ABSTRACT

Sterk W, Hamilton RW, eds. 1991. Operational dive and decompression data: Collection and analysis. EUBS Report (DATA)17-8-90. Amsterdam: Foundation Hyperbaric Med. (ISBN 90-9004500-7)

Stimulated by an increasing number of operational dive data bases in use, the basing of some North Sea legislation on data base results, and the growing use of electronic dive recorders prompted this attempt to review this field as it currently exists. The Workshop, which included virtually all major users of diving and decompression-oriented data systems, began with a questionnaire surveying existing data bases and concludes with this report. Several diving data bases were reviewed, including the venerable International Decompression Data Bank and its successors at the University of Pennsylvania, the Canadian DCIEM's CANDID data base, two successful commercial diving companies' data bases, a more general commercial diving data base oriented towards a diving contractors association, and several collections of recreational diving data, including the U.S. Divers Alert Network data base for diving accidents and decompression sickness incidents. A thorough review covered the U.K. Department of Energy's air diving data base; discussion focussed on the commercial diving guidelines that have been issued as a result of it. Some cautions concerning the veracity of data from commercial diving logs were expressed. The importance of having an objective for the application of a data base was stated and reiterated; improving decompression techniques is a major aim. The types of data and scope of current approaches to analysis were covered. These include traditional gas-loading analysis of individual profiles, and the relatively new and extremely effective limits of maximum likelihood statistics to dive profile analysis. The limits of primary data for use in decompression modeling were stated and discussed. The need for data quality and veracity is being addressed in part by a new technical approach in the form of electronic dive profile recorders. These can either be on-line with a display for the supervisor, or passive and carried by the diver, with data transferred to a computer after the dive. The off-line, diver-carried recorders can provide the needed profile information along with traditional methods for other data, but the on-line devices may be more acceptable to the dive team. Recommendations for their use were discussed, along with formats for transcribing the data into readable form. The Workshop did not endeavor to standardize any aspects of dive profile recording and analysis, but it did serve to begin a dialogue among the practitioners, and it served also to summarize the state of the art.

THE NETHERLANDS NATIONAL DIVING CENTER DATA BASE

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Let me begin with some history. My interest in the collection of operational dive data started in 1975. At that time I was asked to develop decompression tables for long exposure air dives to be used mainly in the Eastern Scheldt. After analyzing the tables existing at that time, developing a computational model, and doing a number of test dives which included doppler monitoring, the tables were put to work by the end of 1977. From the start I required feedback of all dives made on my tables. This procedure was later reflected by consensus in the UHMS workshop on validating decompression tables (Schreiner and Hamilton, 1989). Initially the collection of dive data was done only on paper, and I must confess that several thousands of such "ancient" dives are still waiting to be fed into our data base. The success of the long exposure tables led to a set of standard tables in 1980. The requested feedback increased in number, so I started to organize a computer data base.

INITIAL DATA BASE (dBASE II)

DATE **NAME** **COMPANY** **LOCATION**
START TIME **END TIME**
DIVE TIME **DIVE DEPTH**
TABLE USED (CODE)
REPET DIVE Y/N **REPET INTERVAL**
TABLE TIME **TABLE DEPTH** **DECO TIME**
WORK DESCRIPTION **REMARKS**

Figure 1. The initial data base fields.

NDC DATA BASE (dBASE III PLUS)

LOG NR ***RECORD NR***
DATE **NAME** **COMPANY** **LOCATION**
DIVING GEAR ***DIVING MIX***
START TIME **END TIME**
DESC TIME **DIVE TIME** **DIVE DEPTH** ***JOJO Y/N***
TABLE USED (CODE)
SURD Y/N ***SURF.INTERVAL*** **REPDIVE Y/N** **REP.INTERVAL**
TABLE TIME **TABLE DEPTH** **DECO TIME** ***UPTD***
WAVE HEIGHT ***WATER TEMP*** **WORK DESCRIPTION**
WORKLOAD L/M/H/VH ***DCS Y/N*** **REMARKS**

Figure 2. Fields of the data base presently in use. The added fields are printed in italics.

The initial data base is fairly simple (Figure 1), the computer being a Z-80, the program written in dBase II. As only air dives were collected, it was thought to be sufficient to have dive depth and time to describe the dive profile, while table code provided the decompression profile, including the use of oxygen. Remarks included all additional information, including incidents and accidents.

In 1988 our National Diving Center or NDC decided to adopt my computer model for the generation of decompression profiles. Notwithstanding the availability of a computational model, it was thought necessary also to prepare a set of standard tables, which was published as a loose leaf system, to enable easy update if required and to prevent them from becoming "law." Feedback of data of all dives made on these tables remained my rigid request. Having experience over more than a decade in the collection of such data, I think it necessary that forms to be filled in should as simple as possible. Divers hate paperwork; too complex questionnaires give faulty information. Still, improvements to the initial data base had to be made in order to get more accurate information on the dive profile. It was agreed to set up the data base under the auspices of NDC and that it would be maintained by my company Dadcodat. The data base system was updated to dBase III Plus; a further update is still waiting for dBase IV to be completely debugged. The "mother computer" is an 80386. However, the diving companies have been provided with a Clipper program that can run on an IBM XT or better, to collect their data. To keep it simple, the form to be filled in should occupy not more than one screen. This limited us to the fields shown in Figure 2. Descent time and "yoyo" are recorded to enable us to indicate dives that differ significantly from a square profile. "Yoyo" is defined as coming one or more times to the surface during the dive, or ascending over 10 metres from maximum depth one or more times. UPTD, or if you wish OTU (oxygen tolerance units), is recorded for each dive, based on our previous work on oxygen toxicity. Furthermore, some fields are added to indicate the diving circumstances.

The main purpose of the data base is to protect the reliability of the NDC tables. The requirement is that the incidence of DCS on any schedule should be lower than 0.5%, predicted by open sequential analysis as described by Homer and Weathersby (1985). Any other information that can be extracted from these data to increase our knowledge to design better decompression procedures or otherwise contribute to the safety of diving is heartily welcomed.

Access to the data base can only be obtained after permission of the so called Medical Platform of NDC. This procedure was agreed upon to ensure the privacy of divers as well as diving companies, but has nothing to do with company secrecy or such things. In principle, anybody really interested can get access to the data.

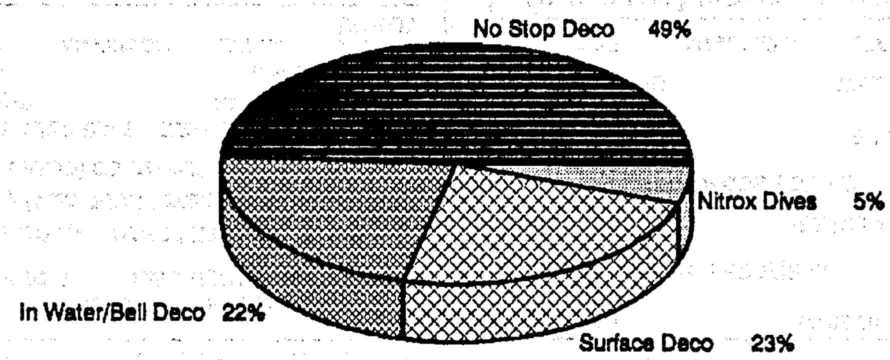

Figure 3. Decompression method used in 25902 dives which are presently in the NDC Data Bank.

At the time of preparing this presentation, nearly 26000 dives were in the data base, and about 3000 are waiting to be included (Figure 3). Interesting about these data is that nearly all are based on the same computational decompression model. Nearly half the data concern no-stop decompression. Enriched air or nitrox diving, although attractive in minimizing decompression time, is still not widely used, being limited to only about 5 %. Inwater or bell decompression and surface decompression are evenly represented.

The scatter plot in Figure 4 displays the diving activity in terms of dive depth against bottom time. The line in the graph represents the U.K. Department of Energy (DOE) limits of bottom times at the various depths. Many of our dives exceed these limits considerably, including especially but not limited to our long exposure dives. The nitrox dives, as can be expected, are found in the 20 metres depth range.

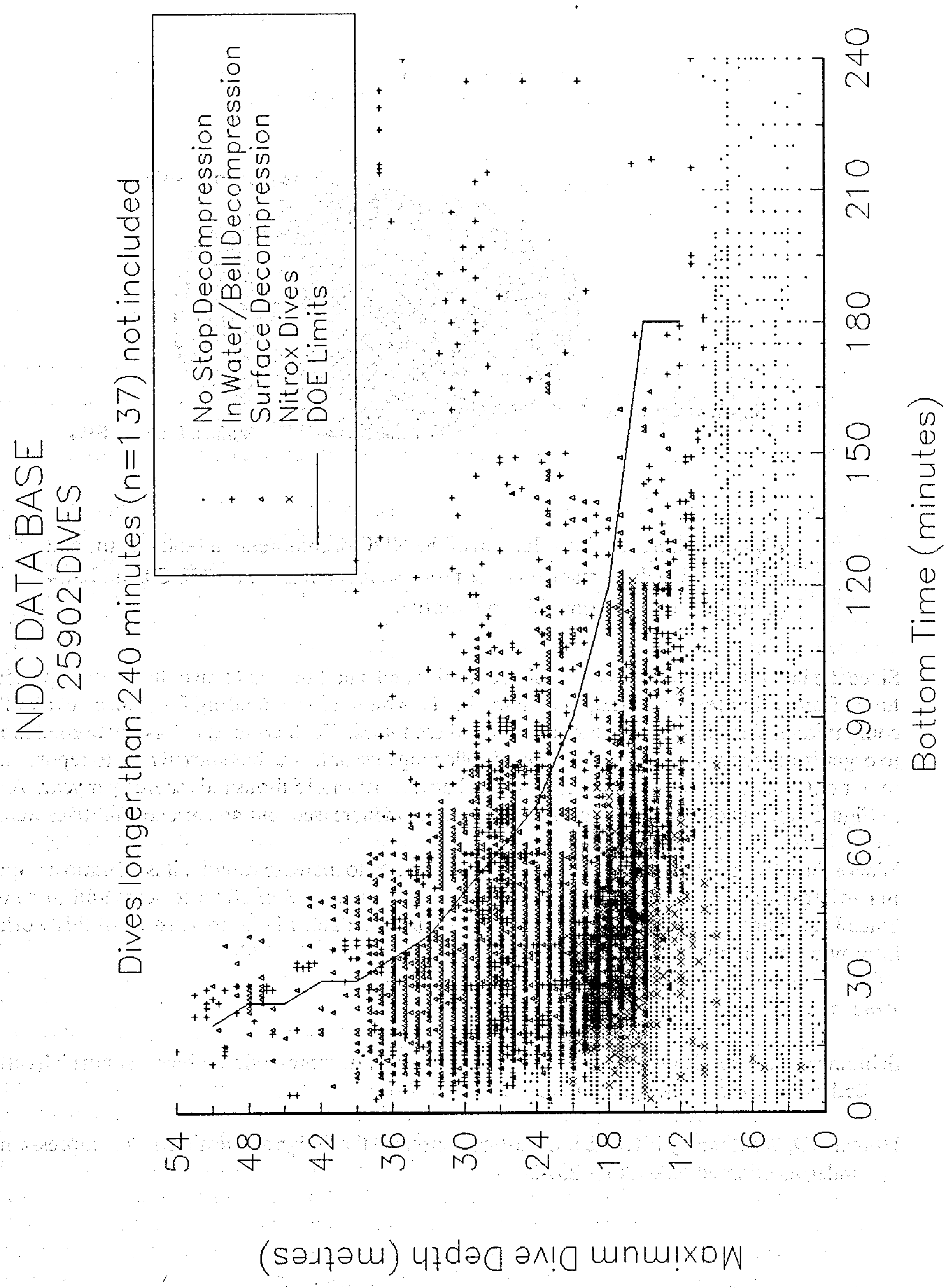

Figure 4. Dives in the NDC Data Base: Diving activity in terms of dive depth against bottom time. The line in the graph represents the U.K. Department of Energy (DOE) bottom time limits at the various depths.

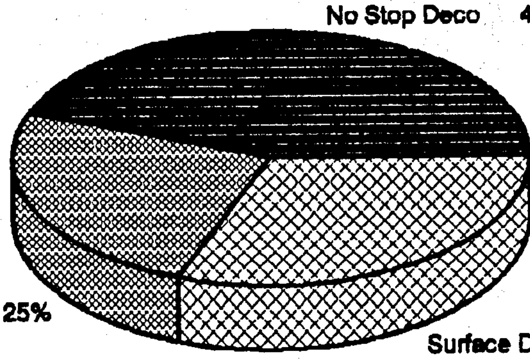

Figure 5. Since the introduction of the NDC decompression tables by the end of 1988, 5574 dives made on these tables were reported to the NDC Data Bank at the time of preparing this presentation.

Since the introduction of the NDC tables, over five and a half thousand dives had been reported at the time of preparing this presentation (Figure 5). This number is increasing fast, since nearly all diving companies in The Netherlands are now using these tables. Furthermore, our Navy needed more time to organize a proper system for their way of collecting dive data, but has started now to report their data to our data base. We expect to receive at least between 10 and 15 thousand records per year. As shown in Figure 5, the contribution of surface decompression increased, but no enriched air dives were made.

Where the number of records in our data base promises to increase rapidly, it is of utmost importance that what we collect is worthwhile, since it requires a great deal of effort to screen all these records. Since I have no intention of wasting my time on useless data, I hope to learn from this workshop if improvements in our data base structure should be made.

References

Schreiner HR, Hamilton RW, eds. 1989. Validation of decompression tables. Report 74(val)1-1-88. Bethesda, MD. Undersea Hyperbaric Medical Soc.

Homer LD, Weathersby PK. 1985. Statistical aspects of the design and testing of decompression tables. Undersea Biomed Res 12(3): 239-249.

INCIDENT ANALYSIS: HOW DO WE DEAL WITH SUBMAXIMAL DATA?

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To refresh your memory, may I draw your attention once more to the scatter plot shown as Figure 4 in my earlier presentation (page 5). It shows diving activity in terms of dive depth and time of the records in our data base. As I said before, the main purpose of our data base is to monitor the reliability of our tables by tracking decompression sickness.

Sofar, we have recorded only 11 cases of DCS, presented in Figure 1. The line in the graph represents again the U.K. Department of Energy (DOE) bottom time limits. In our data, we could not find a relationship between the occurrence and severity of DCS and the dive and decompression methods or decompression stress. Therefore, we see no reason to limit bottom times as the Department of Energy has done. This is in remarkable contrast to the findings of Shields and Lee (1986) in a comparable sample size of dive data in the U.K. sector. They had 79 cases of DCS in 25740 man-dives; 76 of the DCS cases were related to surface decompression. In our data, only one case of DCS Type I occurred after surface decompression so far.

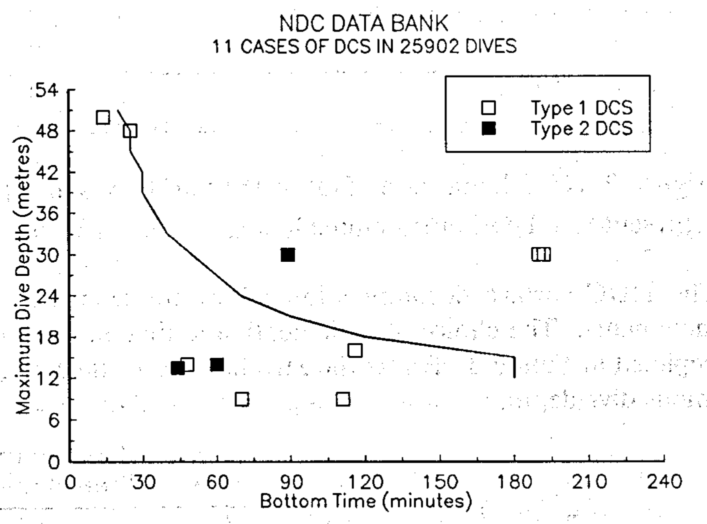

Figure 1. NDC Data Base: 11 cases of DCS in 25902 dives.

However, our data and that of Shields and Lee cannot be compared directly. In our data, decompression tables originating from the same computational model were used in nearly all dives, while in the data of Shields and Lee a wide variety of tables were used. Furthermore, the distribution of the decompression methods differs significantly in both sets of data. Nevertheless, the very low number of DCS in our data gives food for thought. It could be that our tables are better, or that our divers use the tables better or choose a better diving technique. There are so many variables involved, that it is hard to say. Whatever the reasons may be, we think that improving dive and decompression technique is a better way to increase diving safety than to limit bottom times. The latter procedure may in the extreme end up with a bottom time of zero, the divers being send home in the security that they will never get decompression sickness again.

Apart from tracing DCS, we should also see if we can use the data to test our tables. In that respect, we must decide what to do with submaximal profiles.

For demonstration, I have taken the surface decompression dives reported over September 1989. Figure 2 shows the scatter plot of these 181 dives.

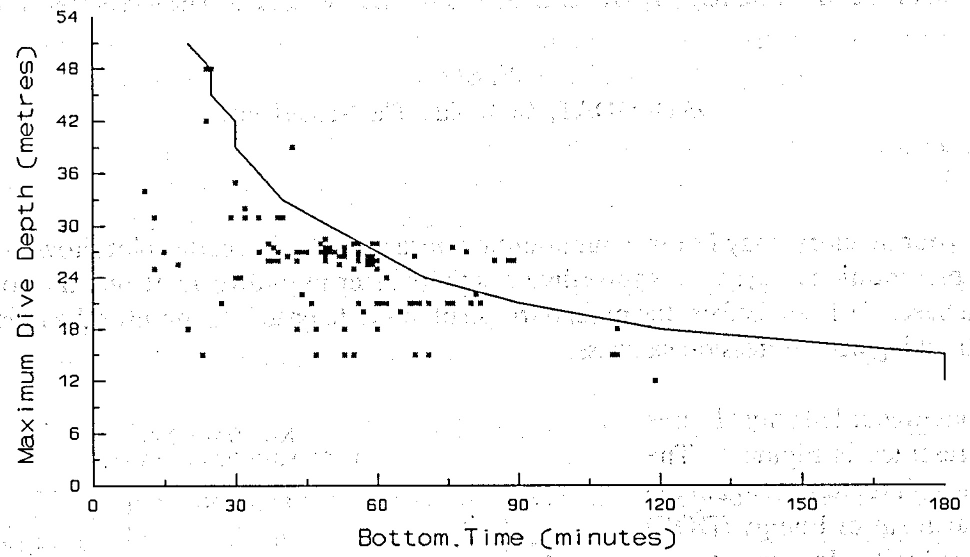

Figure 2. NDC Data Base: Plot of 181 SurD dives in September 1989. The continuous line represents the DOE bottom time limits.

The NDC surface decompression tables are calculated for 3 metres depth and 10 minutes time increments. The choice of table depth and time in relation to dive depth and time for these dives is depicted in Figure 3. Below the zero line is dive time minus table time, above the line is table depth minus dive depth.

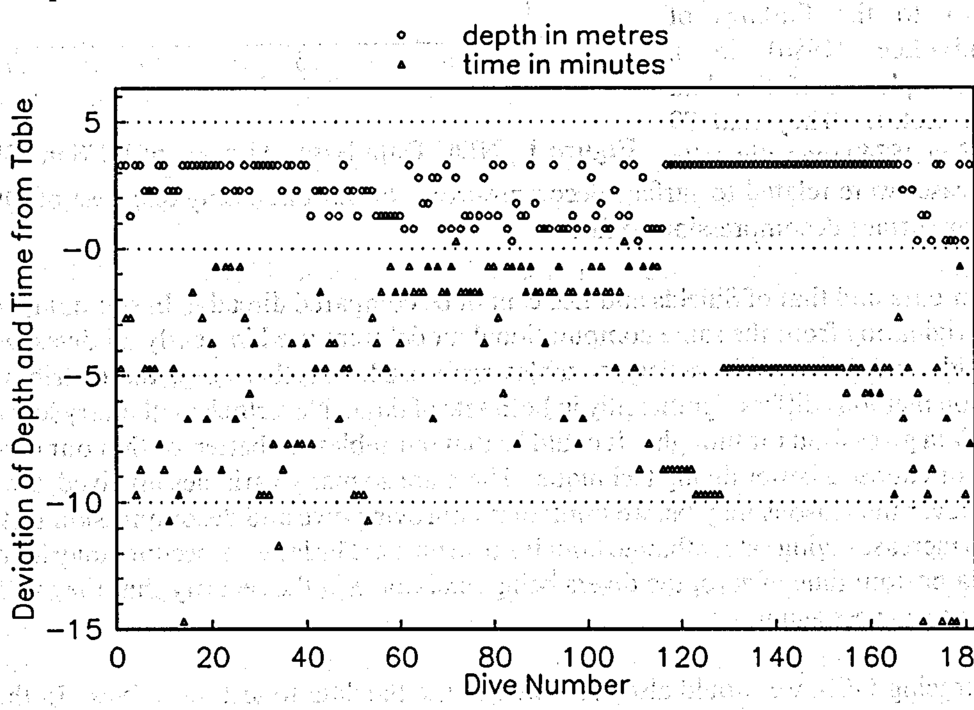

Figure 3. Choice of table depth and time in 181 SurD dives in the NDC data base, 1989 Sept. Dives with actual time shorter than table time are shown below the zero line, while dive depths shallower than table depth are shown above this line.

In none of the dives was the next deeper table depth chosen. For table time, however, in 8 dives the next longer time was preferred. In 4 cases this was due to combined diving, in the other 4 cases a matter of "Jesus factoring", although we discourage this in our instructions on how to use the tables.

Although in 173 dives the correct table depth and time were chosen, does this mean that we can really use these dives as a test of our tables? How close should dive and table depth and time be? If we are very strict and use only an exact match of dive and table depth and time, the data become very scarce (Figure 4). I hope there will be a way around this. At least, maximum likelihood, as far as I understand it, can be applied to submaximal profiles in generating new decompression tables, provided the exact dive and decompression profile is known. This represents another problem in operational dive and decompression data collected from questionnaires or log sheets.

Table Time minus Dive Time	Table depth minus Dive Depth		
	<= 3 metres	<= 2 metres	<= 1 metre
<= 10 minutes	173	77	50
<= 5 minutes	115	54	37
<= 2 minutes	52	37	30
<= 1 minute	25	14	10

Figure 4. NDC Data Base: Choice of Table Depth and Time in 181 SurD dives.

	JOJO	DESCENT < 10 M/MIN.	DESCENT TIME > 10 % OF DIVE TIME	DESCENT TIME > 10 % OF DIVE TIME OR JOJO
NO STOP DECO	15	829	172	184
DECOMPRESSION	439	731	626	1019
TOTAL	454	1560	798	1203
% OF TOTAL	8.1	28.0	14.3	21.6

Figure 5. NDC Data Base: 5574 dives on NDC decompression tables. Deviation from a suqare profile.

So far, I have assumed a square dive profile, defined by dive depth and time. This may not be very realistic. To indicate possible deviations from a square profile, I have introduced the fields "jojo" and "descent time" in the NDC data base. "Jojo" is defined as coming to the surface once or more during the dive, or ascending at least once for more than 10 metres from maximum dive depth. As shown in

Figure 5, this was reported to be the case in 8 percent of the dives. A descent slower than 10 metres/minute is reported in 28 percent of the dives. Provided that dive time is long enough, this may not cause a serious deviation from a square profile. We may put the limit at descent time being 10 percent of dive time. This was exceeded in 14 percent of the dives. Considering both jojo or slow descent, in nearly 22 percent of the dives a significant deviation from a square profile is reported, representing another aspect of submaximal profiles. As long as the actual profile is not recorded, I think the only way to handle these dives is to exclude them from analysis. For the square submaximal profiles, there may be a way to make them still usable.

Reference

Shields TG, Lee WB. 1986. The incidence of decompression sickness arising from commercial offshore air-diving operations in the UK sector of the North Sea during 1982/83. Final Report under Dept. of Energy Contract TA 93/22/147. Aberdeen: Hyperbaric Medicine Unit, Robert Gordon's Institute of Technology.