Survey of Air and Oxygen-with-Air Decompression Practices

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Project description

- Worldwide survey of air and air-based procedures using additional oxygen.
- Responding to an ongoing Navy need for a uniform set of modern, air-based decompression tables.
- Conducted under the guidance of the USN "decompression team"

"Air-with-oxygen"

- Covers all air-based diving with oxygen:
  - Mixtures enriched with oxygen, or
  - Oxygen breathing during dive or decompression.
- Includes a wide scope of dive patterns:
  - air, with air decompression
  - oxygen enriched air (N_2O_2, "nitrox")
  - air with oxygen decompression, in water or chamber
  - oxygen-nitrogen mixes using rebreathers

What is USN interest ?

- The Navy's decompression procedures:
  - Developed in a piecemeal fashion for 50 years
  - Not compatible with each other
  - Variable levels of reliability
- Efforts to correct this deficiency with the USN93 statistically based tables were not accepted by the Fleet.

Project objectives

- Find out what is out there, what is the experience:
  - How do other diving organizations do air diving?
  - What air-with-oxygen procedures are used?
  - How well do they work?
- Obtain or identify tables, procedures, results, reliability.

What we would like

- Experience and scope of dive patterns:
  - Air dives with non-USN procedures.
  - Sur-d/O_2, inwater O_2, enriched air, rebreathers, combinations
- Scope of diving by categories
  - Time, depth, table, procedure; #/year
  - Not interested in individual dive sheets
- Table, algorithm, method details
- Documented DCS profiles

Survey has two phases

- Phase 1
  - determine who has information
  - what data is available
  - what form
  - how much
- Phase 2
  - obtain summary data
  - compile report with observations

Survey sources

- Partner navies and other navies
- Commercial diving companies
- Regulators, occupational agencies
- Table developers' collections
- Scientific diving organizations
- Specific project teams
- ??? Serendipitous sources ???

Some terms used

- Pattern: Type or mode of diving
- Table vs schedule: We say table
- Oxygen-enriched air: O_2N_2, OEA, EAN, nitrox
- Sur-d or sur-d/O_2 or sur-d/air (yuk)
- DCS, not DCI here
- ATA or ata not for partial pressure
- fsw and msw are units of pressure
  - Conversion 3.2568 not 3.2808 fsw/msw

What problems existed ?

- Oxygen toxicity problems on Sur-D
- DCS on certain dive profiles
- Unclear as to how USN incident rate stacks up against rest of world
- Need for integrated tables to shift patterns of diving
- Old tables were just that, old

Dive patterns of interest

- Air with inwater air deco
- Air with inwater O_2 or O_2N_2
- Air with sur-d/O_2
- Air with inwater O_2N_2 and combinations
- O_2N_2 with inwater deco or sur-d
- Constant PO_2

Special procedures

- Altitude
- Multi-level

Deco Team guidelines were excellent and ambitious

- Thorough, to the point
- But not necessarily attainable within the 4 month time frame

About each pattern (Our hopes)

- How used: Rules, J-factors, etc.
- Experience base
  - Records kept
  - Profile precision
    - » Only the table used, or
    - » The actual profile
  - Storage method
  - How did they know there was no DCS
  - Commercial & navies report DCS, others don't

PROBLEM AREAS (or so they think)

- NAVY SAFETY CENTER 1971-1996
- 38,172 AIR DECOMPRESSION DIVES, 40-190 FSW
- 207 CASES OF DCS
- OVERALL DCS INCIDENCE 0.54%

Lower than the 2% they are willing to accept!

AIR DECOMPRESSION
DIVES GREATER THAN 2%

SCHEDULE	DIVES	DCS	%
80/70	50	3	6.0
190/50	91	4	4.4
100/60	137	5	3.6
140/40	86	3	3.5
50/220	59	2	3.4
170/40	82	2	2.4
150/25	192	4	2.1

USN SUR D 02
RISKIEST SCHEDULES

SCHEDULE	DIVES	DCS	%
130/80	52	3	5.8
120/60	99	3	3.0
120/70	125	2	1.6
120/80	64	1	1.6
140/25	88	1	1.1

The survey:
What we looked for

- Extensive experience with USN Air
- Other non-USN air tables
- Oxygen-with-air diving experience

- We focussed on data (but not "primary")
- This may not have been the best approach
- Initial data base just as important
- Did not try to classify DCS or do analysis

The real world, briefly

- Lots of information but hard to get at
- Very few summarized records
  - Or, lots of records, but in old boxes
- Very few computer data bases
- Interview process too optimistic
  - Once we got in contact, no time for this
- We had to live with what the source wanted
- Often poor linkage of DCS with the dives

Who we surveyed

- Military (10)
- Commercial diving companies (14)
- Developers and regulators (4)
- Scientific diving organizations (10)
- Scuba and recreational organizations (5)
- Total 43 organizations
- Survey results in under 4 months

Total dives reported on

- From all sources the report compiles data from a little more than 1,5 million dives.

- 1 million are no-stop air and OEA dives
- 500k are air, sur-d O2, or decompression
- 25k are from a variety of rebreathers

Best results

Organization	# dives	DCS	% DCS
Smithsonian	35,000	0	0.0
NURC / UNC	37,941	6	0.0002
Woods Hole	17,335	1	0.006
Royal Navy	58,933	6	0.010
NOAA	152,991	16	0.010
BSAC	600,000	85	0.014
Oceaneering	104,933	34	0.032
Dan Survey	198,167	67	0.034 *

Almost all are no-stop or OEA dives

Worst results

Organization	# dives	DCS	% DCS
Comex	11448	67	0.585*
USN	38,172	207	0.542
IFEM	4,455	15	0.337
Norwegian Petrol	61,411	38	0.062
American Oilfield	89,729	52	0.058
Selmer/Swed	4,200	2	0.048

Almost all are decompression dives with air deco

Procedure Changes

- Comex changed tables and dropped rate to 0.033 -- they added OEA50 to the decompressions
- USN dropped rate by 50% went to dry suits instead of hot water suits,
  - double jump table
  - eg: 120 fsw uses 140 table

Almost all are decompression dives with air deco

More findings

- No one does all these patterns of diving
- Non-military, non-commercial sources do innovative diving and some have data

- DCS is basically not a major problem
  - Eliminated by reducing stress of dives
- Very little DCS with O_2N_2
- Little inwater air deco; mostly no-d or sur-d

Air diving

- Some big users of USN air by the book
  - NOAA, UNCW; others who had no data
  - Many smaller companies & navies
- Several use USN tables but modified;
  - Oceaneering, SubSea, SCS (AOD)
  - Many use O_2N_2 for deco
- Many mods of USN air tables
- Many different air tables; not entirely clear

Air diving continued

- No-stop dives reported were on average at 60% of the no-stop limit.
  - This was a significant finding
- These resulted in an insignificant DCS rate
- Average depth < 100 fsw
- A key to lowering recreational DCS rate if ever applied

Other air tables

- British Navy
- DCIEM
- Comex/French MOL
- Dutch NDC
- Norwegian
- Finnish Navy
- Oceaneering
- SubSea
- IFEM G-L
- French Navy
- Saipem & contractors
- Sweden: Swen88
- BSAC
- DSAT/PADI
- JAMSTEC

Oxygen enriched air; O_2N_2

- OEA, EAN, EANx, nitrox
- Mostly done with USN and EAD (=PN_2 levels)
- Most navies use this for rebreathers
- For commercial use, the situation has to be just right to be worthwhile
- Some major projects.
- Lots of use in scientific and recreational worlds
- Lots of use in air decompression

Air with in water oxygen or O_2N_2

- Several major projects with this method
  - risk of oxygen toxicity
- DCS record quite good
- Rare in commercial or military
- Advantage for science projects that they do not have to prepare mixes
- Used in civilian sport diving extensively

Special techniques

- We learned little about diving at altitude because existing "Cross Corrections" are conservative and work well.
- Several clever multi-level variations use existing repet tables
- Repetitive diving problems are not solved
  - Almost all we have is gas loading techniques
  - Bubble growth models should be incorporated

Sur-d/O_2

- Very popular in US, less so in North Sea
- It works, especially with good tables
- Some of the new tables address sur-d
- New sur-d tables:
  - Norwegian (adopted J-factors)
  - IFEM L-G Bubble Growth model
    - » Tested, with some success eventually
  - Dutch, conventional experience
  - DCIEM: good, used arbitrary penalty

The British Health & Safety Exec

- Extensive data collections since 1983
- Thousands of dives; table itself not an item
- Some findings:
  - DCS can be controlled by reducing dive time
  - Hot water suits lead to more DCS
  - Sur-d got the blame; however the toughest dives were sur-d

Where to go from here?

- No set of tables solves the whole problem
- Existing tables have a good track record
- Several methods offer promise
- Uniform set of tables will involve a new program but can use existing capability
  - One of the new USN algorithms
  - Or one of the good multipurpose algorithms with some experience
- UHMS Validation Workshop concept good

How this applies to sport diving

- The key to the successful table sets were:
  - Following no-stop limits
  - Using controlled ascent times
  - Applying enriched air on no-stop dives
  - Modifying no-stop limits by default of gas supply
  - Limiting dive stress - better planned dives

What's next?

- Analysis of diving tables collected
- Comparing dive / deco times to existing modified tables
- Creating a new set of integrated tables with emphasis on:
  - Enriched air use
  - shorter no-stop times
  - addition of enriched air for decompression

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