"In actuality, all maps incorporate assumptions and conventions of the society and the individuals who created them. Only by being aware of subjective omissions and distortions inherent in maps can a user make intelligent sense of the information they contain."

Denis Wood, The Power of Maps, Scientific American, May 1993

This review is the first of a two part series evaluating four "desktop decompression" software packages that were recently unveiled at the 1993 tek Conference. Part One of the series provides a background for the evaluation and discusses program features and use. Part Two will discuss and analyze decompression computations generated by the algorithms.

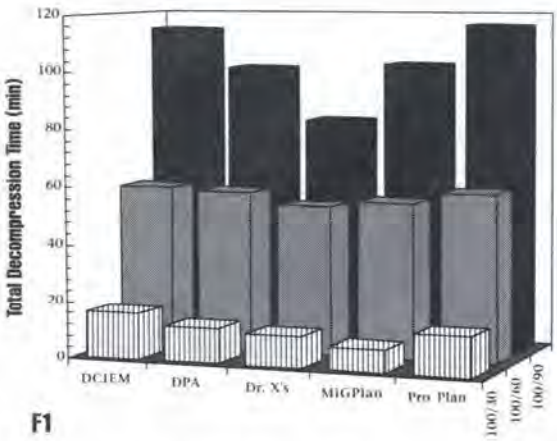
by RW Bill Hamilton and John T. Crea

DESKTOP DECOMPRESSION REVIEW

One of the great "needs" since the advent of deep self-contained technical diving has been for appropriate decompression tables. Unfortunately, there are no applicable "public domain" tables for most technical divers. Some commercial trimix tables have been tried, but these are not really designed for this type of diving, are not optimized, and are not publicly available.

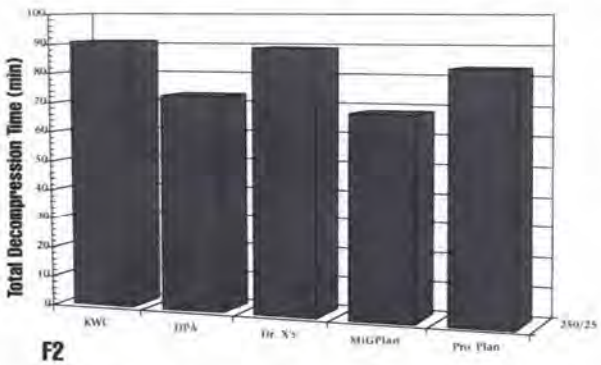
Early technical diving with trimix began with custom tables generated for the specific dive series; many of the early applications were for specific cave diving projects. Custom tables are available from several sources, but they are expensive, especially if a table is used for only one or a few dives. Recognizing this need, several entrepreneurs have recently developed computer programs designed to enable individual technical divers to calculate their own tables. These are moderate in cost, with each of the programs costing about the same as or even less than a single custom table.

This article, the first of a two part series, describes and attempts to evaluate the four currently available programs, which are the Dive Profile Analyzer (DPA)by Cybertronix, Pro Planner by



F1

F1 compares the total decompression time calculated by each program to that of the Canadian DCIEM air tables for a 30, 60, and 90 minute air dive to 100 fsw (31 msw). Note that though the variation in total decompression time becomes more pronounced as the the length of the dive increases. Maximum variation for the 90 minute dive is 33 minutes.



F2

F2 compares total decompression times for each program for a trimix 17/50 dive to 250 fsw (77 msw) for 25 minutes using an EAN 36 intermediate mix and O2 @ 20 fsw (6 msw). These are compared to the Key West Consortium Tables prepared by Hamilton Research Ltd. Note that all of the desktop programs yield shorter decompression times with a maximum variation of 23 minutes. For more information on trimix tables see "Trimix Report," by Michael Menduno, pg. 36.

Aquatronics, Dr. X's Dive and Deco Planner, by DEEP, Inc., and MiG Plan from MiG Technologies. We regard these programs all as a "first cut" at this type of capability, and in this review we try to recommend ways they might be made easier to use and their output more valuable.

HOW THIS EVALUATION WAS DONE

The purpose of these "desktop decompression planners" is to plan an exposure of people to pressure (a dive) followed by a planned return to the starting pressure (a decompression table), all of which will result in an acceptably low risk of decompression sickness. The authors, as "providers" of custom decompression tables, are obliged to be fair in our assessment. Even with some experience in decompression behind us, we found this task enlightening to say the least, and at times a bit frustrating. Both of us have developed and use sophisticated in-house programs for generating tables, one of which is Hamilton Research's DCAP© (Decompression Computation and Analysis Program) which is used in several laboratories, and in doing this we have encountered many problems and have seen the need for many of the features or capabilities of these planner programs. One of us (RWH) took the approach that a new user should not have to call for help in order to use the software, so we tried doing the evaluation in that manner, without using technical support from the developers.

We designed an array of dive plans that we felt would test the programs over the ranges where they would most likely be used. All programs seem to work, all took some effort to learn to use, and all presented some difficulties; we learned that our typical dives were not so typical. Tables T1-T3 summarize their operation and "user friendliness", computations, and information displays. More detail on computations, including gas consumption, and specifically on the conservatism or "J-factors" will be given in the next issue of *aquaCorps*. The conservatism or "J-factors" are critical, since they have a huge impact on the table generated. A table with any reasonable degree of conservatism can be generated with any of these programs (except MiG Plan; see description). The problem is, how does the user know what is right? More about that next time.

Figures, F1 and F2 illustrate some of the air and trimix decompression computations generated by the programs. These are compared to the DCIEM tables (air) and the Key West Consortium tables generated by DCAP (trimix 17/50 with EAN 36 intermediate mix and O2 @ 20 fsw/6 msw).

Note that the J-factors are all turned off or set as low as they go, so none of these would be recommended by their developers.

BACKGROUND AND TERMINOLOGY

Before discussing individuals programs, here is some fundamental terminology and information we feel should be available to the user.

Pressure units: Because the planners deal with **pressure**, we feel they should operate in **pressure units.** Since most Americans still use imperial units, the **foot of sea water,** fsw, is probably a basic unit of choice. A foot of sea water is normally defined as 1/33 atm (1/33 of a Standard Atmosphere, which is defined as 1013.25 mbar), with some slight variations by some (e.g., 33.08). The definition of the unit is not the issue, since variations among the common unit definitions are trivial from a physiological perspective. But decompression planners should produce **quantitative** results, and as such their units should be **precise** and **traceable** to a firm standard somewhere.

If metric units are used, the **metre of sea water,** msw, is universally defined as 1/10 bar or 10 Kpa. This makes the conversion factor between fsw and msw as pressure units equal to 3.2568 fsw/msw (but the conversion of units of length is 3.2808 feet per metre. *See Corps letters, a/c J5: 57-ed.).* The issue of fresh or sea water is a bag of worms, covered in the next installment.

None of the planners define the units they use; Dr.X refers to fsw, the others say "feet." All probably have small unit errors, which we regard as untidy but not physiologically significant.

Partial pressure symbolism: Another pressure-related term could be standardized. The symbol for the partial pressure of a gas as used by physiologists is a capital P, followed by a subscript identifier (such as I=inspired) and the chemical symbol of the gas. Thus P_IN_2 is the inspired nitrogen partial pressure, or just PN_2 with "inspired" implied. The use of "F" to mean "fraction" in the same sense is encouraged. A lower case p as used by chemists has another meaning (as in pH) so can be confusing and is therefore discouraged. Diving operations people may use "PP" to mean partial pressure; this is unambiguous, but we use and recommend the physiologists method of PO_2 for consistency.

Elapsed time display: Tables that present only stop times impose a handicap on the diver. A table should give the accumulated **elapsed time** to the end of each stop. In commercial diving, since the time to get the work done— *bottom time*—may not be known in advance the tables show **decompression time,**

the time since leaving bottom. These are easy to run; just punch the clock on beginning ascent and depart each stop at the indicated time. For tightly planned technical dives **running time**, the elapsed time since the beginning of the dive, works well also. Ideally the user should be able to get both decompression and running time at each stop. Another handy time is the **time to first stop**, since the diver needs to know this.

Oxygen limits: All the programs deal to some extent with oxygen exposure limits and issue warnings when limits are exceeded. Sometimes this is overdone, with so many warnings the user will ignore them. Dr.X beeps a warning whether the dive exceeds limits or not. For CNS oxygen toxicity warnings, DPA, Pro Planner, and MiG Plan use the fraction of the NOAA limits (described in Kenyon and Hamilton, 1989), a CNS toxicity fraction (or "CNS oxygen clock"). Dr.X (apparently) warns when a set PO_2 limit is exceeded. All but MiG Plan accumulate OTU's (oxygen tolerance units); these are not important for any but the most extreme dives.

Narcosis: A widely held assumption is that oxygen plays no role in narcosis, much the same as it does not contribute to decompression. Evidence, other than anecdotal, that this is true is lacking (Linnarsson et al, 1990). Several programs calculate an equivalent narcosis depth based on PN_2; we advise that this be used with caution. It might be better to assume that the narcotic effect is due to both N_2 and O_2.

DESIRED FEATURES

A certain few features, in our opinion, are desirable for programs that generate decompression tables.

None of the programs allow the user to modify a previously entered dive. It seems like it should be easy to include as **defaults** the values for the last dive calculated, so the user could repeat the dive with desired changes; this would be extremely beneficial. For even experienced computer users the ability to "escape" back to a familiar menu is essential once a mistake is made. DPA has a "go back" code, and Dr.X a code for return to main menu, but none has a real "escape." Another essential feature is the ability to save a calculated table to a file, with the filename or table name showing on the table printout also. For existing programs that do not allow this (Dr.X and MiG), utilities such as PRN2FILE enable (some) printer output to be directed to a file. The printed table should also show the parameters or settings used to generate the table, and should be dated.

A computation just as important as the decompression table is the **volume of breathing gas** used on a dive. All these programs except Pro Planner provide esti-

T1: COMPUTER OPERATIONS

Feature	DPA	ProPlan	Dr. X	MiG
Installation	Program or copy files	Use program only	Program or copy files	Program or copy files;
Manual	Loose leaf, 50 pg	Disk, 5 pg	2 pg	10 pg
Examples given, with expected output	Many	None	None	Sample screens
Copy protection	Yes, uses h/w "key"	Yes, must install	None	None
Troubles with installation	"Key" not seen on Dell laptop.	A wrong error message, not critical.	Yes, must be careful	None, easy. None
Waiver acceptance required	Opening screen, detailed	Yes, short	Opening screen, detailed	Opening screen.
Program personalized	Name on tables	Yes, opening screen	Yes, opening screen, on screens, and tables	Opening screen, in waiver
Escape to main menu	Only at end of table; possible to back up	Not often	At any time by typing m, but it forgets mixes	No
Works with $\%O_2$ (not just inerts)	Yes	No, uses inerts only	Bottom, no; EA, yes.	Yes
Can redo previous dive with changes	No	No	Can reuse mixes right away only	Can save mix definitions
Sensible defaults	Not intuitive; does not remember gases	Yes, but all stops have to be keyed in	Only a few	Remembers mixes during a dive
Whole table shows on screen	Scrolls off; view with DOS utility program	Use Print command to view table	No, have to print	Can scroll it up and down
Can save table to file	Saves whole session; overwrites old file	Yes	No	No
Printing	Have to set before running dive	Dot and laser, graphics; good control.	Can't print after viewing	Yes, does not print loadings
Telephone support easy	Not encouraged	Number not listed	Phone number on screen	Yes, listed
Error handling	Poor. Often needs 3-key; but can go back	Can't go back	Tolerant; can't go back	Can't go back; tolerant
Trouble shooting info	Yes, good	None	None	None
User friendliness	Poor at first; not so bad after practice; not intuitive	Pretty screens. Can't go back	Straightforward; very mix oriented	Crisp and simple, few options

mates of gas usage as a function of depth and a predetermined surface rate of consumption. Dr.X and DPA allow a different consumption rate for different stages of the dive. **Utilities for mixing and for topping partially used tanks** are given, but even the best of these (Dr.X) is limited, since the only reuse of a partly empty trimix tank is by adding air; use of pure inert gases or oxygen for topping is best left to the commercial gas suppliers.

There seem to be two approaches a program (or dive computer) can take with regard to informing the user about what it is doing. One is to appear as a "**black box**" which takes input and spits out a table, without telling what goes on inside the box. The other is to be completely **explicit as to what equations are solved.** It would appear that the black box approach puts the burden on the designer to provide a proper decompression, while the latter approach only obligates the program to solve the equation correctly.

We strongly recommend the explicit approach. We would like to know the equations solved in making the decompression calculations. Where the implementation is straightforward according to the 1984 book (on which these programs are based), it may be sufficient to reference it, but if there are changes we want to know them. We especially want to know what the "J-factors" (the conservatism factors) do and how they are calculated. Only the Pro Planner gives details to the extent of including half times, but all reference Bühlmann.

Not every user will be able to evaluate what these equations mean, and even those who do may not be able to judge easily whether the profile generated is reliable. Unfortunately, developers of programs of this type do not (and cannot) provide the support in the realm of decompression physiology to be able to give the user all knowledge needed for using the programs and their output. This has to come from substantial experience and/or from serious technical diving training courses; unfortunately not all the available courses adequately dispense this level of training.

More details on the Bühlmann algorithm (1984) and some philosophy on decompression planning programs will be given in the second part of this series.

DISCUSSION OF THE PROGRAMS

Tables T1-3 summarize the salient features of each of the programs. A discussion of each is given below.

Dive Profile Analyzer (DPA): DPA comes with a loose leaf manual, the only "real" manual in the group. However, it has the figure references all mixed up (unnerving for a decompression program), but it has many examples. A manual is needed because the program is not intuitive and the user needs guidance at first.

Coded input data separated by commas is entered on a command line, following codes shown in a box on the screen. The coding is clever, but initially one feels the data could just as well be entered in response to prompts. However, command line input is faster than menus after a little experience, so this cryptic and initially unfriendly

method is actually quite effective. A "quick review" page would be helpful.

DPA provides a comprehensive table, with running time at the beginning and end of each stop, but does not show decompression time. One inconvenience is that to see the table the user has to exit to DOS and run a program to view the file. The He J-factor would not set at 0 but it will accept 0.01. DPA runs a CNS O_2 toxicity clock, but the output is in a warning, not on the table. The table identifies the third column and PO_2 levels as "bar," but the values in the column are atmospheres, a bit misleading.

PRO PLANNER

Without doubt Pro Planner had the slickest appearance, with a color graphics menu that includes little bubbles rising, a good reminder of what we are doing. Input is intuitive and has flexibility, but every stop has to be entered, and even though it is done with defaults it can be tedious and this seems unnecessary. Having to enter only the inert gases rather than the oxygen percentage is to us inconvenient.

The model specifications say Pro Planner has 16 compartments and 16 tissues, adding to the confusion (these should be called compartments consistently). The specs mention capability with rebreathers to 300 msw or 970 fsw (with an O_2-N_2 mix!), which to us is a bit disconcerting because that makes it look more like a computer game than a serious program; *they can't be serious!* Even trimix to 200 msw (=651 fsw, but it says 640) in our opinion is **well** beyond the scope of this type of program to handle, if for no other reason because of overall operational complexity.

The table screen is well done, with loadings and both a current and a history graph as well as the table (but why is the history on the right and the current dive on the left?). Scales on the graphs are inconsistent, done to fill the space but it makes them hard to compare. Stops are not at even 10 fsw increments, causing one to wonder why. A big disappointment with this program is that the table has no elapsed time.

Nowhere does it tell the user that a laser printer can be selected (by the Printer selection on the main menu), so we dusted off an old 9-pin printer, which worked but very slowly; this proved to be unnecessary as it has two laser printer choices, small and big print (nice!).

T2: COMPUTATIONS

Feature	DPA	ProPlan	Dr. X	MiG
Algorithm	ZH-L16 (not sure of which version)	ZH-L16	ZH-L16, modified (not stated how modified)	ZH-L12 (also a 12 cmpt model, source?)
Halftimes given	No	Yes, but not limits	No	No
J-factors	Increases each inert gas by a %	Increases inert 1% for each 5% factor	"Safety factor" in %; increases bottom time; different with air	4 levels; more conservative limits O2 also
Descent rate control	Instantaneous, can step down.	Instantaneous, can step down	66 fsw/min, set	Instantaneous, can step down
Ascent rate control	Instantaneous	10msw/33fsw per min	33 fsw/min, set	Not given
Can change mix in dive	Yes, at any stop	Yes, at any stop	Select in advance; only 1 trimix allowed	Some options, not all
Constant PO_2 (rebreather)	Yes, called "macro"	Yes	No	No
Can "position" diver though a profile	Yes	Yes	With difficulty	"Load" allows profile freedom but not mix control
Retains loadings to do repetitive dives by gas loading	Says not to do it; have to "position" thru first dive	Yes, well developed	Not possible	Yes, well developed
Multilevel dives	Yes	Yes, well developed	Not possible	Yes, well developed
Flying after diving	No	Yes	No	No
Basis for EAD given	n/a	Not given	n/a	n/a
Diving at high elevations	No	Yes, good to 11500 feet elevation	No	No. A version that does this is available.
OTU count	Yes, by stop & at end, warns on % exposure	Yes, end of dive	Yes, at each stop (615 limit inappropriate)	No
CNS oxygen warning	Only on PO_2 level	Yes; gives % exposure	Only on PO2 level; beeps even when O2 low	Yes, gives % exposure
Gas consumption	Yes, bottom & decom	No	Yes, well developed	Yes, only one level
Calculates tank topping	No	Yes	Yes, with air	No

DR.X

Dr.X takes the "no frills" approach to the screen, using straightforward and intuitive prompts. There is no capability for doing multilevel and repet dives, however. There is a mix selection algorithm which seems designed to keep the new user out of trouble. A nice feature is that one can escape to the main menu by typing "m" at any point, but the dive has to be started over. The gas definitions can be used again, if done right at the end of a dive, but the use of appropriate default values is minimal.

The table is comprehensive, has instructions and warnings and includes running time, but the printout has a copyright statement which seems to be printed right over part of the warning section. The warning area is cluttered and it is an effort to pick out the data. Asterisks mark points where there is a high CNS toxicity risk, but how this is determined is not described, and as mentioned, it beeps even when there is no violation. The table includes a calculated "one minute emergency ascent" which is not the same as the first stop depth; its meaning is not clear to us. The total stop time is given, without the travel time, which is not as useful as total decompression time would be.

A good part of this program and its utilities is directed toward gas management, selecting, mixing, and keeping track of gas consumption. We are told a manual is on its way.

MIG PLAN

The screen has gas definition on the left, a character-based loadings chart in the middle, and a rather cryptic table on the right. The program will select appropriate mixes, in many cases without real control by the user, based on PO_2 and air-equivalent narcosis (see discussion above). The user does not get to dictate gas switches specifically, but rather defines the range of use of each mix and the program does the switching; these appear to be appropriate, but may not be what the user wants. It seems to be possible to enter inappropriate gases without a warning on entry. The program has a "load" function which can be used for profile positioning rather easily. It will retain the loadings over a surface interval, permitting repetitive dives based on gas loading. It will not allow decompression to an intermediate depth, only to the surface. Only one gas consumption rate can be used. Bottom time is defined differently by MiG Plan, encompassing the interval between leaving surface and arriving at first stop. This also makes the displayed run time non-standard.

The table only includes depth, running time and mix name, which is the bare minimum a diver needs but its value for analysis is limited.

The J-factor choice in MiG Plan is limited to certain categories, not a numerical value. The more conservative choices also limit the PO_2 which can be used, perhaps protecting the user against high oxygen exposure but greatly limiting the flexibility of the program. The commentary in the small manual is appropriate in warning about this program's providing the capacity to do dangerous things; the solutions are generally bucked

T3: DISPLAYS

Feature	DPA	ProPlan	Dr. X	MiG
Gas loadings displayed	No	Yes	No	Yes, character graph
Time to first stop	By subtraction only	No	Yes; added to bottom time	No
Decompression time at stops	No	No	No. (But it does show on screen display)	No. And no stop times!
Running time at stops	Yes	No	Yes	Yes, non-standard
Total decompression time for whole table	Stop & travel totals shown separately	Yes	Stops only	No
Total running time	Yes	No	Yes	Yes
Time of day display	No	Yes	No	No
User can put comments on table	No	No	No	No
J-factors used show on table	Yes	Yes	Yes	No
Filename shows on table	Yes (session ID)	No	n/a	n/a
Date shows on table	No. Random code # ?	No	No	No

Illustration by: Jean-Pierre Imbert

off to the training courses, but some bad practices such as yo-yo, reverse, and multiple deep repetitive are mentioned.

CONCLUSIONS

These programs are a first step toward filling the gap between traditional decompression tables and on-line, realtime dive computers. They permit user-controlled dive planning for many special cases where presently there are few options. No one can say whether they produce "safe" output, and people in the decompression business are reluctant to use that word with even their most reliable tables. Reliability depends on the degree of conservatism. We do not worry nearly as much about whether the programs can calculate good tables as we do about whether the users can make the judgement as to when they are good. Details about this and the table computations in general will be covered in a later article.

None of the programs at present qualifies as a "best buy," but they all represent a good start. They are usable now, with some inconveniences and difficulties. The developers see the problem from different perspectives, and ours are different from those. We would like to see, just for the record and not for daily use, more about how the calculations are done. One of us (RWH) is committed to a display of decompression time, but running time is a close second and is best for many of these applications. All the programs could be easier to use; one way they could all benefit is to retain the data from the last dive as defaults for the next one, enabling similar dives (e.g., same depth and different bottom times) to be done. More to come.

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More Information

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Desktop Software

Dive Profile Analyzer.
Author: Corey Berggren Cybertronix, Inc., 3435 Redbud Drive, Knoxville, TN 37920. p: 615.977.0360. Australia: High Tech Divers p: 61.2.418.9507 f: 61.2.418.9513

Pro Planner.
Author: Kevin Gurr. Aquatronics, 42 Marsh Road, Thatcham, RG13 3QR, England, U.K. p:44.635.869.185, f: 635. 869.185 US: IANTD, 1545 NE 104th St., Miami Shores, FL 33138 p/f: 305.751.4873

Dr.X's Dive & Deco Planner.
Author: Sheck Exley. DEEP Inc., Route 8, Box 374, Live Oak, FL 32060 p: 904.362.7589

MiG Plan.
Authors: Jody Svendsen and Dan Nafe. Mig Technologies, 2000 NW 88th Court, Miami, FL 33172 p: 305.594.4994.

"Telepresence" was marvelous, but it could sometimes be a dangerous illusion. You might believe you were experiencing a hundred percent of some remote reality but it was only ninety five percent— and that remaining five percent could be vital: men had died because there was still no good way of transmitting those warning signals that only the sense of smell could detect.

Arthur C. Clark, Ghost from The Grand Banks