Rewards and Challenges of Rebreather Diving

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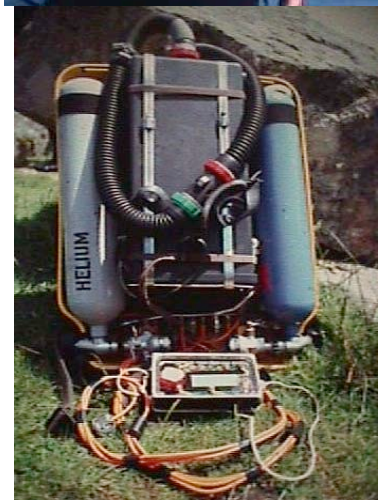
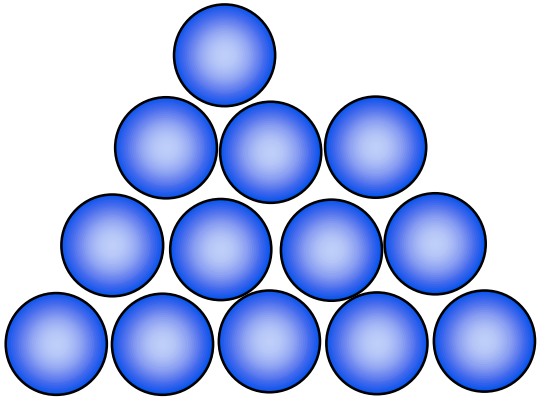
UHMS Scientific Meeting, Maui
June 2007




UNAM

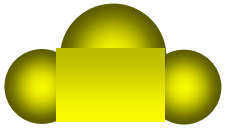
3 hrs at 200 fsw

- Peter Readey (SMI)



13 Scuba Tanks

(80 CuFt Air)

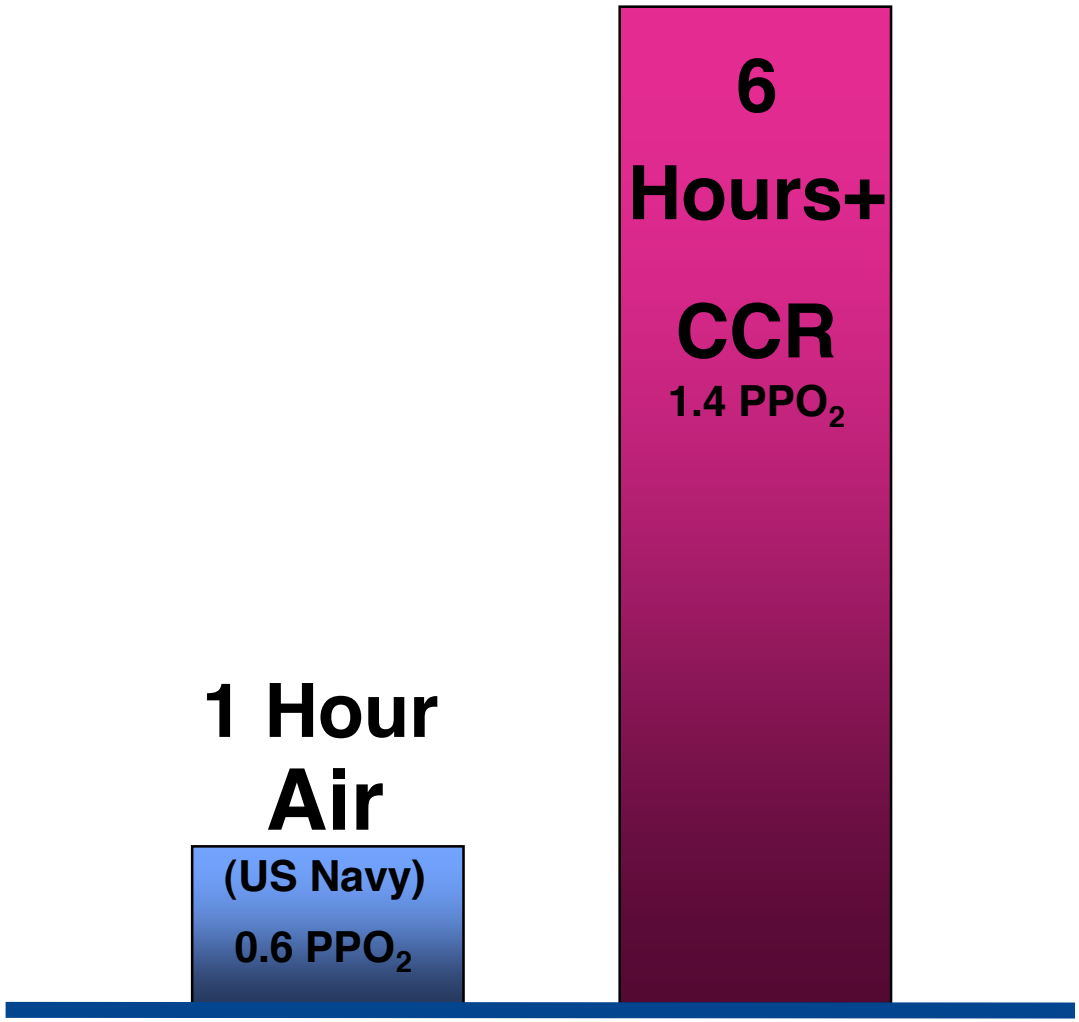


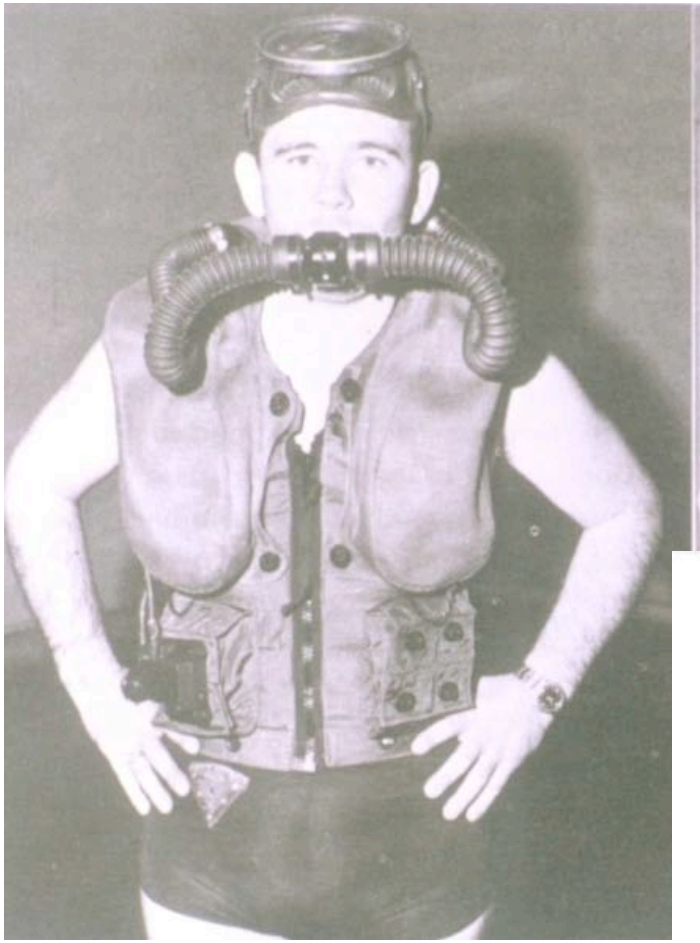
ONE

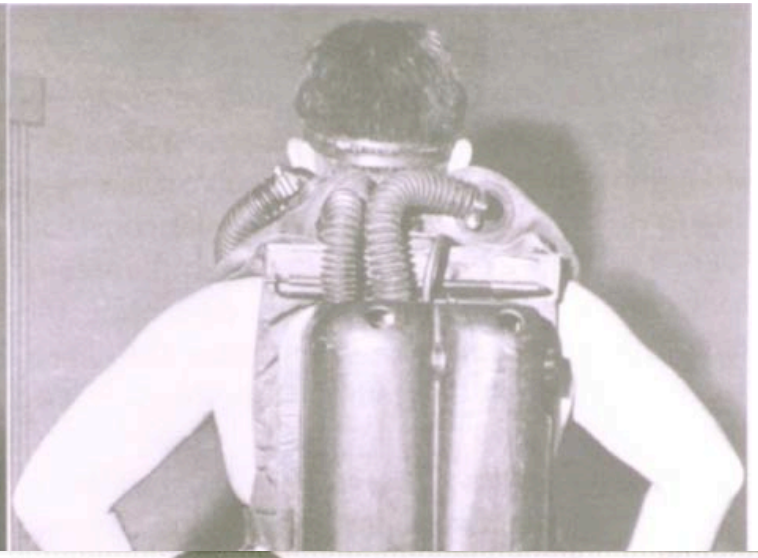
CCR

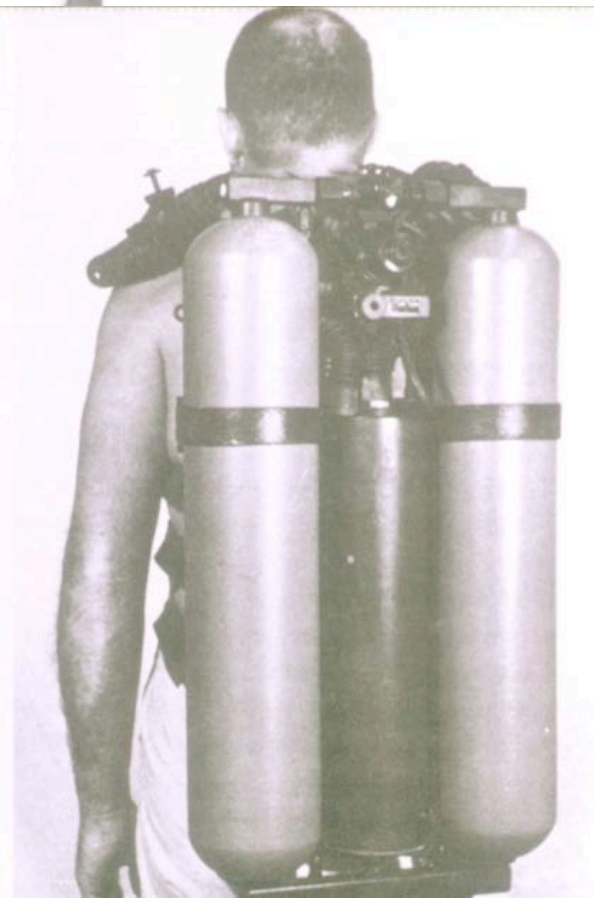
No-D Times at 60 fsw

- Peter Readey (SMI)

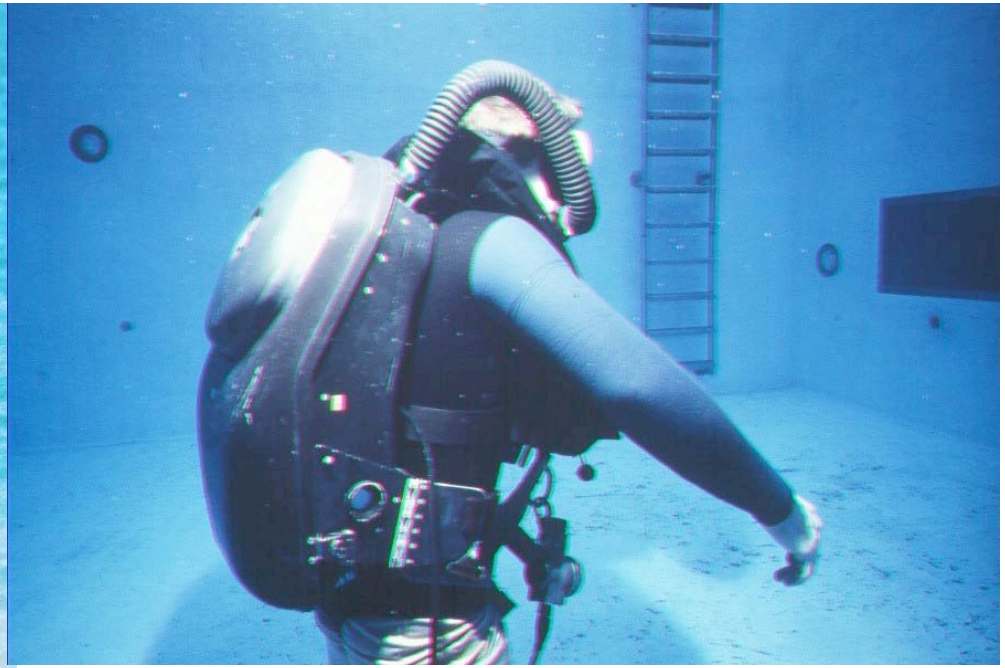


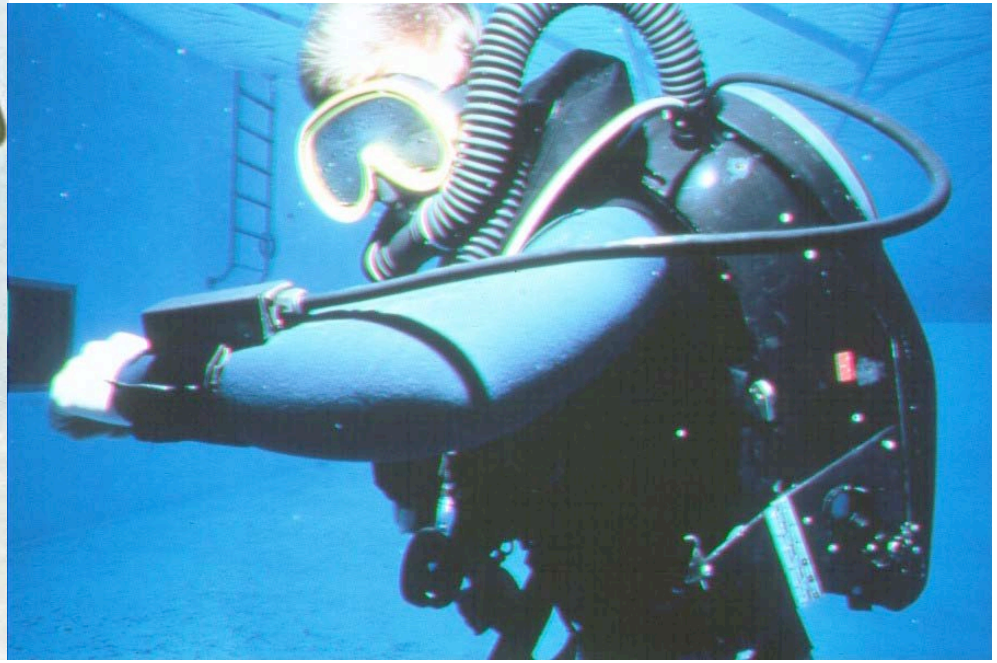







UNDERWATER
DEMOLITION
TEAM 12





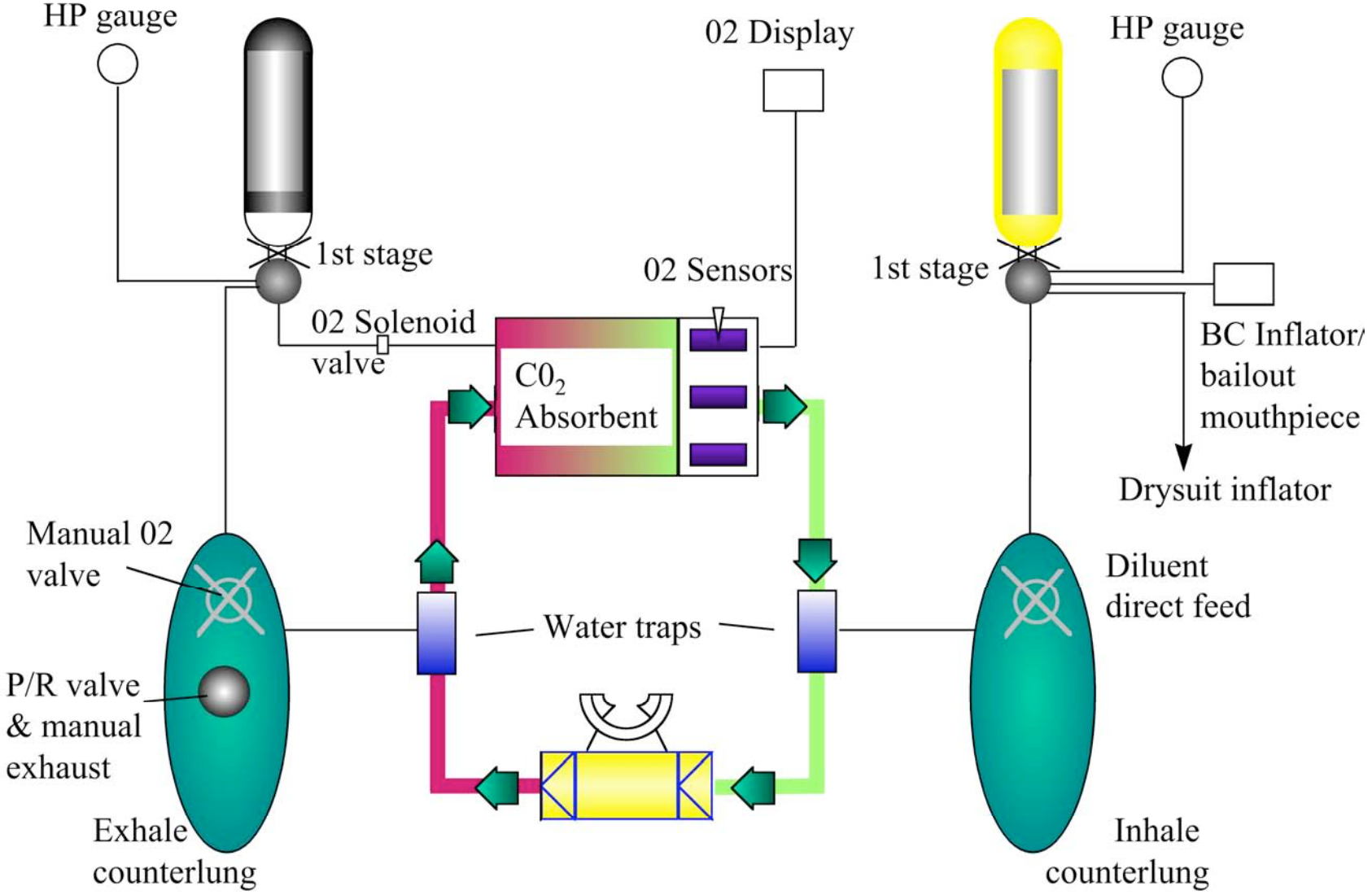

Choices….

Rebreather Testing

- Gavin Anthony - Qinetiq

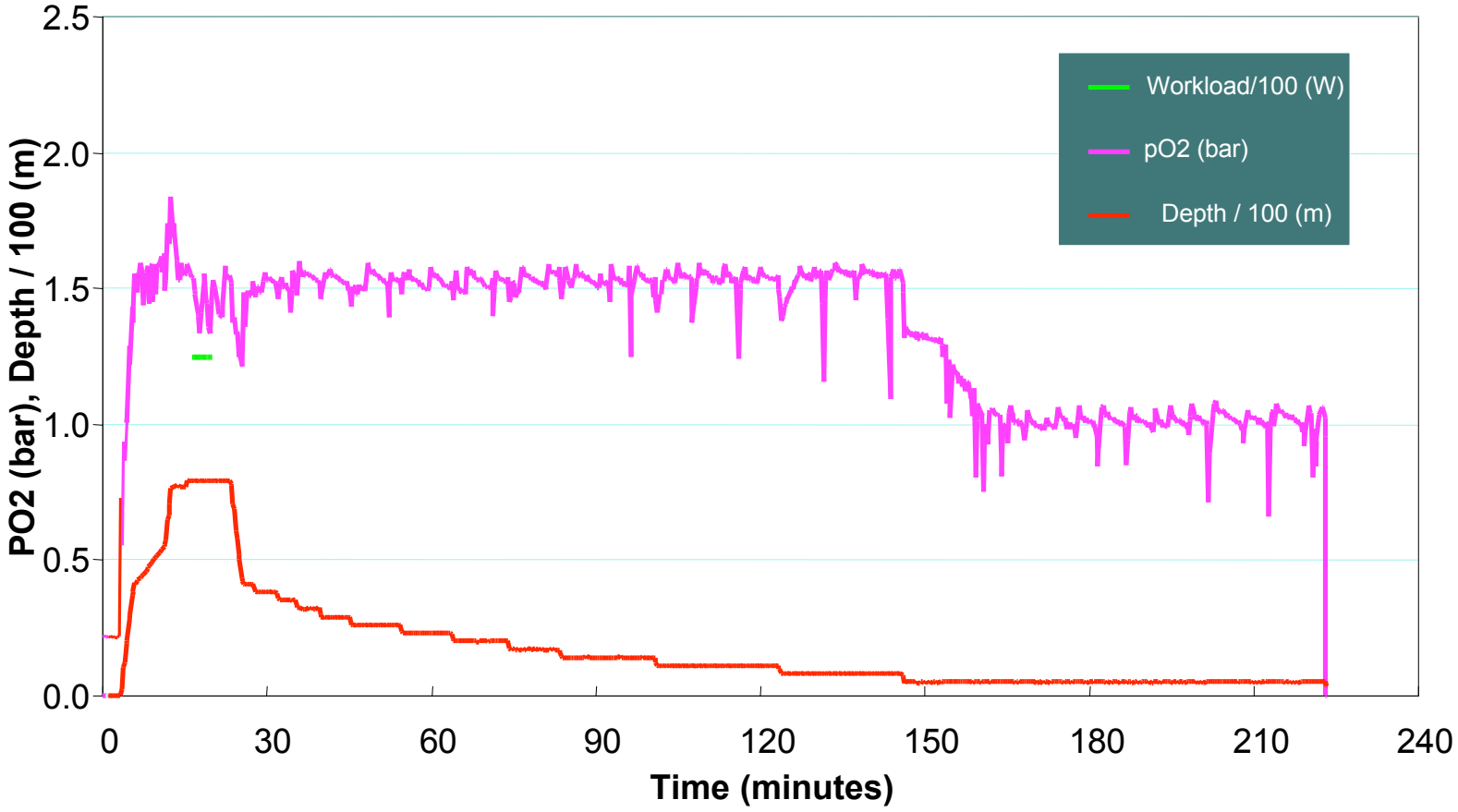
Loop, Oxygen and Diluent

- Martin Parker (AP Valves)



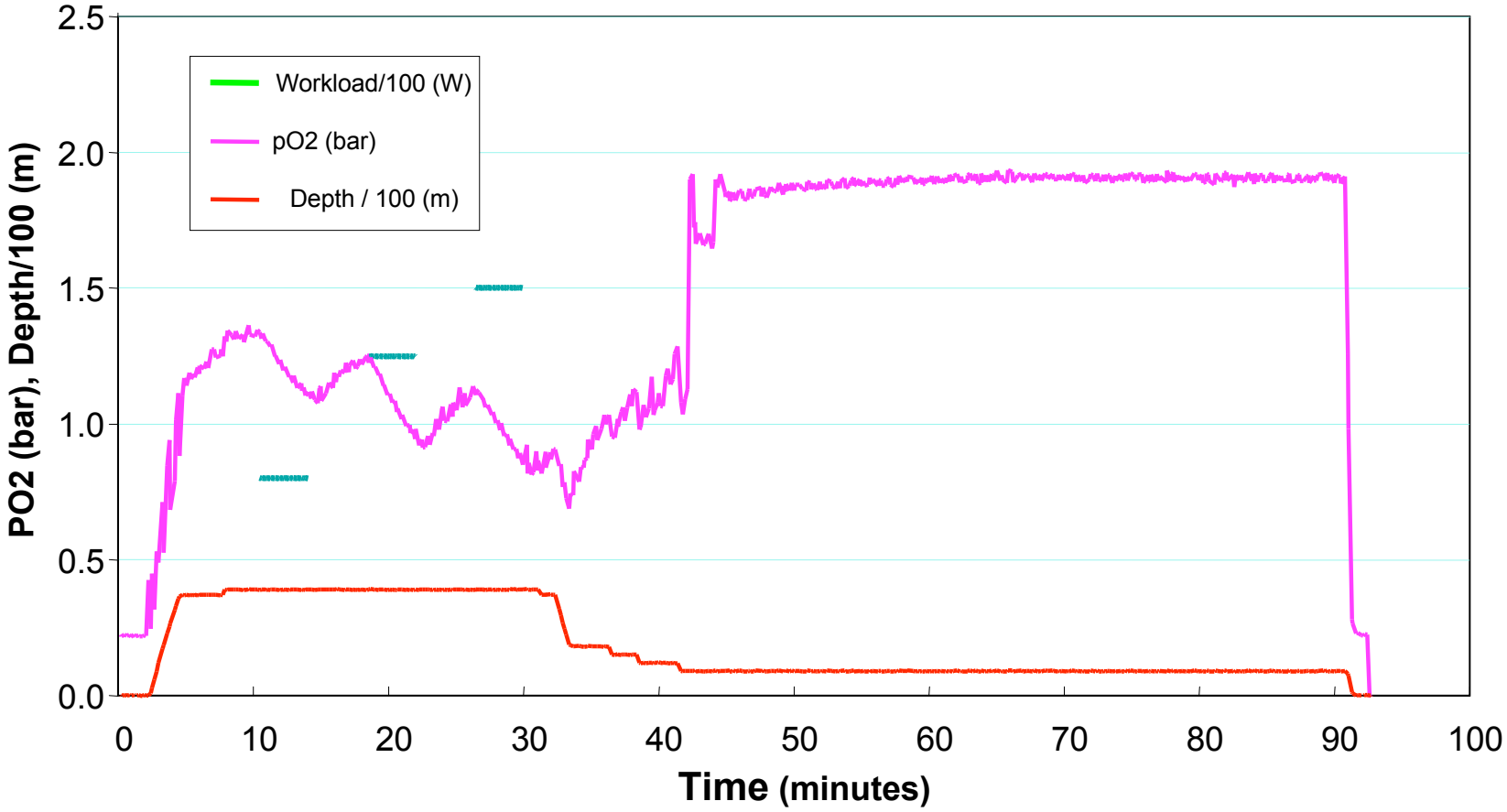
PO_2 Control – Closed-Circuit

- Gavin Anthony - Qinetiq



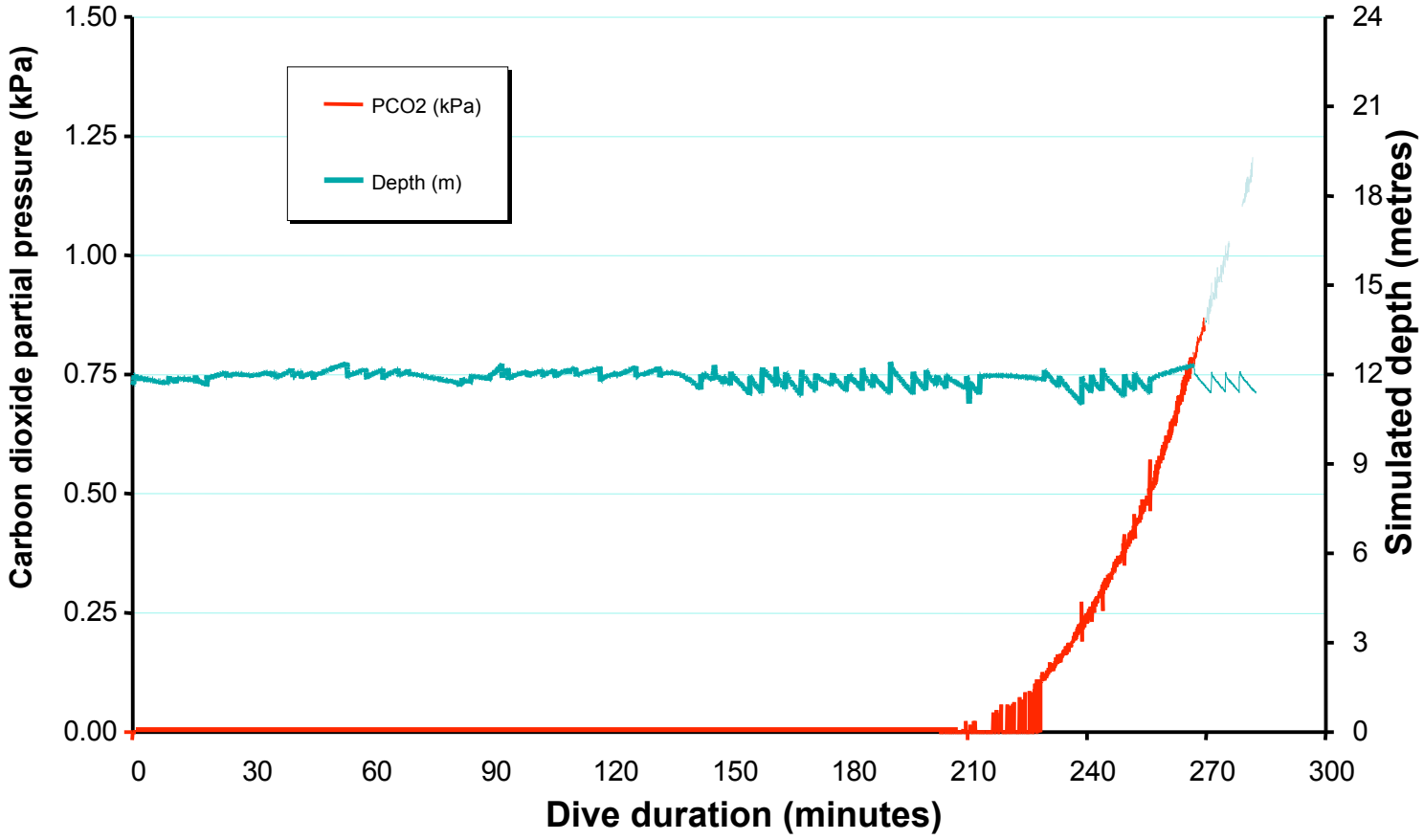
PO_2 Control – Semi-Closed

- Gavin Anthony - Qinetiq



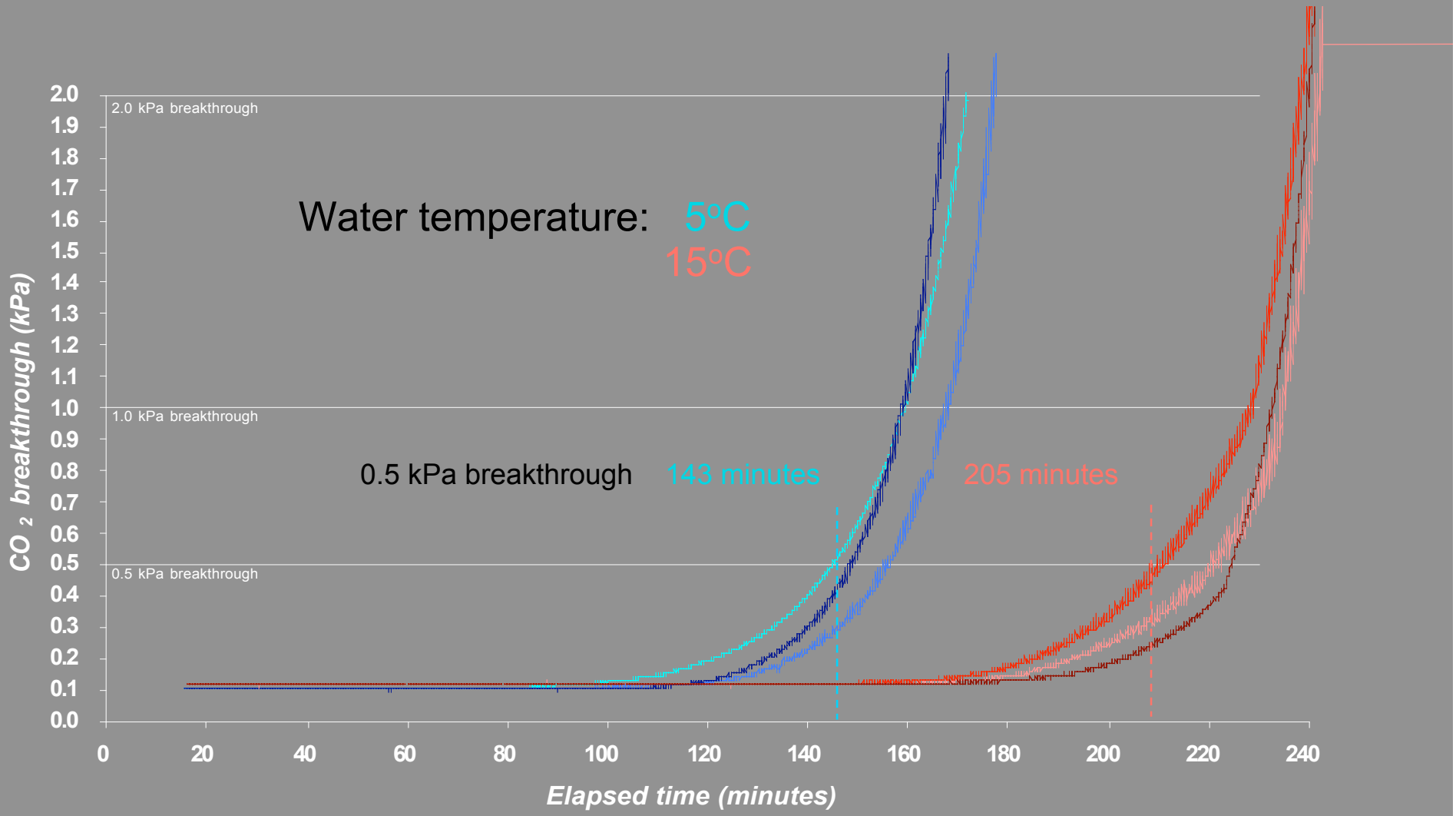
CO_2 Absorbent Canister Life

- Gavin Anthony - Qinetiq



CO_2 Control and Temperature

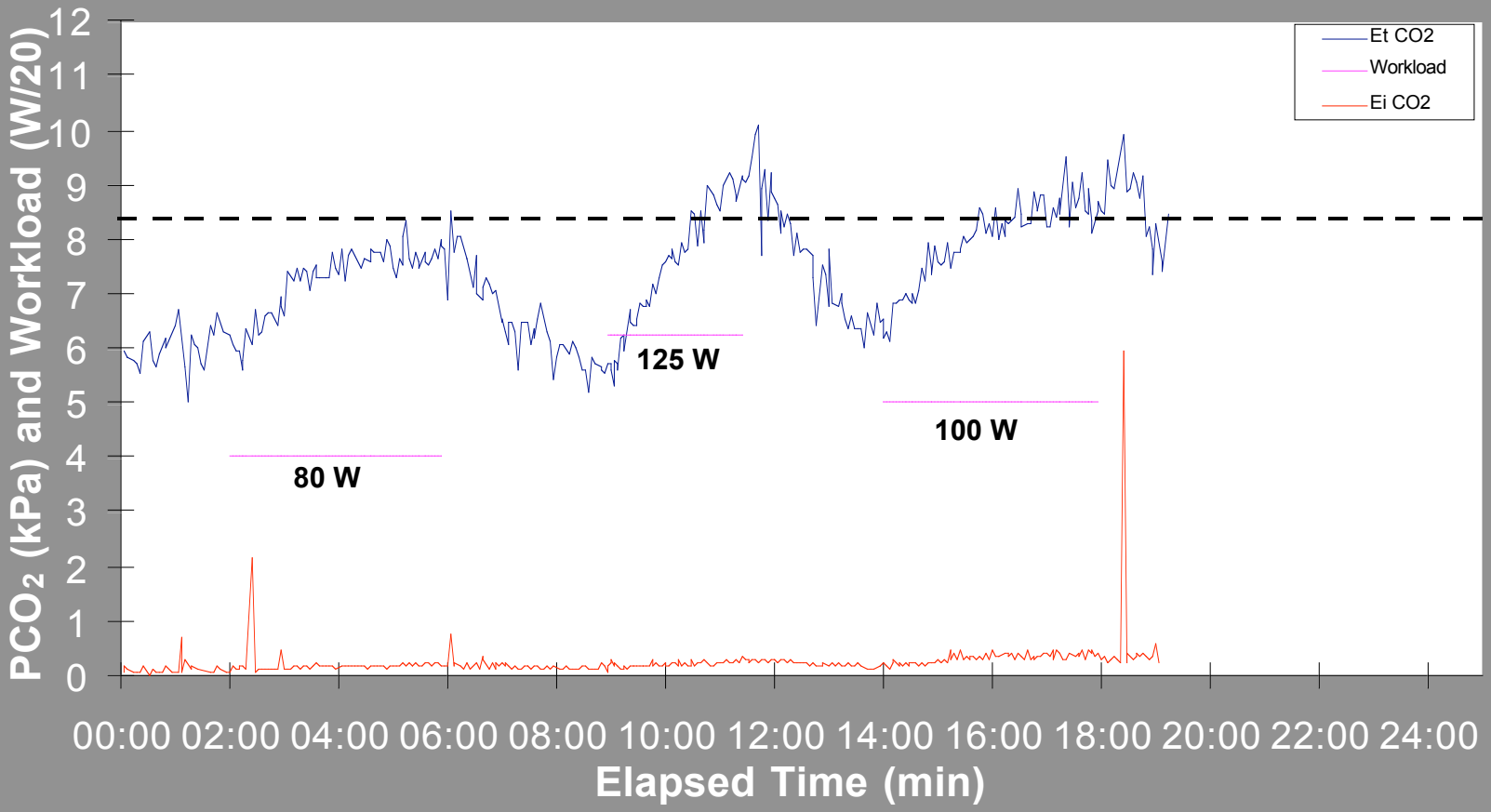
- Gavin Anthony - Qinetiq



CO_2 Control and Work

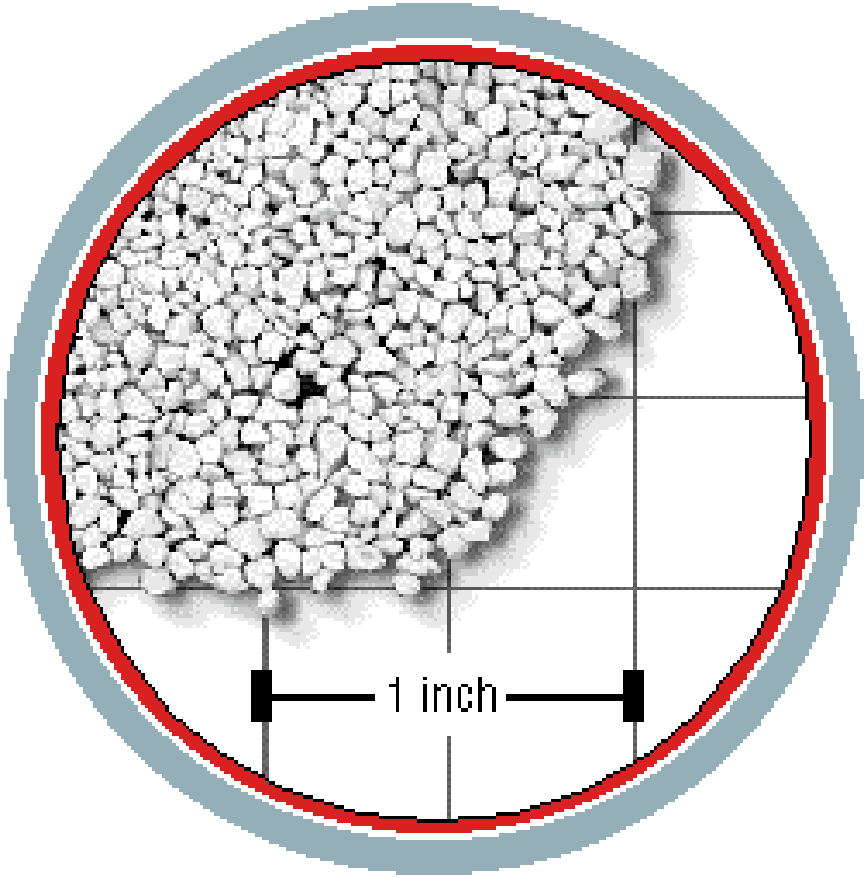
- Gavin Anthony - Qinetiq

- Work accelerates CO_2 breakthrough



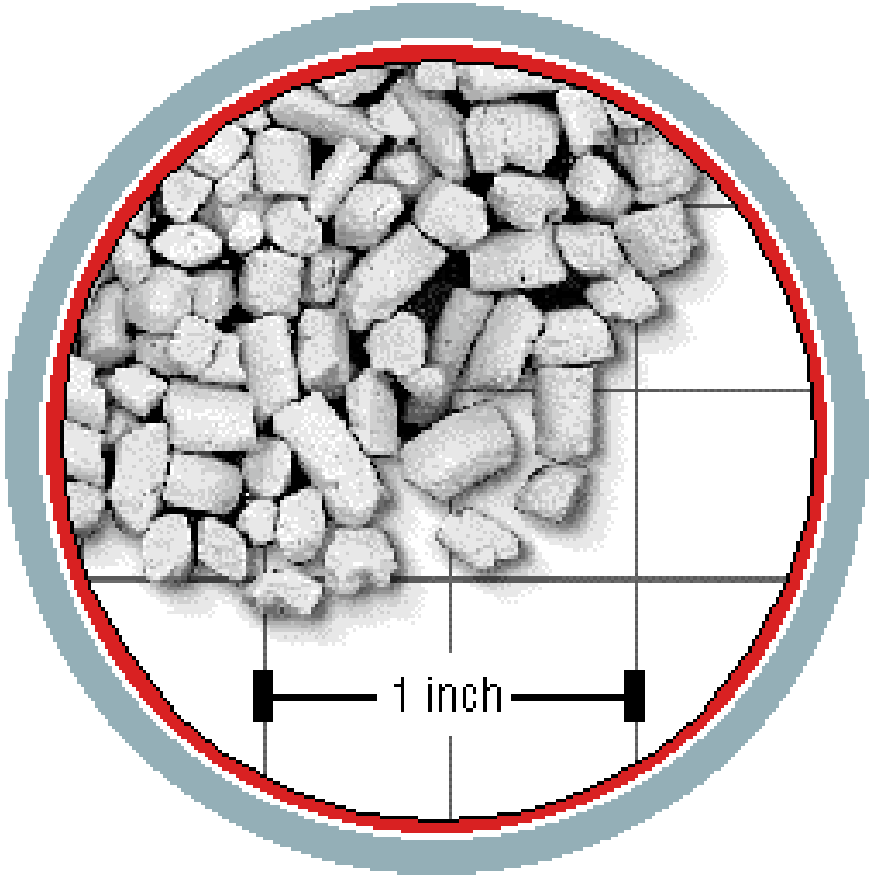
CO_2 Absorbent

- Peter Readey, Steam Machines



8-12 Grain

Better absorbent, worse resistance

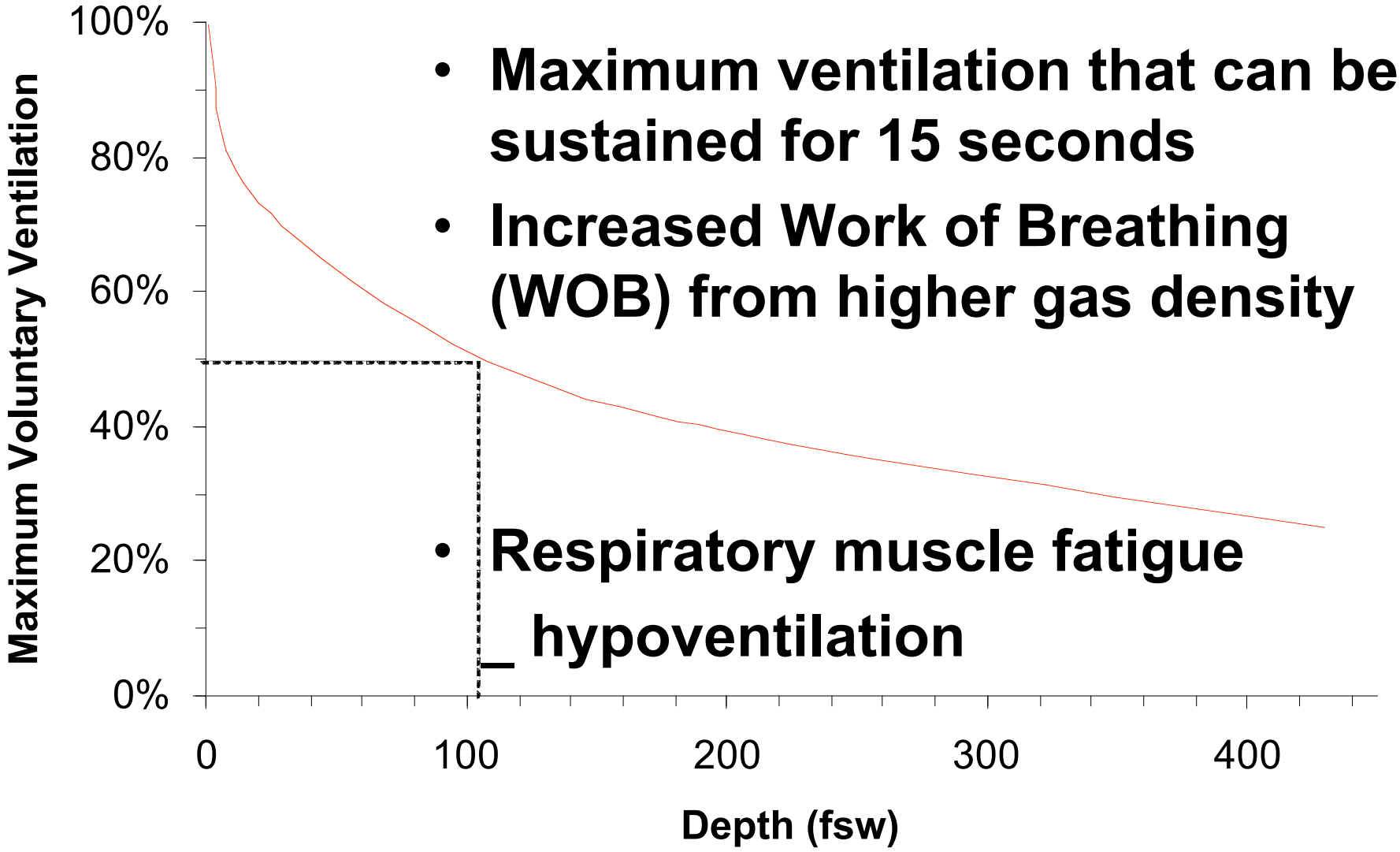


4-8 Grain

Worse absorbent, better resistance

Maximum Voluntary Ventilation (MVV)

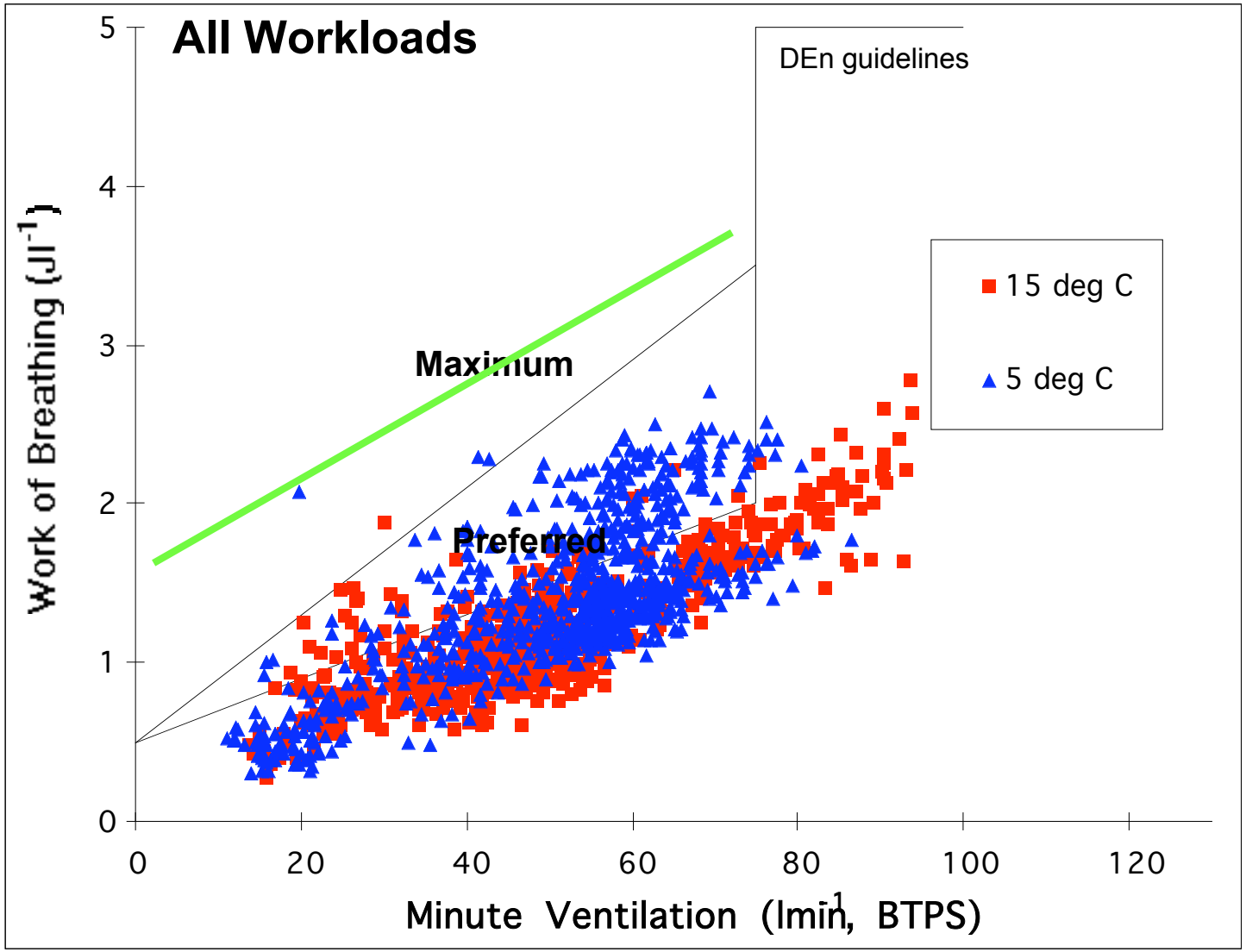
-Camporesi & Bosco (2003)



- **Maximum ventilation that can be sustained for 15 seconds**
- **Increased Work of Breathing (WOB) from higher gas density**
- **Respiratory muscle fatigue**
  - **hypoventilation**

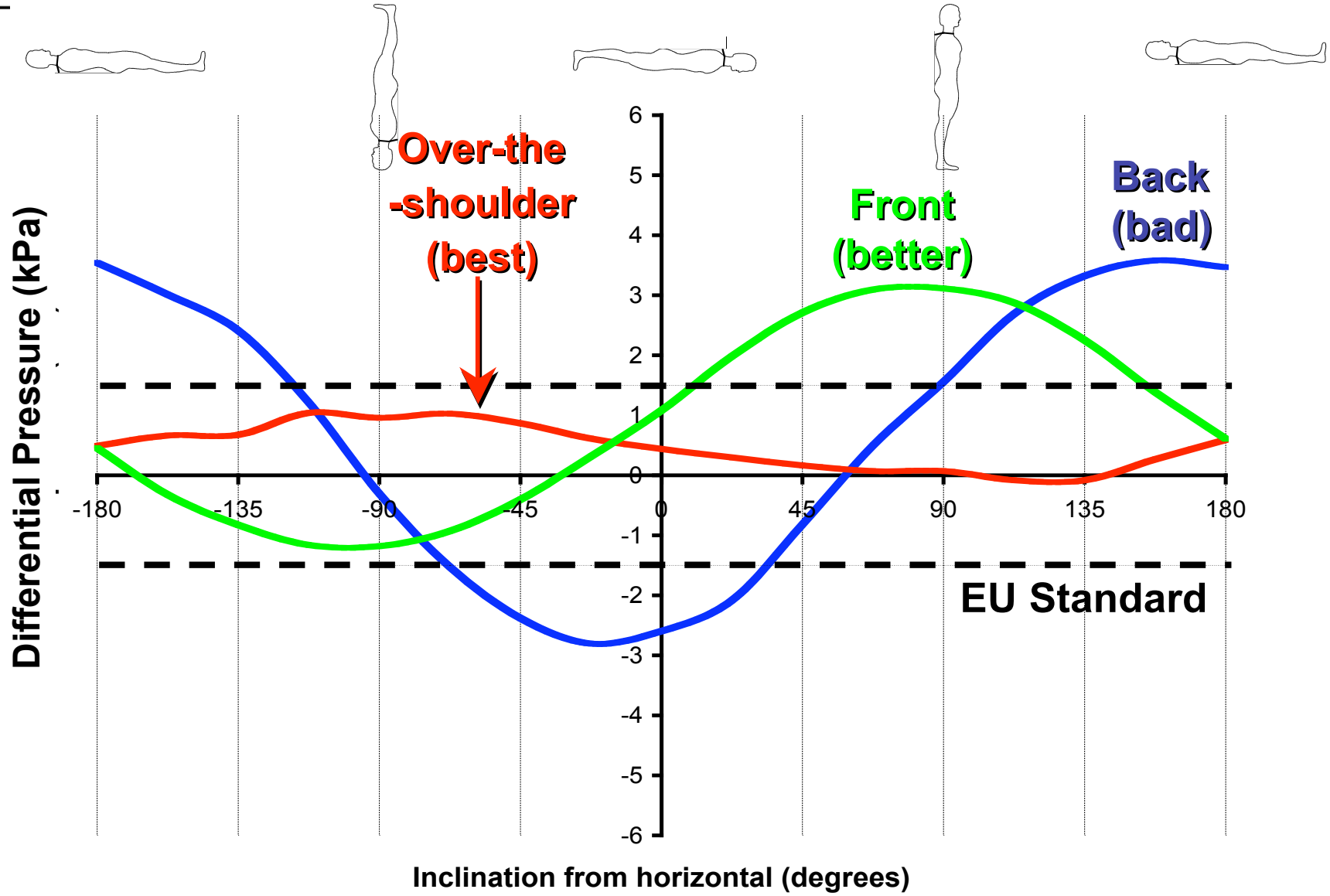
Work of Breathing Limits

- Gavin Anthony - Qinetiq



Static Lung Load

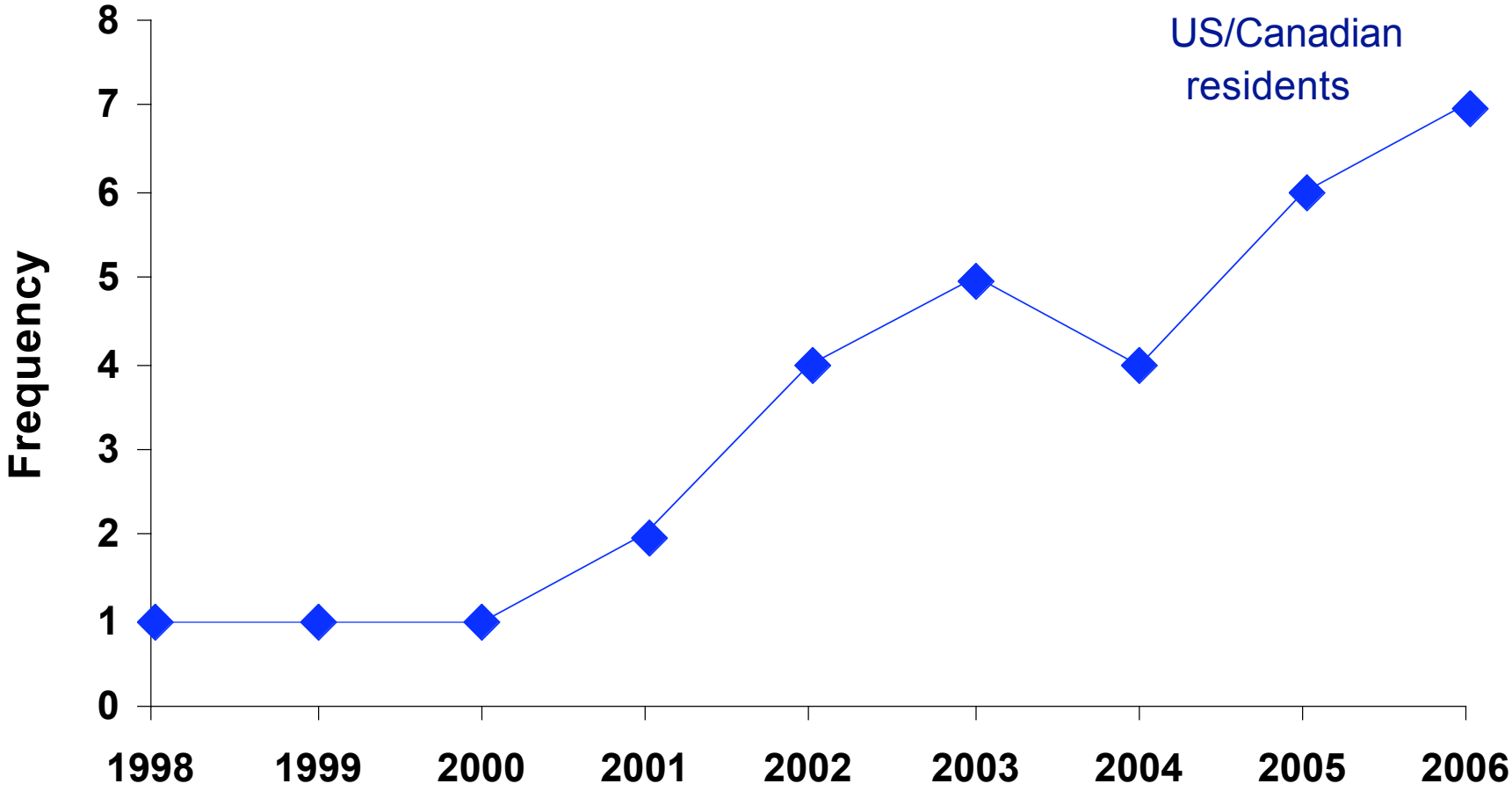
- Gavin Anthony, QinetiQ



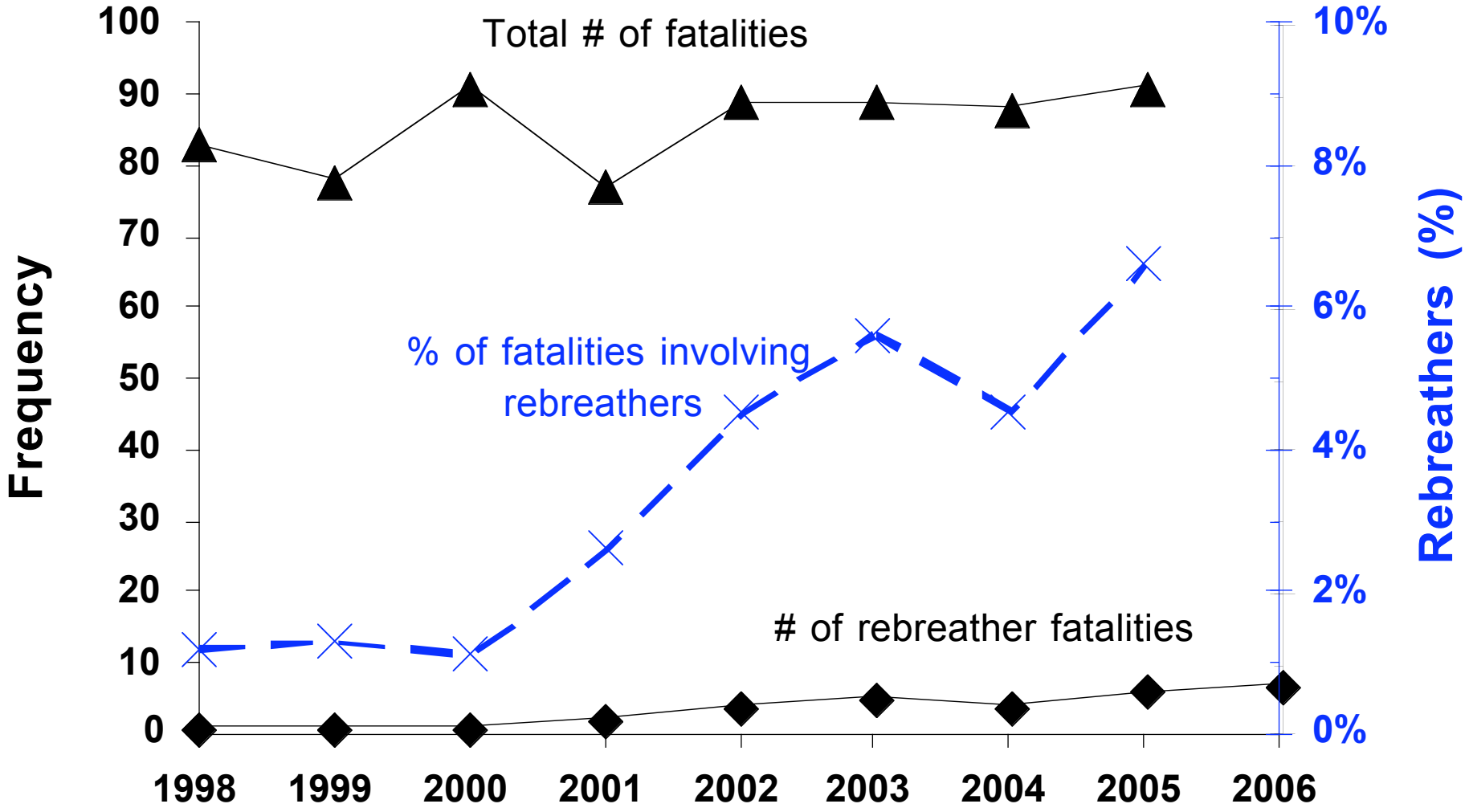
Rebreather Fatality Surveillance

- Diving deaths involving rebreathers appear to be increasing
- We compared fatalities for divers using rebreathers with divers using open-circuit breathing apparatus

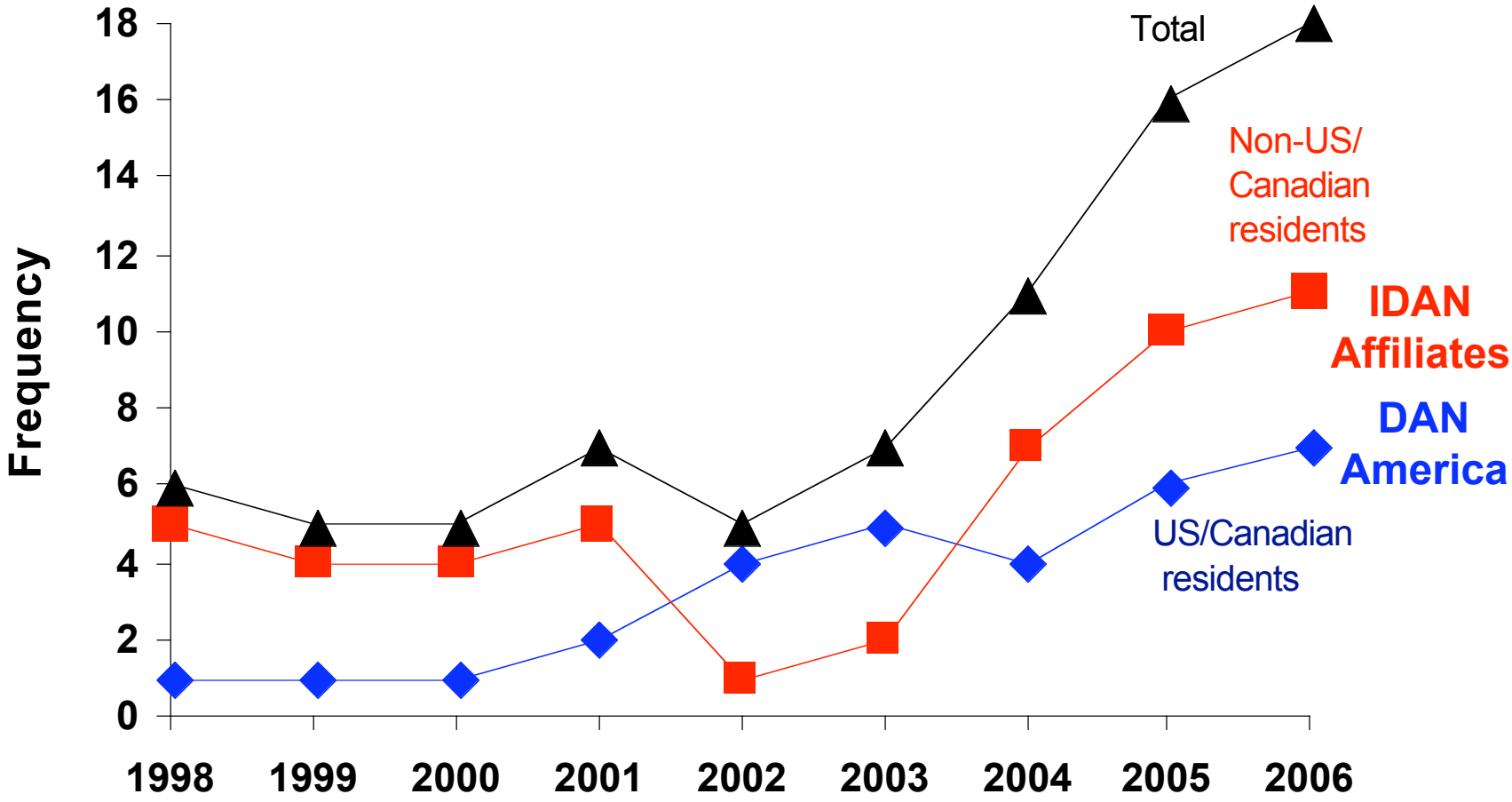
US/Canada Rebreather Deaths



Rebreather Deaths as Fraction of All US/Canada Deaths



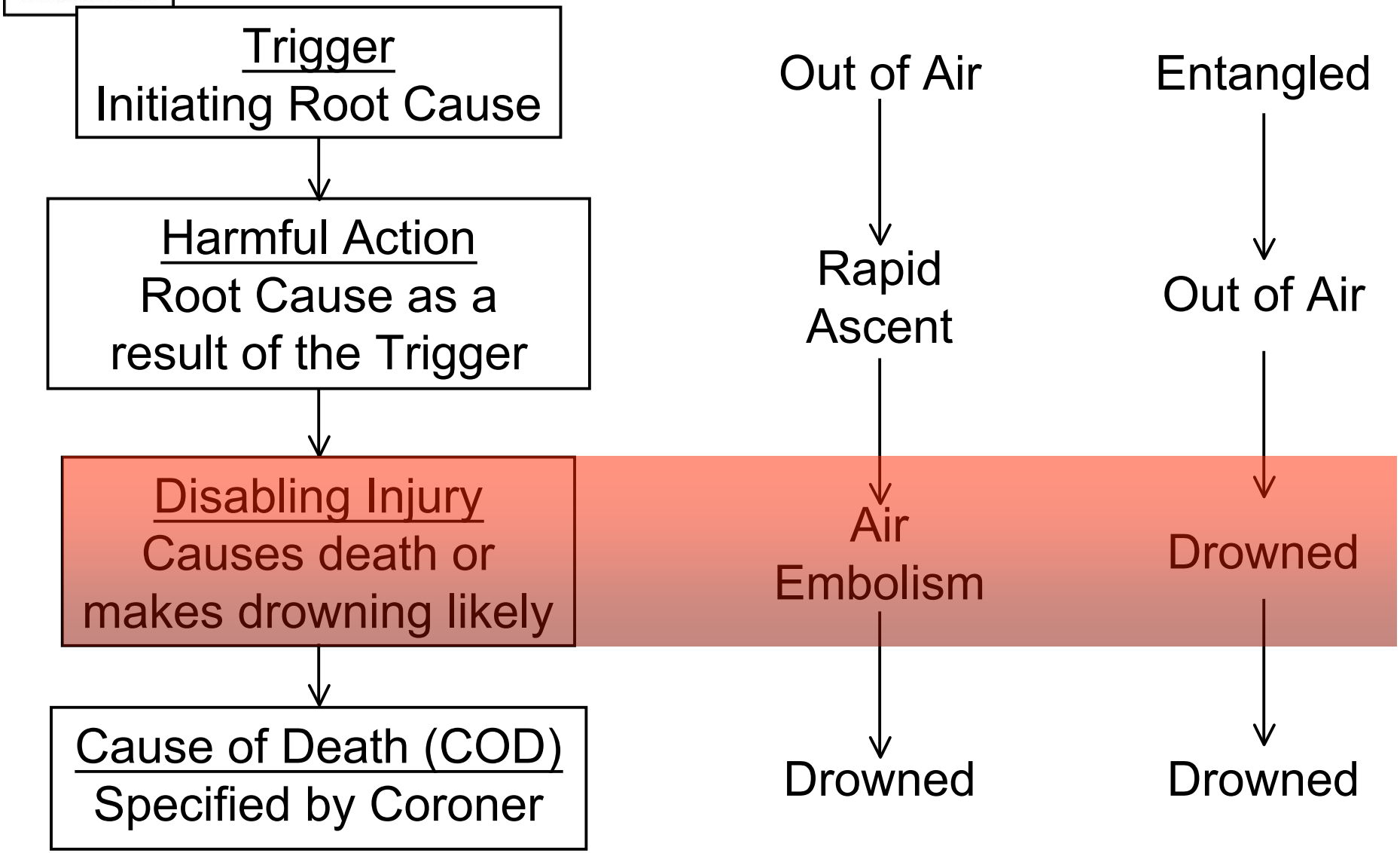
All Rebreather Deaths



O/C vs. Rebreather Deaths

- 947 open-circuit cases (1992-2003)
- 80 rebreather cases (1998-2006)
  - 78 males, 2 females
  - Mean age: 45 (24-72 range, 21 missing)
  - Residency
    - 31 US/Canadian, 48 non-US/Canadian
  - Location
    - 25 US/Canada, 52 non-US/Canada
    - 23 US, 14 UK, 6 France, 3 Australia, 3 Germany, 2….

Root Cause Analysis



Triggers


338 Open circuit cases
30 Closed circuit cases
Percent of Total
50
40
30
20
10
0
Insufficient Gas
Entrapment
Equipment Trouble
Rough Seas
Trauma
Buoyancy

4 Entrapment

- Tangled while attempting body recovery at 880 fsw, drowned
- Tangled in lift bag at 150 fsw deco stop, pulled to surface, DCS
- Tangled in line at 130 fsw in cave, drowned
- Tied self to coral during 20 fsw deco stop, drowned

7 Buoyancy Problems

- Not rebreather related
  - Tangled in lift bag, pulled to surface, DCS
  - Drysuit valve failure, blowup, AGE
  - Drysuit valve corroded, 330 fsw blowup, DCS
- Rebreather related
  - Rapid ascent, removed mouthpiece, sank
  - Rapid surfacing from 20 fsw, dropped mouthpiece, sank
  - Surfaced, swallowed sea water, sank
  - Emergency surfaced at 30 min, sank

3 Rebreather Malfunctions

- Displays found flooded
- O_2 supply failure, emergency ascent, omitted D, AGE
- Unknown malfunction in 330 fsw cave

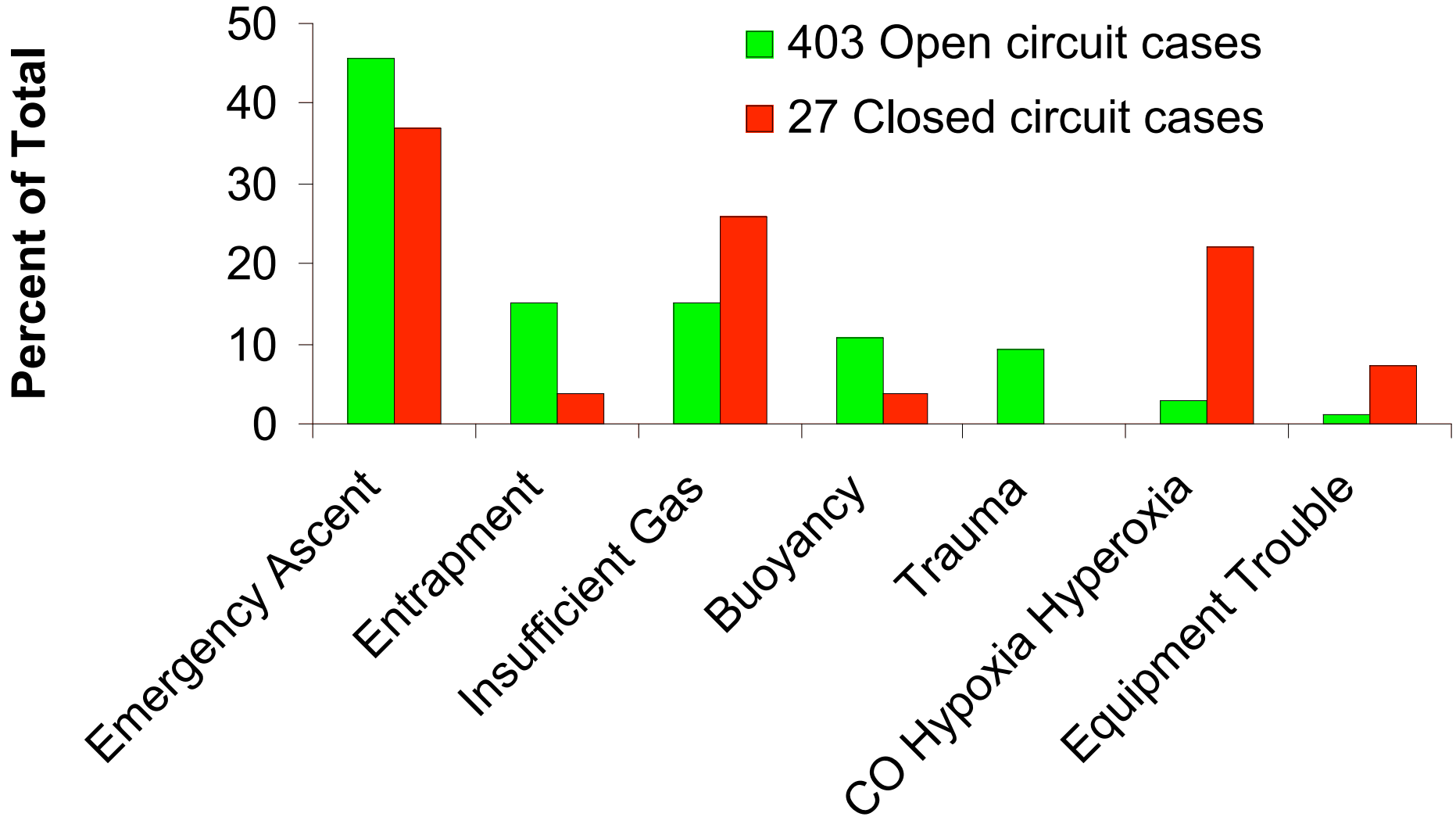
11 Rebreather Procedure (1)

- Did not check gas or turn on displays
- 2 – rig electronics not turned on
- O_2 valve not on
- Setup: O_2 sensor incorrect position,O_2 valve partly blocked, loose connections
- Predive malfunction, used semi-closed mode instead
- Gave display to student, relied on auto

11 Rebreather Procedure (2)

- Gas leak in loop & bad O_2 sensor
- Removed rig in wreck to bypass obstruction
- Gas supply valve set to external, not internal source
- Mouthpiece valve sticking

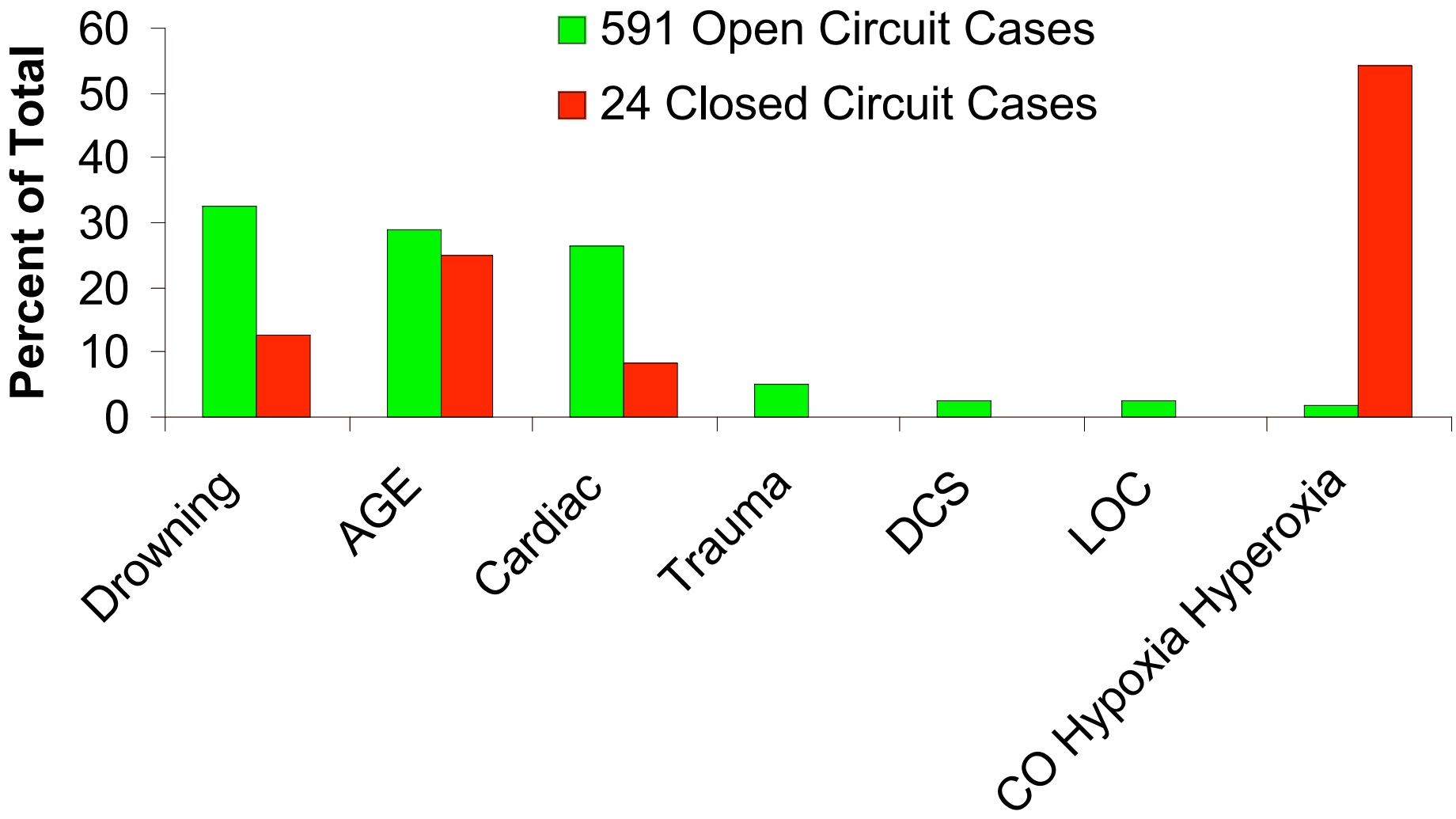
Harmful Action



4 Insufficient Gas

- Direct ascent from 250 fsw, DCS/AGE
- Gas leak in breathing loop, rapid ascent, AGE
- LOC on bottom, O/C bail-out not used
- O/C then buddy-breathe from 187 fsw, drowned

Disabling Condition



Inappropriate Gas (O_2 Toxicity or Hypoxia)

- O_2 Toxicity (5 seizures)?
  - On switch to O/C, LOC, drowned
  - At 35-40 min, LOC, brought to surface, O_2 tank empty
  - Caught in downdraft from 28 to 82 fsw
  - 2 unknown root causes
- Hypoxia?
  - 10 – found on surface or U/W
  - 13 – LOC early in dive

Other

- 26 – solo, separated, lost contact (~33%)
- 14 – practically no information (~20%)
- 8 – semi-closed (10%)
- 4 – kit, homemade, or modified
- Separated from buddy at 268 fsw, shark bite but unknown if pre- or post-mortem
- Dragged by large speared grouper from 140 to 190 fsw, LOC on bottom

Rebreather Fatality Investigation Meeting

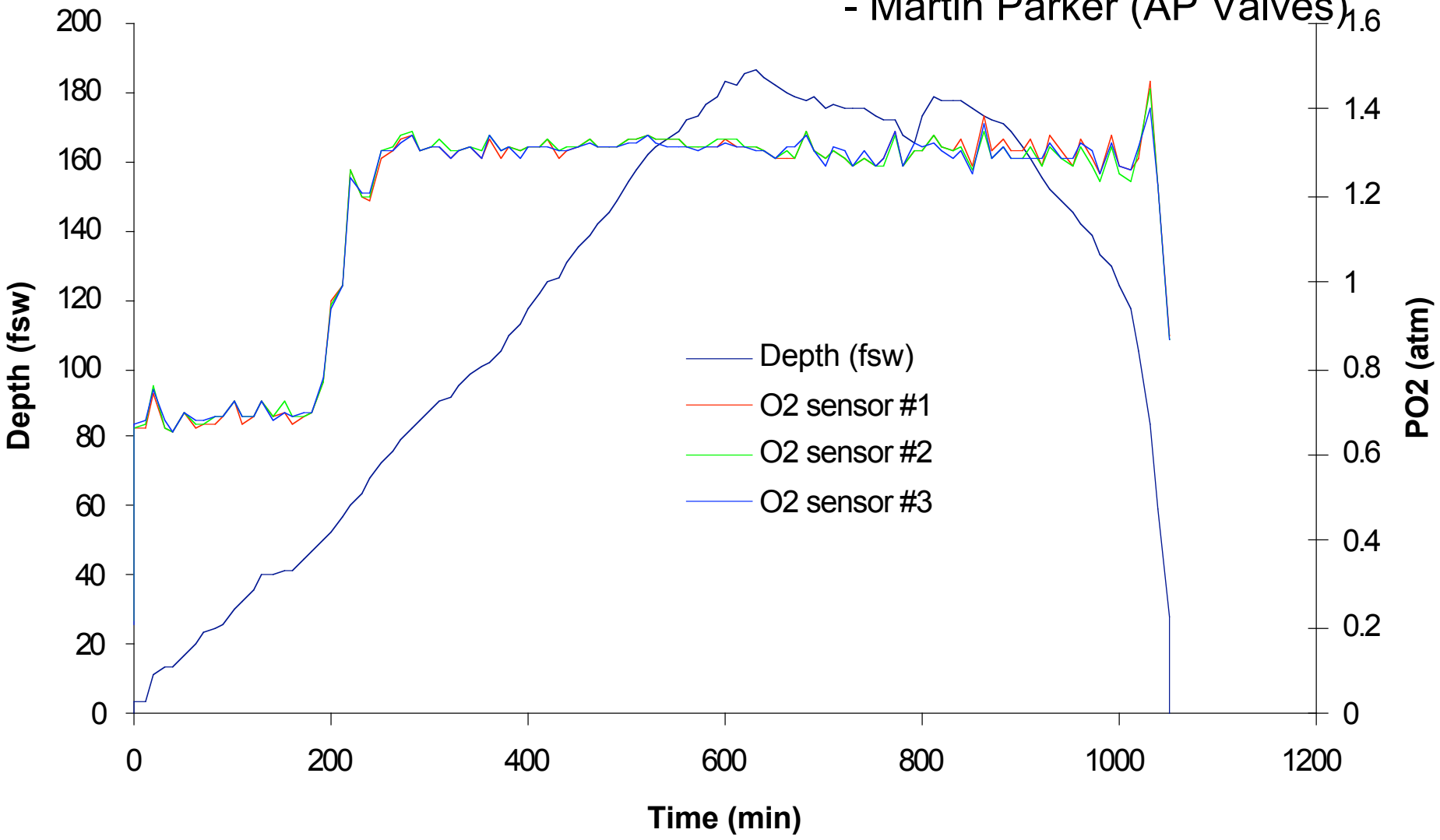
- DEMA 2007, Orlando, 55 attendees
- Objectives
  - Discuss how the diving community might rationally approach rebreather fatality investigation

Diving Fatality Investigations

- Medical factors
  - Coroner's autopsy report
- Equipment factors
  - Chain of custody starting at dive site ("CSI")
  - Test lab ($5,000 per day)
  - Equipment error vs. human error
- Procedural factors
  - "black box"

“Black Box”: Pulmonary Barotrauma

- Martin Parker (AP Valves)



Diving Fatality Reporting Form

This reporting form is entirely confidential.
This is not an insurance claim form.
Send form to:
Divers Alert Network, Duke University Medical Center
6 West Colony Place, Durham, North Carolina 27705
Fatality Research (919) 684-2948, ext. 237

Name: _____ ***Accident Date:*** _____ ***Notified(date):*** _____

Case #: _____ ***Follow up:*** ☐ **YES** ☐ **NO** (foreigner) ☐ **NO** (not recreational)

Diver Class:

☐ Recreational ☐ Technical ☐ Rec/Tech ☐ Student ☐ Task
☐ Public Safety ☐ Uncertified ☐ Unknown ☐ Missing

Available Information:

Date/Location/Contacts:
☐ complete ☐ incomplete ☐ missing

Diver Info/Experience:
☐ complete ☐ incomplete ☐ missing

Diver Health:
☐ complete ☐ incomplete ☐ missing

Dive Data:
☐ complete ☐ incomplete ☐ missing

Accident Scenario:
☐ no witness ☐ complete ☐ incomplete ☐ missing

Equipment Test:
☐ included ☐ tested, N/A ☐ not tested ☐ not retrieved ☐ unknown ☐ missing

Breathing Gas Test:
☐ included ☐ tested, N/A ☐ not tested ☐ none to test ☐ unknown ☐ missing

Autopsy:
☐ no body ☐ included ☐ autopsy done, N/A ☐ no autopsy ☐ coroner summary
☐ death certificate ☐ unknown ☐ missing

Risks Other than Death

- Legislative
  - Local ordinances
  - Federal terrorism laws
- Private litigation
- Public perception that the rebreather community is indifferent to a perceived problem

“Perception is reality”

Acknowledgements

- Gavin Anthony (Qinetiq)
- Dynasty Marine Associates
- Bill Hamilton
- Pete Nawrocky (DiveRite)
- Martin Parker (AP Valves)
- Pete & Shas Readey (Steam Machines)