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# Diving Data Bank: A Unique Tool for Diving Procedures Development

by J-P. Imbert and M. Bontoux, Comex Services

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ABSTRACT

A computer data bank set up by Comex to process diving reports has been used to control and improve diving procedures. Analysis of 5744 early saturation dives proved the existence of an optimum ascent rate for saturation decompressions with a 600 mbar chamber $PO_2$. New saturation decompression procedures were developed and validated using the data bank.

## INTRODUCTION

As a commercial diving company, Comex continually faces the problem of controlling and developing its diving procedures. However, it must be admitted that after almost 100 years of diving and research the mechanisms of decompression are still not completely understood and that the development of decompression procedures remains largely a matter of trial and error. For this reason, Comex studied the possibilities of using a diving report system for the monitoring of its operations.

The diving reports are working documents which allow operational personnel to run specific check-lists, go through pre-defined schedules and keep records of relevant parameters. These reports contain invaluable information concerning the operations, but a major difficulty remains of how best to process this mass of data to benefit from the offshore experience.

In 1974 Comex started a computer system to process its diving reports and try to access this information efficiently. The system has been kept running ever since and now contains over 150,000 diving reports collected from worldwide operations. The files contain data on all diving methods (air, mixed gas diving or deep diving), all types of work (construction, hyperbaric welding, inspection, maintenance,...) and constitute a unique source of information on commercial diving.

References and illustrations at end of paper.

The Comex Data Bank has been used to study diving activity, analyse market trends and manage personnel, but its most notable application has been in the monitoring of diving procedures. Statistical analysis of the diving reports has been turned into a scientific method for decompression procedure development that was used for the revision of the French Air decompression tables in 1986 (1). The purpose of this paper is to illustrate how this method was used to develop and validate new Comex Heliox Saturation Procedures in 1984.

The previous Comex saturation procedures specified constant chamber Oxygen partial pressure ($PO_2$) combined with varying rates of ascent, according to the theories in force at the time. The introduction of the "critical volume" assumption (2) and the work of VANN (3) indicated that there should be a linear relationship between the safe rate of saturation decompression and chamber $PO_2$. Accordingly, a decompression with a constant chamber $PO_2$ should be conducted with a constant rate of ascent.

Because the outcome of a decompression is unpredictable and depends on a large number of factors such as dive conditions or individual susceptibility (4), the study of decompression safety performances thus requires recording thousands of dives carried out by hundreds of different divers. Only commercial offshore operations can provide the large volume of information necessary for a meaningful statistical analysis. The objective was to determine whether or not Comex Data Bank would support the emerging theories and whether better procedures could be designed.

## MATERIAL AND METHOD

### Comex saturation procedures

Comex first carried out Heliox saturation operations in 1969 on board ASTRAGALE in the Bay of Biscay. Since that time, and with the development of North Sea operations, thousands of dives have been performed with this diving method.

As opposed to most other diving contractors, who have based their diving procedures on the U.S. Navy Diving Manual, Comex has always used original saturation procedures developed by its scientific team at the Marseille Hyperbaric Center (5). For this reason these procedures display certain characteristic features :

- the ascent is carried out by continuous decompression without any night stops.
- the permitted excursion distance for bell dives from storage depth is relatively small compared to the U.S. Navy practice. For instance, at 150 m. storage depth, it was 13 m. in the 1974 edition and only 10 m. in the 1979 revision.
- the chamber $PO_2$ is set to 600 mbar for final decompression to surface. This is based on studies carried out by Comex scientists on the optimum use of Oxygen during decompression (6, 7, 8). This relatively high Oxygen level (most commercial diving companies use 500 mbar $PO_2$, and U.S. Navy only 350 mbar) has permitted increasing the decompression speed while still maintaining the same degree of safety.

Comex instructions have been modified several times (1972, 1974, 1979) to improve their safety performances and operational flexibility but, up to 1983, changes only concerned the rates of ascent. For instance, in the 1974 edition, the decompression rates varied from 30 min/m at 150 m. to 40 min/m at 20 m. In the 1979 revision, at the same depths, these were altered to 35 min/m and 45 min/m.

### Source of information

All data used in the analysis come from saturation diving reports collected in the Comex data bank files from 1968 to 1983. These reports are part of the Comex internal reporting system and include three different forms :

- The diving reports, which are filled in by the diving supervisor whenever a dive is carried out.
- The chamber logs, filled in by the life support technicians, which contain all the information relevant to chamber ambient parameters, but also details of the treatment in case of a decompression sickness (DCS).
- The accident reports, which are used in case of illness, injury or DCS.

The saturation dives mostly concerned offshore operations recorded after 1974, but also included some early deep experimental dives carried out at the Marseille Hyperbaric Center. These saturation dives were all conducted using the same 600 mbar chamber $PO_2$, but decompressed with various ascent rates according to the procedures in use at the time.

### Collection and validation of the reports

The reports are supplied in pads with autocopying sheets. One sheet remains on the worksite, one goes to the project files and the last one is forwarded to the Safety and Methods Department of Comex at Marseille.

The reports are checked for errors and entered in the data bank by experienced life support technicians or diving supervisors. The computer then runs on time verification of data consistency such as comparing excursion and storage depths and decompression time checks.

In addition to the above precautions, the validity of the data is checked at site level. The local trends are compared to the general results in order to identify systematic errors of procedures or simply missing reports that would bias the statistics.

Each and every DCS was investigated whenever possible with information from worksite safety inspections, medical examination or interview with the diver. All known incidents/accidents were taken into account, whether officially reported or not, whether treated or not, whether classified as bends, "niggles" or just doubtful. Over this large number of dives, some divers were inevitably involved in several DCS episodes. However no correction was introduced in the DCS incidence, as individual susceptibility was not considered as an independent variable in this study.

## RESULTS

### Saturation dives

Over the period concerned, 5744 diver saturation decompressions were recorded at depths ranging from 20 to 300 m. (See Figure 1).

It can be seen that most of the dives were carried out during North Sea operations (100 to 150 m. water depth).

630 professional divers were involved in these saturations who performed an average of one to two saturations per year, limited to 30 days each by company policy.

Saturation decompression sickness

The only cases of DCS recorded during these saturation decompressions concern "pain only" (type I) DCS. No cases of neurological (type II) DCS have ever been recorded during these saturation decompressions.

All the DCS recorded occurred towards the end of the decompression. Figure 2 displays the distribution of first symptom onset depths versus the starting depth of the decompression. Some of the DCS have recurred at surface, but none of them have ever been declared after reaching the surface.

DCS risk and rate of ascent

The DCS risk has been calculated for type I DCS and expressed as a percentage of hits over the number of saturations. Figure 3 displays this DCS risk as a function of the ascent rates in the 5744 saturation decompressions conducted with 600 mbar chamber $PO_2$.

Because the ascent rate varied during the decompression, the rate indicated in Figure 3 has been calculated as the mean rate of ascent in between the storage depth and the depth of the deepest recorded DCS for each set of saturation instructions.

## DISCUSSION

Validity of the data bank results

To our knowledge, the Comex data bank is the only example of a diving reports computer system run by a commercial diving Company and has obvious advantages. The volume of data is large and the quality of the information is high. A diving company has the authority to impose a reporting system and to control the way the reports are filled in. Results of the system were compared to other known diving data banks, such as the US Navy (9) or the one developed by Dr. T. SHIELDS in UK for the Department of Energy (10) and appeared in good agreement for air diving operations (11).

However, the system has inherent limitations because the information comes primarily from the analysis of reports.

As far as incidents/accidents are concerned, it has been recognized for a long time that the number of reported cases does not always correspond to the number of actual problems. One of the reasons for this is administration ; people forget to fill in the reports, fill them in insufficiently, or even lose them.

Another reason is related to the subjective assessment of the problem. For instance, there are clear cases of DCS that are treated with the right procedures, but there are also mild cases such as "niggles" that are sometimes given some Oxygen on mask, or just treated with a hot shower. Not to mention the divers who, for reasons of their own, do not report the case !

To get around these difficulties, cross checking was run with complementary information obtained from site safety inspections, interviews during medical examinations, systematic investigations or informal discussions. However, it is recognized that the system, like all reporting systems, provides an underestimate of the actual problems related to diving.

Relation between chamber $PO_2$ and saturation ascent rates

The first Comex saturation decompression procedures were calculated on variations of a model based on the supersaturation concept. The rationale was extremely simple because the model reduces to a single tissue having the slowest gas exchange rate and the critical supersaturation it can tolerate. The tissue compartment was assumed to have an exponential rate of gas exchange :

$$\frac{dPt}{dt} = K\,(P - PO_2 - Pt) \quad \ldots\ldots\ldots\ldots \quad 1$$

where P represents the ambient absolute pressure, Pt the tissue inert gas tension, $PO_2$ the chamber Oxygen partial pressure and K a constant specific to the gas exchange rate of the slowest compartment (240 to 300 minutes time period).

The maximum permitted tissue tension was assumed to be related to the ambient pressure by the following relationship :

$$Pt = a\,P^2 + bP + c \quad \ldots\ldots\ldots\ldots \quad 2$$

where a, b and c were empirical coefficients.

Derivation of equations (1) and (2) is straightforward and yields a saturation ascent rate which depends both on chamber $PO_2$ and depth :

$$\frac{dP}{dt} = -K\left(\frac{aP^2 + (b-1)P + c + PO_2}{(2\,aP + b)}\right) \quad \ldots\ldots\ldots\ldots \quad 3$$

- The safety performance of the procedures are continually controlled by diving report analysis.
- The procedures are modified whenever a problem is identified.
- The modified procedures are then sent offshore to selected worksites for evaluation.
- The modified procedures are issued as final company procedures only after improved safety performances have been fully documented.

It is believed that the process is continuous because the procedures will always be perfectible and that analysis of the large amount of data from the offshore operations will support gradual improvement of decompressions.

The benefit of such a method is now widely recognized as it was organized on an official basis in the U.K. in 1983 for the safety performance monitoring of the North Sea air diving operations (10). However, the Comex Data Bank still remains the first example of its systematic use and covers all aspects of decompression methods.

## CONCLUSION

A large volume of dives is now required to document any change in diving procedures : scientists need it to validate their theories, diving companies to control their sites, government agencies to approve the procedures.

Analysis of early Comex saturation experience has provided support to decompression theories predicting a linear relationship between chamber $PO_2$ and saturation ascent rate. The minimum safe decompression rate for 600 mbar $PO_2$ was shown to be 40 min/m., a value well in accordance with other saturation ascent rates published in the literature for various chamber Oxygen levels.

This study illustrates how the use of the Comex Data Bank first helped in identifying problems of decompression safety, but also how it permitted finding solutions. It then allowed the validation of modified diving procedures before they were issued as new company procedures.

The Comex Data Bank thus appears a very efficient tool for progressive improvement of decompression procedures.

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Figure 1 : DISTRIBUTION OF SATURATION DIVES OVER STORAGE DEPTHS

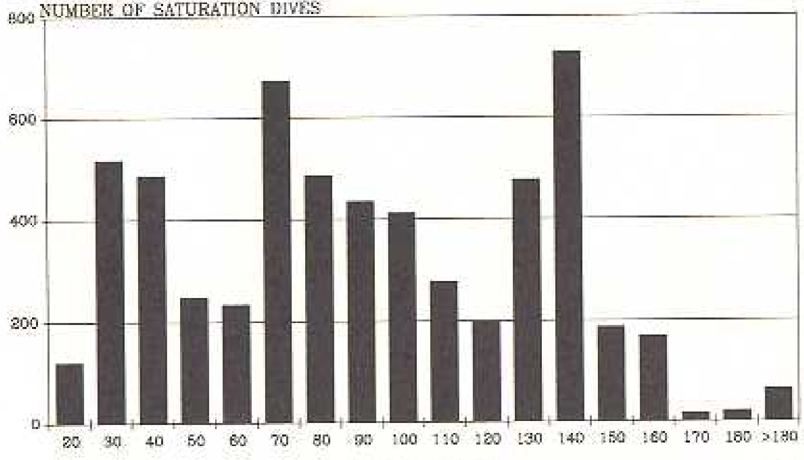


Figure 2 : DISTRIBUTION OF FIRST SYMPTOMS ONSET DEPTHS

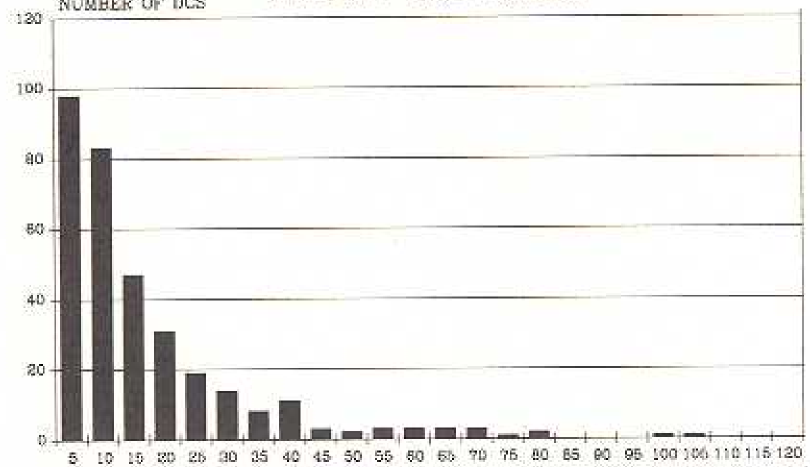


Figure 3 : DCS incidence versus saturation ascent rates with 600 mbar chamber PO2

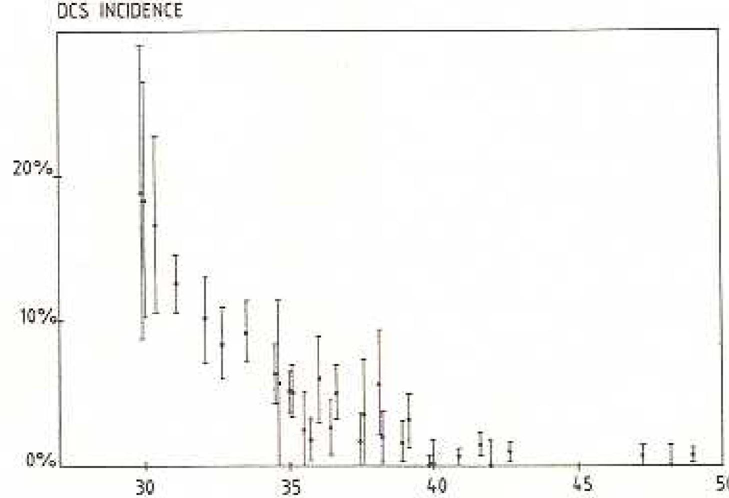

Figure 4 : FIRST SYMPTOMS ONSET DEPTHS VERSUS DECOMPRESSION STARTING DEPTHS

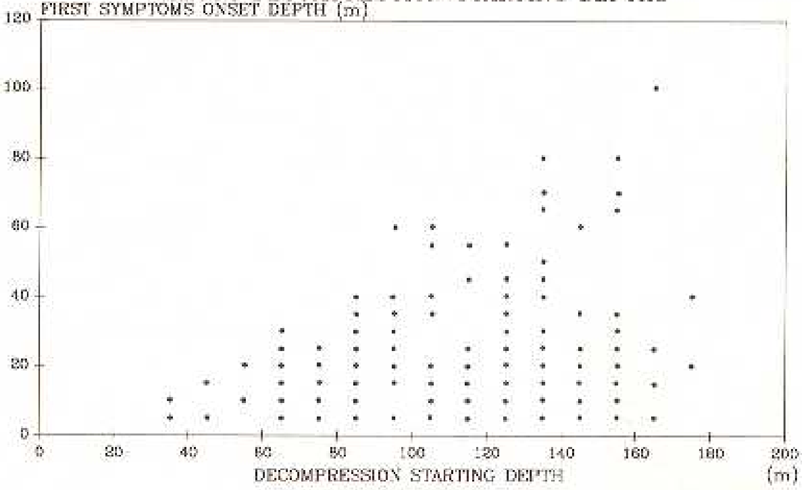


Figure 5 : RELATIONSHIP BETWEEN CHAMBER PO2 AND SATURATION RATE OF ASCENT