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Fighting the 3 Hazards in rebreather diving

Assoc. Prof. Dr. Arne Sieber


AVATA

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Closed Circuit Rebreather

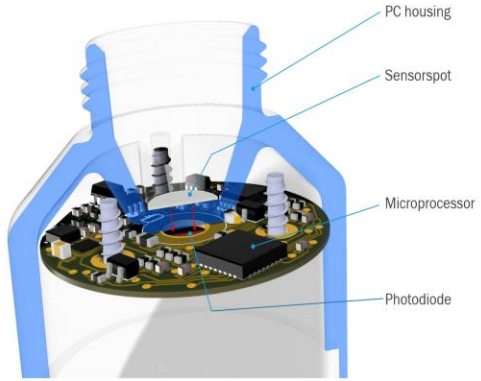
Main user interface:
mouthpiece

O2 + Diluent

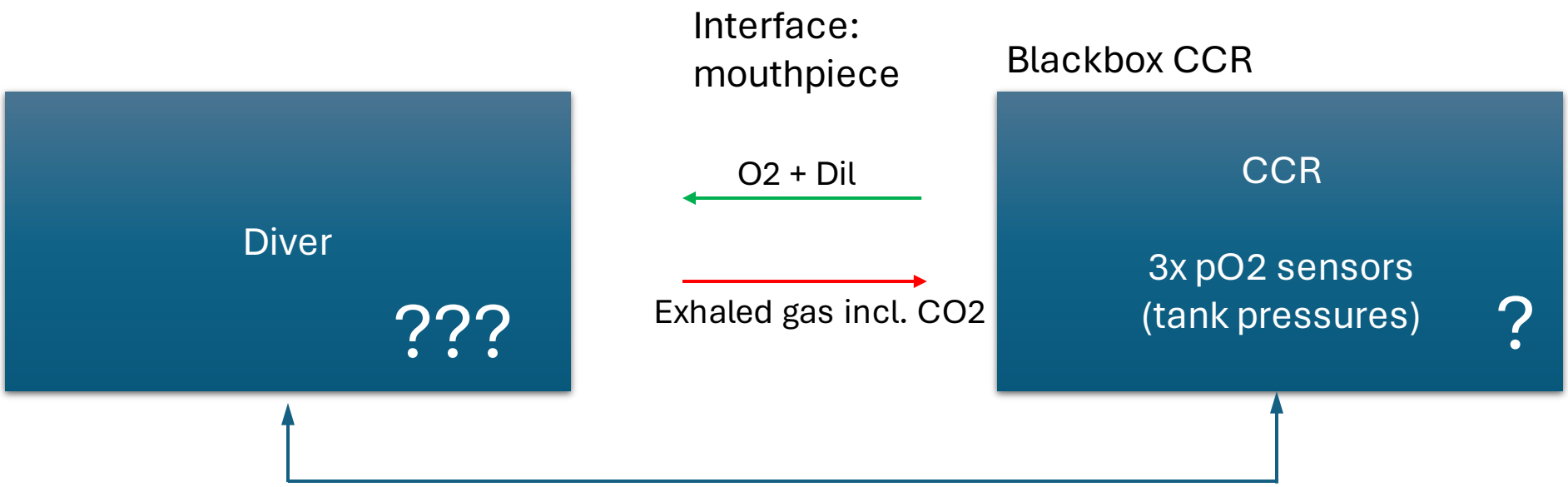
Exhaled gas incl. CO2

CCR

3x pO2 sensors
(tank pressures)



System: Diver + CCR



- pO2 values
- tank pressure values
- depth, dive time
- decompression obligation
- diver can switch pO2 setpoints or adjust

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3 Hs

Hypercapnia

- Too high CO2 levels in the inhaled gas
  - Scrubber is exhausted
  - Scrubber bypass
  - Temperature too cold
  - Workload too high, RMV too high
  - Too deep
- Pendulum breathing
  - Problem with the flapper valves in the mouthpiece
- Too high work of breathing
  - Too high gas density
  - Too deep
  - Rebreather with too high WOB
  - Rebreather with too high hydrostatic imbalance
  - Too high physical activity
  - Stress factors, ergonomics, environment, etc.

Hypoxic: pO2 too low

- Incorrect O2 sensing
  - Failure of the sensors
  - Failure of the electronics or software
  - Incorrect calibration
- No O2 supply
  - Tank is empty or not open
  - O2 injection malfunction

Hyperoxic: pO2 too high

- Failure of the O2 sensing system
- O2 injection stuck open
- Wrong diluent gas
- Too fast descent

-> Decompression schedule is based on pO2 !

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3 Hazards

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Ergonomics

Measures to decrease workload and stress

- More compact and streamlined systems
- Easy to understand and intuitive user interfaces
- Less clutter – wireless systems
- Ergonomic CCR design, for instance alternatives to bulky bail out valve mouthpieces

Streamlined Systems

Ergonomic BOV

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Holistic concept

Sensors

- Rebreather monitoring
  - Reliable O2 sensing system
  - Reliable CO2 sensing
  - Failsafe system design
- Diver monitoring
  - Heart Rate
  - RMV, breathing rate, breathing volumes
  - SO2
  - EtCO2
- System diver / rebreather monitoring
  - Position of the diver in the water
  - Counterlung volumes
  - Breathing pressures
  - External work of breathing
  - Hydrostatic Imbalance

Intelligent systems

- Data Processing
- Validation of signals
- System modelling
- Signal fusion, AI,…

User Interface

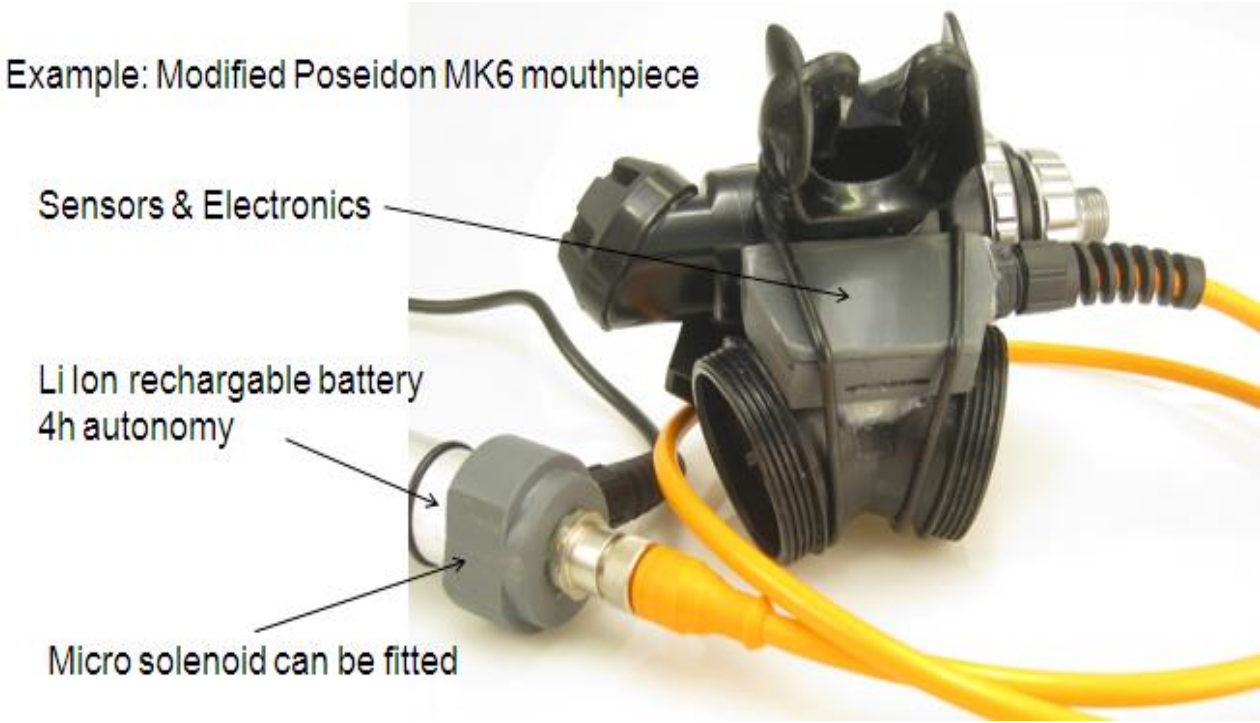
All OK

Switch to bailout
Open O2 tank
Surface now
Calm down – reduce workload
…

Easy-to-understand messages to the diver on a screen or HUD, ideally with easy-to-understand symbols

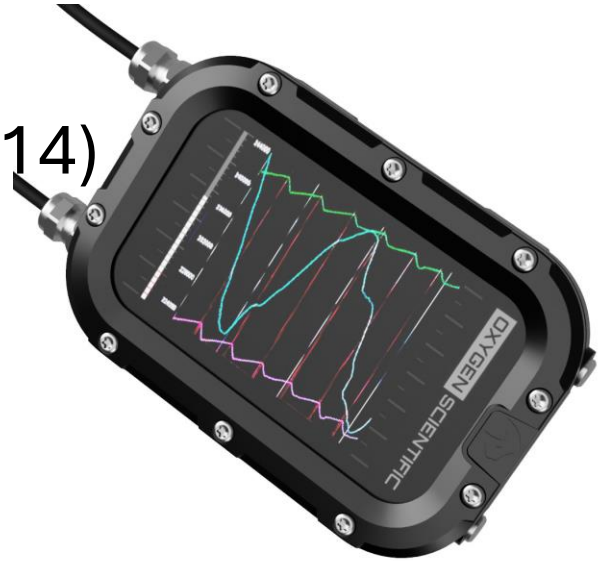
EtCO2 monitoring

- EU Marie Curie ITN Liefeloop, R&D of gas sensors for rebreathers
- First EtCO2 monitoring in a mouthpiece
- Academic result, no further development due to high fabrication cost



Diver monitoring

- ECG, SO2 (ONRG project, 2012-2014)
- Monitoring of breath-hold divers
  - SO2
  - Involuntary breathing movements
  - NIRs / Cerebral oxygenation
  - Body position



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Future CCR – Key R&D goals

- Ergonomic solutions – less workload/stress for the diver
- Sensors
  - Reliable gas sensing
  - Physiological parameters of the diver
  - System-related parameters, like WOB, hydrostatic imbalance, position in the water
- Sensor data processing
  - Sensor signal fusion, Neural Networks, AI
  - Intuitive/easy-to-understand interfaces

Final goal: More efficient and safer diving