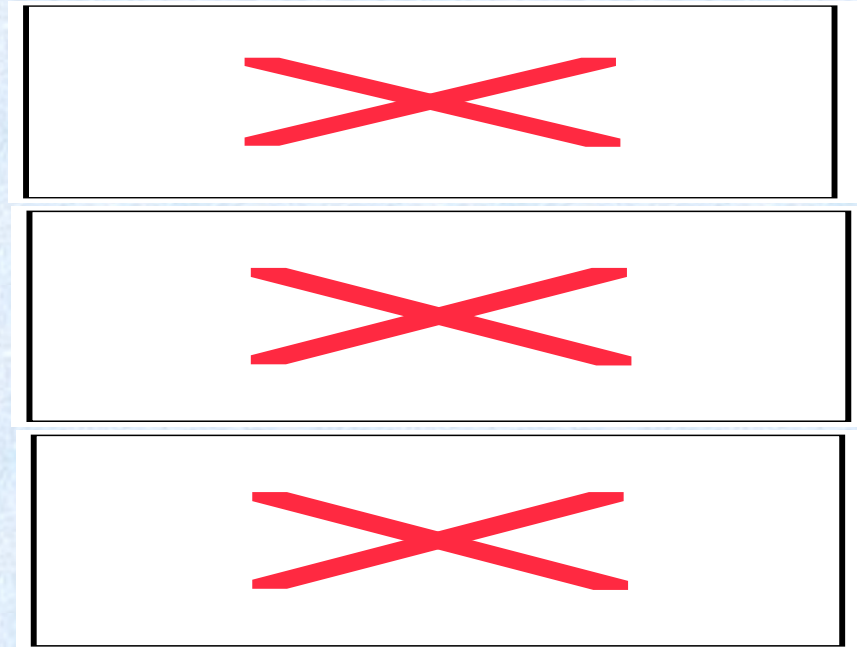
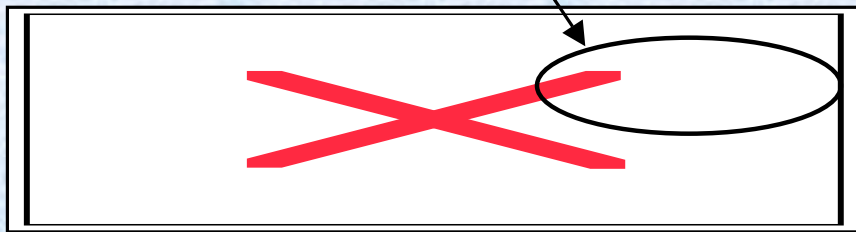


CO₂ scrubber gauge

Design of diver display

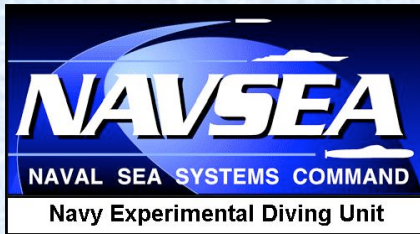


Absorbent
(Sofnolime 812)



Expected accuracy:

Expect average errors of about 10% of the actual endurance time.



CO₂ scrubber gauge



Endurance tests are typically performed at only one conditions: a minute ventilation of 40 L/min and a CO₂ load of 1.6 L/min.

Actual endurance time depends very much on exercise load and water temperature. Thus, it can be far different than expected and can be reduced by up to 75% or be 100% longer than stated.

Only a real-time gauge
would reveal the actual endurance time.