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"SOX" SURFACE DECOMPRESSION TABLES IN THE EASTERN SCHELDT

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RN standard air table 11, incorporated in the "Guidelines for safe diving" publication P78 of the Directorate of Labour, has been the official decompression table in the Netherlands since 1967. In the seventies, it was realized that the table was not safe for commercial diving, especially for the deeper and longer dives. Therefore, in connection with Vriens Diving Company, I developed safe decompression schedules for long exposure air dives, using a neo-Haldanian computational model. As experience grew, the model was also used to design special decompression procedures for special jobs. Nevertheless, there was still a need for safer "standard" tables for routine jobs. From this need originated the SV (Sterk-Vriens) tables in 1980.

In the Eastern Scheldt, however, it was preferred to use the "official" P78, except for long exposure dives. Only after P78 was withdrawn, it was decided to use the SV tables instead. Part of the SV tables are surface decompression tables using oxygen, coded "SOX" in our database. These tables permit also repetitive diving.

From the start in October 1984 until the end of 1985, nearly 1900 SOX dives have been made in the Eastern Scheldt, without any case of decompression sickness. However, it is demonstrated from analysis of the SOX data, that general conclusions about safety may not be drawn from such figures. Apart from table aspects, many human and environmental factors may be involved. The only permissable conclusion can be, that SOX tables proved to be very safe for the diving population at stake and the work done in the Eastern Scheldt.

INTRODUCTION

Since 1967, P78 was used as the guideline for diving practice in the Netherlands. P78 is a publication of the Directorate of Labour and contains instructions for safe air diving as well as decompression and treatment tables. The decompression tables are in fact RN standard air table 11, here used for in water and surface decompression. In the seventies, it became clear that these tables were not very safe for commercial diving, particularly in longer or deeper dives [CIRIA UEG (1976), Leitch et al. (1982)].

The necessity of long exposure air dives for the work in the Eastern Scheldt, supported me to develop more suited tables in close cooperation with Vriens Diving Company. Fortunately, the demand was for safe tables and not for the shortest possible decompression time. Using a Neo-Haldanian computational model, such tables were prepared and tested. It was realized, however, that quite a number of test dives would be necessary to

establish whether a table is safe or not [Vann (1982), Homer et al. (1985)]. For economic reasons, only a limited number of test runs was possible for each new schedule. This was done to eliminate gross mishaps and to familiarize the divers with the new tables. After that, such tables were put at work in accessible locations under close supervision. Only after this went all right, the tables were free to be used elsewhere.

Meanwhile, the habit was developed to collect dive and decompression data of all dives made on these tables. These data were fed into a computer database and used to readjust the model and the tables where necessary, as well as to control proper use of the tables. This procedure also stimulated an intensive interaction between diving practice and theory. Over the years, the computational model gained in reliability for prediction of safe decompression for all kinds of diving procedures. As confidence grew, the computer model was utilized more and more to design special decompression schedules for special jobs, used by Vriens Diving Company for projects all over the world. This appeared to be much more versatile than standard tables could ever be. However, there was still a need for a set of "standard" air diving tables for routine jobs, but more flexible and safer for commercial diving than the at that time available standard tables. From this need originated the SV (Sterk-Vriens) tables in 1980. These tables cover in water as well as surface decompression using oxygen, with possibilities for repetitive diving.

In the mean time, only the long exposure air diving tables from my computer model were used in the Eastern Scheldt, with special permission of the Inspectorate of Labour. For all other dives in this area, P78 was used as "official" table. Although various "official" tables often depend on a limited number of test dives [Vann (1982), Carlioz et al. (1985)] and are often not specially designed for commercial diving, they tend to have the confidence of the authorities and the diving companies. Pointing at the advantage of special tailored dive and decompression procedures, including the use of nitrox for bounce and saturation diving, appeared to be useless. Preference was given to the official P78. This remained so until the end of 1983, when the Directorate of Labour announced that P78 would be withdrawn, as old-fashioned and not safe. This caused some consternation and forced the authorities to look for alternatives, particularly for the diving in the Eastern Scheldt.

To get time for a final solution, I was asked to adapt P78 for temporary use in such a way, that safety would be increased. This I did, among other things by using oxygen for surface decompression. At the same time, I required a system for collection of all dive and decompression data, as was already tradition for Vriens Diving Company. This was accepted and DCO (Diving Combination Oosterschelde) did an excellent job by putting to work a fine database system at the beginning of 1984, that did not only keep track of dive and decompression data, but also of various other aspects of the work to be done. The dive and decompression data were delivered to me on floppy disk for further analysis.

After considering several possibilities for decompression tables for the Eastern Scheldt, including special designed schedules, it was decided that the SV tables were suited for the job. I still have the feeling that this was also caused by the fact, that these tables were used by Vriens Diving Company since 1980 and had appeared in print, which made them look "official", while the original computer model was still looked upon as "experimental". Nevertheless, several divers, many of them temporarely borrowed from other diving companies during a period very intensive diving, resisted strongly the use of the SV tables. They preferred the old P78 or eventually the adapted form. This delayed the introduction of the SV tables until October 1st 1984. Ever since, these tables are in use to full satisfaction. They acquired the confidence of the diving population in the

Eastern Scheldt very fast and slogans like "SV tables? Order a wheelchair!" are now history.

THE "SOX" TABLES

An important part of the SV tables are the surface decompression tables using oxygen. These tables were coded "SOX" in the database and will be referred to as such hereafter. Figure 1 shows the SOX table for a maximum depth of 35 metres. The tables are calculated for 5 metres diving depth and 10 minutes diving time increments. Short in water stops are used for the longer and deeper dives until the 9 metres stop. Since quite some work was at a 30 metres level or a little deeper, tables were also prepared for 45 minutes at 30 metres, just avoiding the necessity of in water stops, as well as a complete table for 32.5 metres. After surfacing from the 9 metres stop, chamber recompression on oxygen to 12 metres is required within 3 minutes. After a stay at 12 metres, staged decompression with 3 metres steps to the surface is applied, with regular 5 minutes on air interruptions of oxygen breathing. The possible advantages of this procedure instead of decompression in the chamber at 12 metres on oxygen, are recently mentioned by Arntzen (1985).

Oppervlakte - decompressie met lucht en zuurstof.
Opkomstsnelheid is maximaal 10 meter/minuut.
De stoptijd gaat in bij het bereiken van de stop.
Tijd van oppervlakte tot 1ste stop in deco - kamer is maximaal 3 minuten.

lu - lucht
ox - zuurstof
In water stops altijd met lucht.

Oppervlakte - interval is 720 minuten.

DUIKDIEPTE 35 METER.

duiktijd	tot 1ste stop	in water stops (meter)					stops in deco - kamer							totale decotijd	uptd	herhaling
							12	9		6		3				
		21	18	15	12	9	ox	lu	ox	lu	ox	lu	ox			
10	3.5	-	-	-	-	-	10	-	-	-	-	-	-	14.7	38	2
20	3.5	-	-	-	-	-	10	-	5	-	-	-	-	19.7	59	2
30	2.3	-	-	-	1	1	10	-	10	5	-	-	10	41.7	95	2
40	2.3	-	-	-	2	2	10	-	10	5	10	-	5	48.7	115	1
50	2.3	-	-	-	3	4	20	5	10	-	10	-	10	66.7	160	1
60	2.3	-	-	-	6	4	20	5	20	5	10	-	10	84.7	192	1
70	2.0	-	-	1	8	8	20	5	20	5	20	-	10	101.7	222	1

Figure 1. SOX table for a maximum depth of 35 metres. Lu=air, ox=oxygen. "Herhaling" points at repetitive table to be used.

The SOX tables are designed for use with a minimum surface interval of 12 hours and allow for a repetitive dive after at least 4 hours. This 4 hours period was chosen, apart from aspects of gas loading and unloading, to minimize the risk that the preceding dive had already caused "subclinical" decompression sickness, since most cases would have become manifest

within this period [Edmonds et al. (1983)]. Furthermore, 4 hours between dives appears to be practical for most commercial diving operations. Particularly the possibility of repetitive diving after surface decompression was considered as a big advantage for the work in the Eastern Scheldt. This was also one of the reasons, why the SV tables were chosen. The safety of this procedure was already established by Vriens Diving Company in a fair number of offshore diving operations, apart from the test dives during the development of these tables.

EXPERIENCE IN THE EASTERN SCHELDT

From October 1st 1984 until the end of 1985, a total of 1893 SOX air dives were made, without a single case of decompression sickness. Figure 2 displays the depth distribution for these dives. Quite a number of dives were

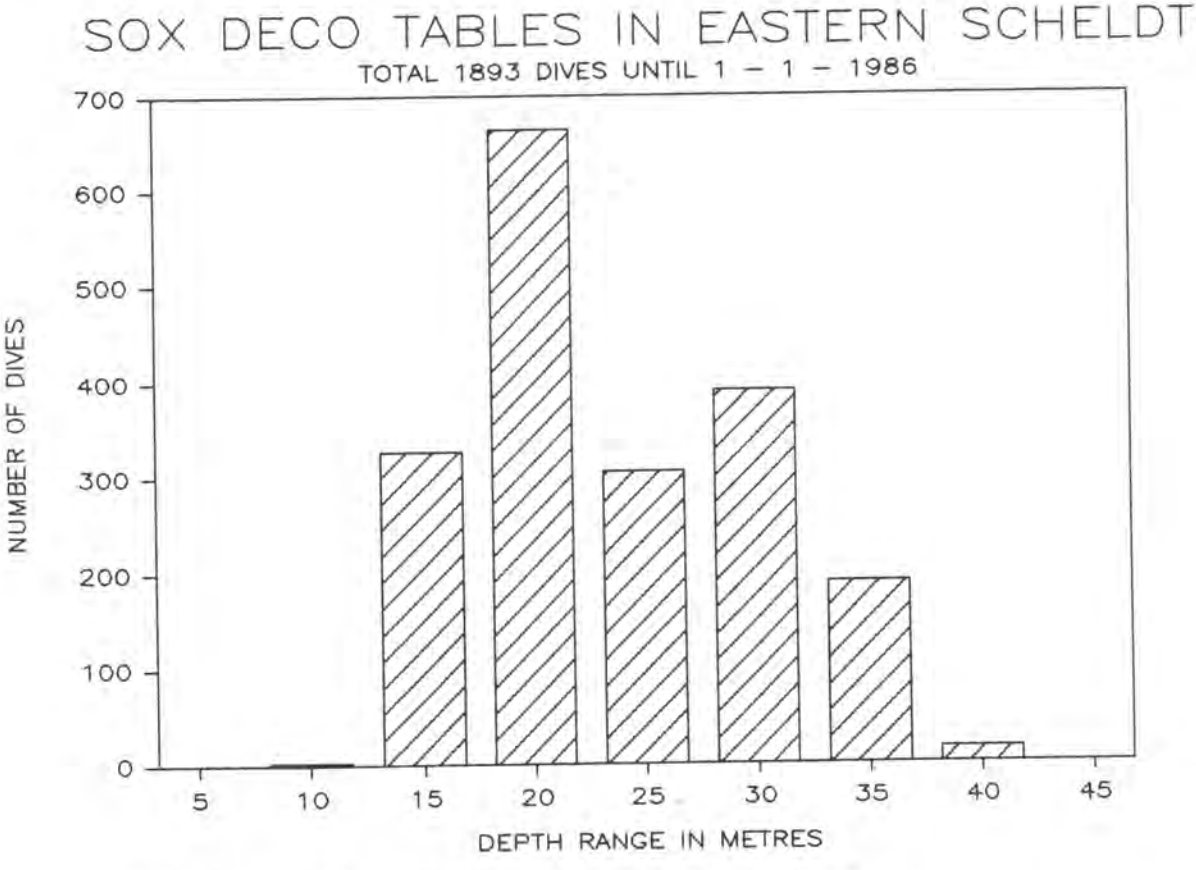

Figure 2. Distribution according to diving depth.

made to depths up to 25 metres. This depth range is particularly suited for no-stop diving on oxygen enriched air or nitrox, but again some conservatism made it impossible for DCO to introduce such procedures before the autumn of 1985. After that time, the number of SOX dives at depths up to 25 metres diminished significantly.

The distribution of table depth and time of the SOX dives is shown in table 1. At the shallower depths there are some nice clusters in number of dives, but they fade away at the greater depths. This is of course due to the location and type of work, although more deeper SOX dives have been made in 1986. Nevertheless, the reputation of safety of the SOX tables in the Eastern Scheldt appears to be built on the use in

shallower air dives.

Apart from looking at which part of the tables are used, it seems important to analyze how the tables are used. In all 1893 dives, repressurization to 12 metres after surfacing was performed within 3 minutes, so this important condition was met fully. Next to that, I have looked for the distribution of table selection with respect to actual diving depth and time. This is shown in table 2. It appears that 26 times the next deeper depth or greater time was chosen. This old diver's habit, resulting from the use of standard tables, is hard to defeat. Diving up to table time and depth is seldom used. When we consider this to be the case when diving depth is within 1 metre of table depth and diving time within 2 minutes of

SOX TABLES IN THE EASTERN SCHELDT
TOTAL 1893 DIVES UNTIL 1 - 1 - 1986

TABLE DEPTH (METRES)	TABLE TIME (MIN.)													
	10	20	30	40	45	50	60	70	80	90	100	110	120	130
15	*	*	*	*	*	*	112	60	14	0	1	2	1	1
20	*	*	135	149	*	333	108	42	7	5	0	1	0	0
25	*	40	67	92	*	38	35	12	4	0	1	0	*	*
30	6	55	68	163	68	13	5	1	0	*	*	*	*	*
32.5	5	45	105	17	*	2	0	0	*	*	*	*	*	*
35	4	25	18	13	*	1	0	0	*	*	*	*	*	*
40	4	6	8	1	*	0	*	*	*	*	*	*	*	*

NUMBER OF DIVES

* = no-stop time or not available in table

Table 1. Distribution according to table depth and time.

SOX TABLES IN THE EASTERN SCHELDT
TOTAL 1893 DIVES UNTIL 1 - 1 - 1986

TABLE TIME minus DIVING TIME (MIN.)	TABLE DEPTH minus DIVING DEPTH (METRES)		
	<= 5	<= 2	<= 1
<= 10	1.867	879	371
<= 5	1.056	499	210
<= 2	532	265	105
<= 1	252	132	56

NUMBER OF DIVES

Table 2. Distribution according to table selection.

table time, this is valid in only 105 out of 1893 dives, or merely 6 % of all recorded dives. The distribution of table depth and time for these dives is shown in figure 3.

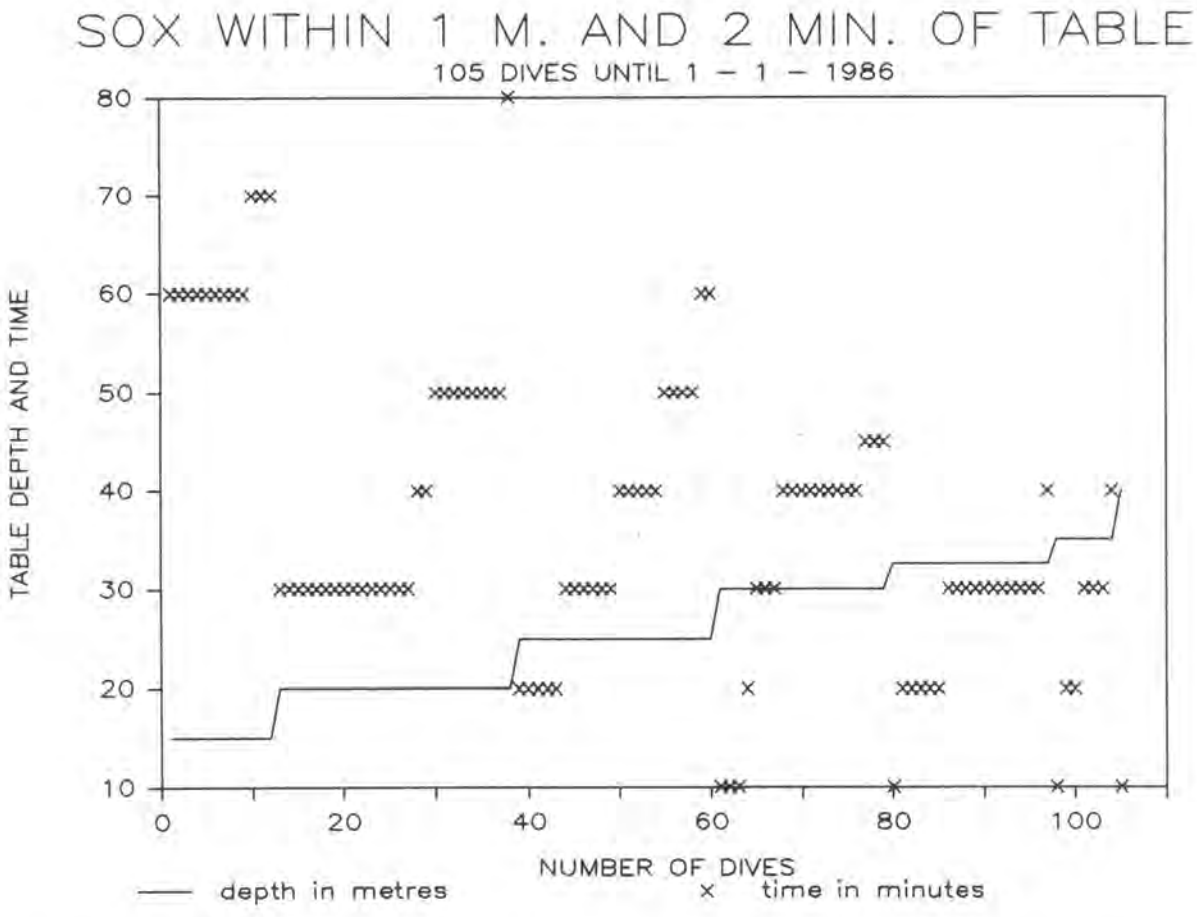

Figure 3. Distribution according to table depth and time for the dives within 1 metre of table depth and 2 minutes of table time.

SOX TABLES IN THE EASTERN SCHELDT
TOTAL 165 REPET. DIVES UNTIL 1 - 1 - 1986

TABLE DEPTH (METRES)	TABLE TIME (MIN.) 10	20	30	40	50	60	70	80
15	*	*	*	*	*	16	9	2
20	*	*	17	17	64	3	3	1
25	*	8	0	5	2	1	1	0
30	0	3	2	2	0	0	0	*
32.5	0	0	2	0	0	0	*	*
35	1	1	2	0	0	*	*	*
40	0	1	2	0	*	*	*	*

NUMBER OF DIVES

Table 3. Distribution according to table depth and time for repetitive SOX dives. * = no-stop time or not available in the table.

Although the advantage of repetitive diving after surface decompression was emphasized for the work in the Eastern Scheldt, only 165 of such dives were made. The distribution of table depth and time for these repetitive dives is depicted in table 3.

SOX TABLES IN THE EASTERN SCHELDT
TOTAL 165 REPET. DIVES UNTIL 1 - 1 - 1986

TABLE TIME minus DIVING TIME (MIN.)	TABLE DEPTH minus DIVING DEPTH (METRES)		
	<= 5	<= 2	<= 1
<= 10	151	50	21
<= 5	71	25	11
<= 2	43	13	7
<= 1	12	4	3

NUMBER OF DIVES
WITH SURFACE INTERVAL BETWEEN 4 AND 6 HOURS

Table 4. Distribution according to table selection for repetitive SOX dives.

Analysis of how the tables were used is shown in table 4. Only repetitive dives with a surface interval between 4 and 6 hours are considered. As can be seen, diving up to table time and depth has occurred in only a small number of dives.

DISCUSSION AND CONCLUSIONS

The recent fuss about the possible unsafety of surface decompression procedures, commented on by Hamilton (1985), is contradicted by our experience, as in the Eastern Scheldt nearly 1900 of such dives did not cause one single case of decompression sickness. Even repetitive diving with surface decompression went well, although only 165 of such dives were recorded in the Eastern Scheldt. Also the Norwegians have favourable experience with their surface decompression tables [Arntzen (1985)].

One should be cautious, however, not to jump to conclusions about the supposed safety of these tables. First of all, the SOX tables were only used up to 40 metres in the Eastern Scheldt. The number of deeper dives in the Norwegian series, presented by Arntzen (1985), is also very limited. Next to that, the circumstances in the Eastern Scheldt permitted to meet the allowed maximum of 3 minutes surface interval and our divers were very strict in sticking to the rules. I assume this also to be the case for Arntzen's series, collected from two construction diving jobs. From own experience I know, that on several patforms in the North Sea it is nearly impossible for the divers to be recompressed within 5 minutes after surfacing. My policy is, to forbid surface decompression when the elementary rules can not be met.

The analysis of the SOX diving data in the Eastern Scheldt demonstrates once more, that plain figures about how many times a table is used, together with a "bends incidence rate", are in fact worthless. At least should be known, which part of the table is used. While looking for decompression sickness incidence of the USN tables, Berhage et al. (1980) found in over 16.000 dives, that half of the schedules were not used at all. Next

to which part of the table is used, it is important to be informed about how the table is used. We are all familiar with the habit of divers to add time and depth to the actual diving data, before entering a table. This is common practice, at least in the North Sea, when using USN tables [Arntzen et al. (1980)]. Also in the present series, while we do not encourage this habit, only a limited number of dives have been made up to table time and depth. Furthermore, actual data about dive profile are lacking most of the time. For the Eastern Scheldt is known, due to the type of job, that almost all the work is done at the indicated diving depth, but descend time for instance is not recorded. Here, the use of a dive profile recorder, as demonstrated by Nashimoto et al. (1985), could be benificial, although I do not think this to be feasible for every commercial diver at short notice. It should, however, put an end to the worries about the (in)accuracy with which diving data are provided.

Apart from table aspects, safety as far as decompression sickness incidence is concerned, is also influenced by many human and environmental factors [Carlioz et al. (1985)]. With so many variables involved, it is I think unforgivable to draw firm conclusions about table safety in general from even many data on a particular job. In my opinion, this does not make the collection of such data worthless. As operational diving is the ultimate goal and much more operational than experimental diving is going on, these are the data we need. Consensus must be reached, however, which data should be collected and what is the best way to do it.

From the present series of data I may conclude, that the SOX tables proved to be very safe for the diving population at stake and the work done in the Eastern Scheldt. For other populations and other jobs, it is necessary to keep track of the diving data, before similar conclusions about the safety of these tables may eventually be drawn.

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