IFEM-EBSDC NITROGEN – BASED DIVING TRIALS DATA BASE

Collected, Structured and Utilized in the Design and Evaluation of Decompression Analysis Methods

Sources of Diving Trials Data

USN Experimental Diving Unit
USN Medical Research Laboratory
USN Medical Research Institute
RN UK Royal Naval Personnel Laboratory
Canada Defense and Civil Institute for Environmental Medicine

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# 12-12-91
Foreword

The extensive laboratory “Diving Trials” documentation within this report represents detailed descriptions and analysis of human subject exposures to compression and subsequent decompression procedures simulating diving activity, and with results interpreted by evaluation of occurrence or absence of decompression sickness features, in each Trial and Subject.

The nitrogen-related diving trials data base contains information on 6,551 man diving trials performed at U.S. Navy, Canadian Forces and UK Royal Navy laboratories over a multi-year period, indicated by the date of the projects reports. Approximately half of the man-dives data were co-operatively supplied by the combined assets of U.S. Naval Medical Research Institute (NMRI), the Navy Experimental Diving Unit (NEDU), and the Naval Medical Research Laboratory (NMRL).

The scope of these Decompression Trials Data is related to the cited “Air” Diving and other “Nitrogen-Oxygen” procedures, including the breathing gas mixtures used, and to the specific “schedules” of the decompression exposures used.

The purpose of IFEM-EBSDC in collecting and analyzing this large amount of well controlled and well documented testing was to develop a new model for inert gas exchange which could be used to develop improved nitrogen-based decompression schedules. The IFEM-EBRDC Decompression Analysis Program (DAP) is a computer model designed to simulate gas exchange physiology in multi-tissue compartment models for the diving environments. An auxiliary data base program was designed to collect the output from the analysis program.

Analysis of the “Diving Trials” procedures and results by the IFEM Environmental Biomedical Stress Data Center included both the then conventional USN and other navies method of deriving “Values of Excess Tissue Inert Gas Partial Pressure” (ΔP) (17) and the IFEM Data Center method of deriving an Index for Degree and Time Course of a “Bubble Growth Index in such Tissues” (BGi) (19).

* * *

This transmission includes the Input files for the DAP program and hard copy printouts of the Files. There are 14 separate Files containing varying numbers of profiles. The analysis program was written for the DOS operating system so that the Input Files are written in ASCII text. A description of the setup and terminology used to construct and interpret these Files starts on page 4.

* * *

Each File Name indicates the Source Organization which performed the exposures. Files are listed on page 3 with the codes for “Source” used in each file and the “Source” appears in the first line, identified as LABEL of each profile. Details of “Source” are found on page 7. Dates of Sources are included in Source files.

N2DB-DES2.DOC
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<thead>
<tr>
<th>Hard Copy Printout</th>
<th>File Name</th>
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<th>Reference</th>
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<td>EDU 1351 R</td>
<td>14</td>
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</table>

N2DB-DES2.DOC

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CONSTRUCTION OF FILES

Header: Each file has a header of several lines of text containing summary information about Sources of the profiles included in the file. These comment lines begin with "//" (without quotation marks) and are not processed by the programs.

The header is followed by a blank line.

Exposure Set-up The actual input always begins with set up lines containing general information for the dive.

LABEL This line is a series of descriptor codes used by the DAP analysis program or the DAP data base program. Always the first line in a profile. Details for constructing the LABEL are found on page 6.

- Bottom depth
- Bottom time
- Source
- Descriptor string - Details and codes are listed on page 8 and 9 under Descriptor field

Example: LABEL 80 85 "EDU1351R" AIR1, OXY2, SURD3, S1, EXP8, DCS1, B0, MB1, W8, D0, T0;

Describes a dive to 80 ft for 85 min where the diver breathed air during the dive and oxygen during decompression. Decompression was SurD/O2. The source was US Navy Experimental Diving Unit Report 13-51 (ref 14).

DEFGAS Lists all breathing gases used during the dive. For convenience we list in same order all the time. May be capital or small letters.

Example: DEFGAS O2 N2 HE;

DEFMIX n Defines the %age of each gas listed in the DEFGAS command in each breathing gas mixture. n identifies the mix. At least one DEFMIX command is required for each dive. DEFMIX 1 is always air.

Examples: DEFMIX 1 20.7 79.3; Specifies diver is breathing air
DEFMIX 2 100.0 0 0; Diver is breathing 100% O2
DEFMIX 3 5.0 0 95.0; Diver is breathing a helium-oxygen mixture
Describe exposure  The commands below describe the actual exposure and are used in any order required.

SAT n  SATURATION Saturates tissues to current breathing mixture. Usually air at sea level to start the exposure. The number n identifies the gas mixture breathed by the diver (DEFMIX).

Example: SAT 1;  At start of dive diver is saturated with DEF MIX 1 - air

LINEAR n  Perform a linear maneuver to new depth n. May use LIN n

Examples:

LINEAR 80;  Diver goes to 80 feet at RATE (Default rate = 10 FPM)

LIN 50 RATE 5 MIX 2;  Diver goes to 50 feet at 5 feet/min and breathes DEF MIX 2

LEVEL n  Stay at depth for given time n. May use LEV n

Example: LEVEL 30;  Diver stays at depth for 30 minutes

MIX n  Sets the current breathing mixture: n denotes the DEF MIX command

Example: MIX 2;  Starting at this point diver breathes DEF MIX 2.

LINLEV m n  Command to perform sequence of maneuvers alternating linear and level maneuvers. m is target depth, n is time at target depth.

Example:

LINLEV 80 3 70 6 60 10;  Diver goes to 80 feet, stays at 80 feet for 3 minutes, goes to 70 feet, stays 6 minutes, goes to 60 feet, stays 10 minutes.

MIXLEV n m  Command to perform sequence of alternating MIX and LEVEL maneuvers at constant depth. n is MIX number, m is time.

Example:

MIXLEV 2 15 1 5 2 15 1 5;  Diver breathes O2 for 15 minutes, air for 5 minutes, O2 for 15 minutes, air for 5 minutes.
RATE n Sets the ascent or descent rate to n. Rate retains its value until changed. (In feet, default is 10 FPM)

TIME Overrides rate for current linear maneuver. Does not alter default rate.

RESET Resets the clock to time = 0. In these files the clock is reset at end of bottom time and on arrival at surface at end of decompression phase.

NEXTDIVE Identifies the start of another profile. Required at the beginning of every profile in a file except the first one.

RATE1 Sets first ascent rate for a decompression calculation probably not used here.

STOP; Last line in file, required.

DEC Should not be used in these files, Indicates that program should calculate a decompression.

DEPTH n Sets the depth. Usually used when descent time not available.

ADDITIONAL INFORMATION CRITERIA for constructing a LABEL command and the DESCRIPTOR CODES used are described here.

The LABEL command in the DAP program allows a unique set of identification codes to be attached to each dive. The LABEL codes could be searched in both the DAP analysis program and the DAP Database programs allowing for specific dives to be retrieved. With this capability, a standardized code convention was adopted to identify all dives in the International Environmental Biomedical Data Center data bases.

LABEL command syntax:

LABEL <bottom_depth> <bottom_time> <source> <descriptors>

where,

<table>
<thead>
<tr>
<th>&lt;bottom_depth&gt;</th>
<th>Depth of dive (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;bottom_time&gt;</td>
<td>Bottom time (minutes)</td>
</tr>
<tr>
<td>&lt;source&gt;</td>
<td>Source of the data</td>
</tr>
<tr>
<td>&lt;description&gt;</td>
<td>Pertinent information about the exposure described below.</td>
</tr>
</tbody>
</table>
SOURCE indicates the source of the data. For laboratory data, the reporting agency is identified with capital letters which identify the institution, numbers identify a specific report, i.e. EDU557R or CANR28X. The last character of the source name for laboratory data, a in list below, either an R or X, indicates whether the input files were made using data from a published report (R) or from data provided by another source (X), such as Naval Medical Research Institute. The source code is always enclosed in quotation marks. The following source codes have been used in these files.

<table>
<thead>
<tr>
<th>Laboratory Data - Report source</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Navy Experimental Diving Unit</td>
<td>EDU # a</td>
</tr>
<tr>
<td>Canadian Forces or Defense and Civil Institute</td>
<td>CAN # a</td>
</tr>
<tr>
<td>for Environmental Medicine</td>
<td>CANDID 9 a</td>
</tr>
<tr>
<td>U.S. Naval Medical Research Institute</td>
<td>DC8 a</td>
</tr>
<tr>
<td></td>
<td>RI # a</td>
</tr>
</tbody>
</table>

The number(#) can be all or part of the identification number of the report. In some of the Canadian reports the last character in the number part is a letter which refers to the series described in the report. In a few cases the number is the character set UNK which identifies these dives as unpublished data provided by the Naval Medical Research Institute (NMRI). The source name indicates that they are exposures provided to NMRI by DCEIM.

DESCRIPTOR FIELD Used to list all pertinent information about the exposure. The field can be up to 80 characters long. Description codes are separated by a unique delimiter to increase readability: a comma was used. The following descriptor codes have been adopted:

DESCRIPTION
Divers' breathing gas during bottom time (use one):
- Air
- Helium/oxygen mix
- Nitrogen/oxygen mix
- Helium/oxygen/nitrogen mix
- Other

Divers' breathing gas during decompression (use one or more):
- Air
- Oxygen
- Nitrogen/oxygen (different % from bottom mix)
- Helium/oxygen (different % from bottom mix)

Decompression procedure (use one):
- No Decompression
- Standard staged in water decompression
- Surface Decompression
- Transfer under pressure (Bell Bounce)
- Saturation
- Self-contained diving
- Submarine escape
Sub procedure (use one)
   No sub procedure                  S0
   No water stops with surface decompression   S1
   In-water O2 with surface decompression     S2

Number of exposures (divers)                     EXP#
Number of cases of decompression sickness      DCS#
Number of divers with some kind of symptoms    SYM#
Number of DCS cases treated with recompression B#
Number of DCS cases not treated                MB#
Number of divers wet during exposure          W#
Doppler monitoring conducted (0=No, 1=Yes)     D0 or D1
Temperature controlled (0=No, 1=Yes)           T0 or T1

The # in some codes denotes inserting an integer of any size pertaining to the description,
   i.e. EXP104, DCS4, B3, MB1, W0

Descriptor codes may be entered in any order, however an attempt was made to keep the order the same in all files. Not all descriptor codes are required, such as when no information is available or some information is not considered pertinent.

Examples of some LABEL commands:

LABEL 300 10 “CANDID9X” AIR1, AIR1, STD2, S0, EXP4, DCS2, B1, MB0, W0, T0,D0
LABEL 170 30 “EDU545R” AIR1, AIR1, SURD3, S0, EXP33, DCS3, B1, MB2, W33, D0, T0
LABEL 74 240 “RI8697X” NOX3, NOX3, STD2, S0, EXP4, DCS1, B1, MB0, W0, D0, T0
LABEL 110 40 “EDU1351R” AIR1, OXY2, SURD3, S1, EXP2, SYM0, B0, MB0, W2, D0, T0

UNITS OF MEASUREMENT

<table>
<thead>
<tr>
<th>Unit</th>
<th>Measured in</th>
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</thead>
<tbody>
<tr>
<td>Depth</td>
<td>feet</td>
</tr>
<tr>
<td>Time</td>
<td>minute</td>
</tr>
<tr>
<td>Rate</td>
<td>feet/min</td>
</tr>
<tr>
<td>Pressure</td>
<td>feet sea water</td>
</tr>
</tbody>
</table>

N2DB-DES2.DOC
Examples:
Three actual input files are given below as examples. They contain only the material on the left side in capital letters. The explanatory notations on the right side were added in small type.

NEXTDIVE; Air dive to 120 feet for 50 minutes with SurD/O2 decompression
24 divers, 1 DCS, 4 wet divers, 1 diver, Doppler monitoring

LABEL 120 50 "CAN18NR" AIR1,OXY2,SURD3,S0,EXP24,DCS1,B1,MB0,W4,D1,T0;
DEFGAS O2 N2;
DEFMIX 1 20.7 79.3; Breathing gas mix - Air
DEFMIX 2 100 0; Breathing gas mix – 100% oxygen
SAT 1; Saturate diver on air at sea level
DEPTH 120; LEVEL 50; Assume instantaneous descent, no details provided. 50 min at 50 feet
RESET; End bottom time, reset clock, start decompression
RATE 60; Set descent rate to 60 feet per minute
LINLEV 40 2.67 30 6.83; Go to 40 feet at 60 ft/min, stay 2.67 min, to 30 feet and stay 6.83 min
LINEAR 0 TIME 2; Go to surface in 2 minutes
MIXLEV 1 4; Breathe air (mix 1) for 4 minutes
MIX 2; Change to Mix 2 (100% O2)
LINEAR 40 TIME 1; Go to 40 feet in 2 minutes
MIXLEV 2 30 1 5 2 12; Breathe O2 for 30 min, breathe air for 5 min, breathe O2 for 12 min
LINEAR 0 TIME 2; Go to surface in 2 minutes
MIX 1; Breathe air
RESET; End of decompression, reset clock
LEVEL 240; LEVEL 120; Track gas physiology on surface
NEXTDIVE; Air dive to 80 feet for 123 minutes, Standard air decompression
10 divers, 1 DCS, 10 divers wet, Temperature measurements

LABEL 80 123 "EDU885X" AIR1,AIR1,STD2,S0,EXP10,DCS1,B1,MB0,W10,D0,T1;
DEFGAS O2 N2;
DEFMIX 1 20.7 79.3; Breathing gas mix Air
SAT 1; Saturate diver on air at sea level
LINEAR 7 TIME 0.2; Go to 7 feet in 0.2 minutes
LEVEL 1.9; Stay for 1.9 minutes
LINEAR 67 TIME 2.7; Go to 67 feet in 2.7 minutes
LINEAR 80 TIME 0.9; Go to 80 feet in 0.9 minutes
LEVEL 117.3; Stay at 80 feet for 117.3 minutes
RESET; End of bottom time, reset clock, start decompression
LINEAR 30 TIME 0.9; Go to 30 feet in 0.9 minutes
LEVEL 13.9; Stay at 30 feet for 13.9 minutes
LINEAR 20 TIME 0.2; Go to 20 feet in 0.2 minutes
LEVEL 32.1; Stay at 20 feet for 32.1 minutes
LINEAR 10 TIME 0.3; Go to 10 feet in 0.3 minutes
LEVEL 168.2; Stay at 10 feet for 168.2 minutes
LINEAR 0 TIME 0.5; Go to surface in 0.5 minutes
RESET; End of decompression, reset clock
LEVEL 240; LEVEL 120;
Dive on Nitrox mixture
2 divers, 1 DCS

LABEL 80 60 "RI8697X" NOX3,NOX3,STD2,S0,EXP2,DCS1,B1,MB0,W0,D0,T0;
DEFGAS O2 N2;
DEFMIX 1 20.7 79.3; Breathing gs mix - Air
DEFMIX 2 35.0 65.0; Breathing gas mix - 65% N2 – 35% O2
SAT 1; Saturate diver on air at sea level
LINEAR 30 TIME 0.4; Go to 30 feet in 0.4 minutes
LEVEL 0.2; Stay at 30 feet for 0.2 minutes
MIX 2; Change breathing mix to nitrox (Mix 2)
LINEAR 80 TIME 0.8; Go to 80 feet in 0.8 minutes
LEVEL 58.6; Stay at 80 feet for 58.6 minutes
RESET; End bottom time, reset clock, start decompression
LINEAR 30 TIME 0.8; Go to 30 feet in 0.8 minutes
MIXLEV 1 0.2; At 30 feet breathe mix 1 (air) for 0.2 minutes
LINEAR 10 TIME 0.4; Go to 10 feet in 0.4 minutes
LINEAR 0 TIME 0.3; Go to surface in 0.3 minutes
RESET; End of decompression, reset clock
LEVEL 240; LEVEL 120;
NITROGEN-BASED DIVING TRIALS

Sources of Data


N2DB-DES2.DOC
12. Van Der Aue, O.E., Brinton, E.S. and Kellar, R.J. Surface decompression, derivation and testing of decompression tables with safety limits for certain depths and exposures. US Navy Experimental Diving Unit Report No. 5-45. Panama City, FL, 1945.


