Stichting Duik Research

Een verkorte weergave van :
“Duikcomputers
Een vergelijkend onderzoek naar hun prestaties en veiligheid”

A short presentation of:
“Dive computers
A comparative investigation of their performance and safety”

Partly in English (Summary, Prologue, Conclusions, figures&legends and evaluation per type of dive computer)

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Het complete rapport kan besteld worden tegen een kleine vergoeding, zie www.duikresearch.org.

The complete report can be ordered for a small amount, see www.duikresearch.org

Summary

The Dutch Foundation Dive Research (SDR) has tested more than 50 dive computers (DCs) with air-only simulations in 75 sessions under some 10 basic different circumstances. One session considered the application of a Nitrox mixture. The tests were performed in a wet small vessel. The DCs were subjected to multilevel simulations, in general to an equivalent pressure of 45 msw (meter seawater) with a repetitive simulated dive to 27 msw. Several modifications of the 45 msw dive were applied. Also deep dives to 51 msw and shallow dives were made. To establish the degree of conservatism the DCIEM tables were used as reference.
Summarizing the results indicates that DCs do not always bear out (entirely) the claims in the manual. Every type appeared to have to some extend one or more shortcomings.
Time, depth and temperature as measured by the DC were generally accurate within specifications. As far as the no-deco limits and no-flying times go, older DCs were far too liberal. On these points, newer models did perform better and the newest DCs were sufficiently conservative. Most DCs of this category corrected to too fast ascents as well but highly variable, from severe to mostly too weak. However, none reacted properly to yo-yo behavior. From time to time unexplainable inconsistencies and/or unstable behavior were found so serious that this must be considered to be intolerable.
When large deviations from the expected behavior of the DC occur or in case of a calamity, such as battery failure it is far better to ascent conservatively and not use the DC any longer. To continue its use may worsen the situation and increase the risk of decompression sickness

We present here the characteristics of the types of DCs tested. Most of then are frequently used in the Netherlands, in Belgium and other European countries.

Samenvatting

De SDR heeft ruim 50 duikcomputers (DCs) getest met gesimuleerde luchtduiken in een klein, met water gevuld drukvat. Eén sessie werd besteed aan de toepassing van een Nitrox mengsel. In ruim 75 sessies zijn allerlei gesimuleerde profielen getest. Ook zijn extreme temperaturen gebruikt. De testen zijn uitgevoerd met meer-niveau-simulaties (voortaan multilevelsimulaties genoemd), meestal naar 45 msw (meter sea water) met een herhalingssimulatie naar 27 msw. Om de mate van conservatisme te beoordelen is als referentie de DCIEM tabel gebruikt.
Kort samengevat komt het resultaat er op neer dat DCs niet altijd (geheel) waar maken wat de handleiding vermeldt. In het algemeen is dit gelukkig wel het geval. Tijd, diepte en temperatuur worden bijna altijd. conform de specificaties aangegeven. Wat betreft de nultijden of niet-decolimieten en de niet-vliegtijden zijn oudere DCs onvoldoende conservatief, nieuwere modellen scoren op deze punten beter en de nieuwste DC zijn meestal voldoende conservatief. Een aantal DCs uit deze categorie corrigeren te snelle opstijgingen min (meestal) of meer adequaat, maar een reactie op jojoën was zeer uitzonderlijk en bovendien zwak. Bedenkelijk is dat er af en toe bij duiksimulaties onverklaarbaar gedrag is aangetroffen, zo ernstig dat dit eigenlijk ontoelaatbaar is. Bij grote afwijkingen van het verwachte gedrag van de DC of bij sterk verslechterde omstandigheden, van welke aard dan ook, is het beter de duik volgens de regels af te breken en de DC niet langer te gebruiken. Bij voortgezet gebruik bestaat de kans dat de situatie verergert, dus dat de kans op decompressieziekte groter in plaats van kleiner wordt.

We geven hier (in het Engels) de eigenschappen van de geteste DCs. De meeste van hen worden vel gebruikt in Nederland, België en andere Europese landen.

Prologue

This report is based on an investigation of the Foundation of Dive Research (SDR) and is performed with an UWATEC miniature compression chamber.

Voorwoord

Dit rapport berust op een onderzoek van de Stichting Duik Research (SDR) en is uitgevoerd met een UWATEC testvat..

The investigation started in December 2002 and still is continued. An important reason of this is that always new types of dive computers are brought out
The tens of sessions with the test chamber, in which with treads and measures, frequently four or five the dive computers (DCs) including the cumbersome tube models were installed, have been carried out by Drs. Eduard van Riet Paap and the author. Two sessions have been performed in the Carol van Gelderen tank of the foundation Recompressietank Maarsseveen (SRM). This is a 6-person compression chamber, once owned by Smit Internationale. This tank has been originally taken over by the SDR and then by the SRM.

Request
The author has tried this compose report with care. The reader should discover however omissions, incorrect interpretations or errors, then report is very appreciated of this on e-mail address info@duikresearch.org.

Het onderzoek ging in december 2002 van start en wordt nog steeds voortgezet. Een belangrijke reden hiervan is dat steeds weer nieuwe typen duikcomputers worden uitgebracht.
De tientallen sessies met het testvat, waarin met passen en meten de duikcomputers(DCs), vaak vier of vijf, inclusief de lastige te hanteren slangmodellen in het testvat geplaatst moesten worden, zijn uitgevoerd door Drs. Eduard van Riet Paap en de auteur.
Twee sessies zijn uitgevoerd in de “Carol van Gelderen” tank van de Stichting Recompressietank Maarsseveen (SRM). Dit is een 6-persoons compressietank, ooit het bezit van Smit Internationale. Deze tank is indertijd door de SDR overgenomen en vervolgens door de SRM.

Verzoek
De auteur heeft getracht dit rapport met zorg samen te stellen. Mocht de lezer echter omissies, onjuiste interpretaties of fouten ontdekken, dan wordt melding hiervan op het E-mail adres info@duikresearch.org zeer op prijs gesteld.

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Inhoudsopgave

1. Inleiding

Duikcomputers (DCs) bieden vele voordelen boven het gebruik van tabellen. Duiken volgens een tabel gebeurt volgens een strak diepte-tijd regime. De DC geeft veel meer vrijheid want de partiële N_2-druk van elk compartiment (een fictief weefsel, gekenmerkt door zijn halveringstijd) wordt elke minuut berekend en hieruit volgt de nultijd of beter de Niet-Decolimiet (No-deco limit, NDL)[1]. Hoe gecompliceerd een duikprofiel er ook uitziet, de DC rekent het allemaal *du moment* door. Veel nieuwe DC typen kunnen duikplanningen maken. Bij het gebruik van tabellen zijn menselijke fouten gauw gemaakt, zoals bijv. bij herhalingsduiken en multilevelduiken. Ook een foutloze uitvoering van de duik volgens het duikplan is geen vanzelfsprekendheid. Met een DC is dat allemaal een stuk makkelijker.
De DC speelt in op de actuele situatie, dus ook op onvoorziene omstandigheden waardoor het duikplan moet worden gewijzigd. Dit doet de DC door het deco-schema aan te passen.

DCs geven elk moment (direct of indirect) aan hoeveel tijd nodig is om aan de oppervlakte te komen. Zijn ze lucht geïntegreerd[2] dan berekenen de DCs elk moment of er voldoende lucht is om aan de oppervlakte te komen. Ze waarschuwen wanneer moet worden opgestegen als de luchtvoorraad onvoldoende dreigt te worden voor de opstijging.
Er zijn tegenwoordig ook DCs die met de watertemperatuur rekening houden, d.w.z. de NDL aanpassen.

Het duiken met een DC is om de bovengenoemde eigenschappen en redenen een waar genoegen. Er rijzen echter ook vragen, zoals:
- Is hun onderliggende model conservatiever dan een gerenommeerde tabel zoals DCIEM?
- Kunnen ze nooit falen?
- Zijn ze foutief te gebruiken terwijl het schijnbaar goed gedaan wordt?

In het uitgebreide rapport worden ze allen behandeld.

2. Het testen van duikcomputers

Doelstellingen

Er zijn een aantal algemene doelstellingen, die overigens niet altijd geheel los van elkaar staan.
1. Werkt de DC technisch gesproken zonder storingen? Dit heeft betrekking op een storingsvrije weergave van diepte, duiktijd, NDL, stopdiepte en stopduur, desaturatietijd, niet-vliegtijd (NVT), temperatuur etc.
2. Is het gedrag conform de specificaties in de handleiding? Dit betreft niet alleen voldoende nauwkeurigheid van de diverse weergaven (zie 1.), maar ook hoe de DC bijv. decoduiken, herhalingsduiken en sterke afkoeling verwerkt. Tenslotte is de vraag van belang hoe gereageerd wordt op ongewenst gedrag van de duiker, zoals te snelle opstijging, stops overslaan, niet afmaken van een stop en jojoën.
3. Hoe is het gedrag ten opzichte van een gekozen standaard of norm? Dus de vraag naar de mate van conservatisme of veiligheid.
4. Hoe verhoudt het gedrag van DC's zich ten opzichte van elkaar.

Te onderzoeken aspecten

- Mechanische betrouwbaarheid
- Leesbaarheid display.
- Tijdaflezing.
- Diepteaflezing.
- Temperatuuraflezing.
- NDLen.
- NVT en desaturatietijd.
- Herhalingsduiken.

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[1] Voor de nultijd wordt de afkorting NDL gehanteerd , een term die direct aansluit bij de Engelse literatuur.
[2] De flesdruk wordt continue geregistreerd waaruit het verbruik op de gekozen diepte berekend wordt.

- Meerdaags duiken.
- Decoduiken.
- Bescherming tegen te snelle opstijging.
- Effect diepe stop (diepte is helft van verschil MDD en decoplafond, inbegrepen de veiligheidsstop).
- Bescherming tegen jojoën.
- Bescherming tegen extreme temperatuur en afkoeling.
- Effect van persoonlijke instelling
- Gebruik van Nitrox (Ean).

3. Evaluation per type of DC

The motivation of these evaluation can be found in "Dive computers, A comparative investigation of their performance and safety", see www.duikresearch.org.
For the following evaluation, it is underlined that the results of the tests per type is generally based on one, sometimes two tests and at most three standard tests (45 msw and repetition 27 msw), the Companion excluded. It is possible that other specimens of the same type perform different. It is also possible that with other simulation profiles the performance is basically different, leading to other conclusions and recommendations. In the description it is indicated how to correct NDLs and NFTs in order to improve safety of the dive. The given numbers are rough estimates.
The descriptions are concluded with: DISAPPROVED, NOT APPROVED, AND. DISAPPROVED means that SDR claims that the respected DC type is not sufficiently safe according to present insights. NOT APPROVED means that SDR an instable performance or other serious limitations/shortages. APPROVED means that SDR did not find one serious negative characteristic for save diving.

Sherwood Source
This DC has been developed some 15 years ago. Its NDLs are too long and NFT (no flying time) is not displayed. On the basis of the present insight about NDLs and NFT it is *recommended not to use* this DC anymore.
DISAPPROVED.

Aladin Pro (Scubapro)
This DCs was developed some 20 years ago. Despite this, NDLs were reasonable. NFTs (no flying time) were much too short. Reproducibility was bad.
DISAPPROVED.

XR2 (Aeris)
This DC was still sold in 2006. It seems to have an algorithm developed in the eighties. It is even much less conservative than the Suunto Companion. With multilevel dives at levels shallower than 15 msw NDLs are tens of minutes longer than advanced DCs. Stops are not indicated when necessary according to DCIEM tables and many other types of DCs. Emergency ascent don't have any consequence for the surface schedule.
It is concluded that this DC, anyway this specimen, is not useful.
DISAPPROVED.

Aqua Lab (Seac Sub)
For shallow dives this DC is more conservative than D6 and Smart. For very deep dives the reverse holds. This DC doesn't adapt its deco schedule after an emergency ascent. NFTs are relatively long but with some dives (e.g. short dives) shorter than the 12-24-36h rule.
Recommanded with remarks

Solution and Nitrox version (Suunto)
Specific tests were not performed. A reduction of NDLs with 3 min at all depths is sufficient to make the DC conservative. NFTs should be increased with 4-16 hours according to the 12-24-36 hour rule.
This DC can be used (with remarks).

Companion, Vapor, Vapor Air, SME, Spider, Eon (all Suunto) and Dive Mate
These DC's have to long NDLs And (dangerously) increase NDLs after a too fast ascent. In accordance with their model, these DCs does not protect against any kind of yo-yo's. These DCs have not been not developed

for multiday-repetitive diving. NFTs should be increased many hours according to the 12-24-36 hour rule.
The use of these DCs is subjected to various serious limitations.
OUTDATED.

Mares Surveyor (and Nitrox version)
This DC is for some five years not any more commercially available. Although it is conservative, this DC has the same features as the above group with respect to a too fast ascent and yo-yo's, but in addition, its NDLs can be *instable and inconsistent* (found with all three tested specimens). NFT should be increased with ca. 4-8 hours according to the 12-24-36 hour rule.
Summarizing Although this DC can be used for a first dive, during a repetitive dive (and after excessive yoyo's) there is a risk that the DC displays NDLs which are some 25% to large.
IRRELIABLE.

Vyper (first released type, Suunto, RGBM)
Surprisingly, three of the four specimens of this DC (with RGBM) showed 2-6 times long NDLs at depths less than 20 msw, and especially at 12 msw after a simulation at 45 msw when compared to the well performing 4th one and other Suunto RGBM DCs (released before 2000). The too fast ascent (from 45 to 24 msw, 60 msw/min) resulted in a comparatively mild penalty (5 min obligate safety stop at 3 msw). NFTs seem correct.
Summarizing This DC is useful, but with deep dives, the diver should be aware of the above shortcoming which may occur (and in that case considerably shorten the displayed NDLs shallower than 20 msw). This seems to occur with a part of the produces specimens.

Cobra (first released type, Suunto, RGBM**)**
With the first dive, the Cobra was less conservative (as also holds for other RGBM Suunto's released before 2004) with respect to *NDLs* than other advanced DCs. These DC can be used when NDLs of the first dive are reduced with 2 min between 40 and 30 msw, and every shallower range of 10 msw 2 min more. This holds during the stay at MDD and during the ascent. The Cobra is slightly more conservative with a *repetitive dive* and becomes most conservative with *multiday diving*. Its response to *omitting a stop* is adequate (imposing a deeper stop). The penalty at a too fast ascent was too mild; only an advised safety stop. This DC (weakly) penalizes yoyo's only with extreme yoyo-behavior. *NFTs* are good or close to the norm. With heavy dives, the deco-ceiling is continuous. This reduces the bubble grow. Instructions for the use of the logbook etc. are not all/always clear. Making a PC connection and retrieving files is not always successful. Using the personnel setting P1 gives a very substantial lengthening of total ascent time and even more for P2. They have originally been developed for altitude diving and therefore they do not optimal correct for non-optimal conditions. (Holds for all Suunto DCs.
This DC is useful (with a remark).

Gekko (Suunto, RGBM**)**
With a first dive, the Gekko is less conservative with respect to NDLs (No-decolimits) than the Cobra and more advanced D6, UWATEC DCs, RGBM DCs of Mares and other advanced DCs. Therefore, for NDLs of the first dive a diver younger than 40 years is advised to reduce NDL with 2 min between 40 and 30 m, and every shallower range of 10 m two more min. For divers older than 40 years see *www.duikresearch.org*, Correctie voor leeftijd en conditie as the strongly recommended alternative for P1 and P2 settings.
The performance with Nitrox is correct. It gives NFT not as a time interval but indicates flying prohibition with a airplane icon. NFTs are to short: use the 12-24-36(-48)h rule. The penalty at a too fast ascent was absent or too mild. Instructions in the manual are not always clear. Downloading of dives is impossible.
This DC is useful (with remarks).

D6, Vyper Air (Suunto, RGBM)
The D6 and the Cobra perform very similar. The design is beautiful and it can also be used as a wrist watch with a compass included. For diving is gives much info on its display (many icons) but one should have eyes with good acuity.
With the 45 msw standard test the D6 behaved the same as the Cobra. This holds also for the 27 msw repetition dive (except for a 10 min longer NDL at the end of the 9 msw level). With Nitrox, it behaves conservative.
The response to a too fast ascent (45 to 6 msw, 60 msw/min) showed an obligate stop of 5 min (Cobra 8 min) at a chosen depth of 5.9 m. The stop at 3.1 msw was the same (4 min). Surface interval was lengthened to ca. 2.5 h. Such an ascent with 150 msw/min! resulted in only an obligate stop at 3 msw for 3 min and a safety stop.

As all Suunto DCs with RGBM, the RGBM feature seems not to work during the fist dive. The benefit of RGBM for repetitive diving and multiday diving is limited (and absent for long shallow dives). The 50% and 100% RGBM setting resulted in the same ascent procedure.
Heavy yoyo's were penalized, but there was no dive prohibition. RBT of the Vyper Air is under study.
This DC is recommended (with some remarks).

Trac (Scubapro)
A NDL reduction is not emergencyed but the NFT should by extended by 4-8 hours.
Specific tests were not performed. One should limit the ascent speed to 10 msw/min. (Ignore the manual at this point).
With the consequent reserve, this *DC despite its release in the nineties is certainly useful*.

Aladin® Z, Nitrox, Air Nitrox, Air X, Pro and Sport (UWATEC)
These DCs can be called at least conservative. Its response to *skipping a stop* is adequate (imposing a deeper stop). These DCs should and do protect against *too fast ascents* and against decrease of body temperature by shortening NDLs, or lengthening deco-times. These DCs do not penalize any of our yoyo-simulations. For this DC, NFT may be lengthened by 4 to 8 hours according to the 12-24-36 hour rule.
In the 10-20 msw depth range with many types of dive profiles, the majority of the specimens can show long lasting *instability* of the displayed NDLs of ca. 10 min. This shortcoming possibly only occurs under laboratory conditions.
These DCs are less recommended due to the noticed instability.

Mares M1
With respect to NSLs this DC appeared to be conservative to very conservative for the first and a repetitive dive. The optional safety stop was also displayed after the last obligate stop at 3 msw. The deep stop, implemented in the underlying model, is optional. When executed, it is expected (theoretically) to shorten total diving time but this was not the case. A penalty at our too fast ascent could not be established. This DC did not penalize any of our yoyo-simulations. It is suggested to lengthen NFTs by 4 to 8 hours.
This DC is recommended (but with some remarks).

Nemo Sport and Wide (Mares)
With respect to NDLs this DC appeared to be very conservative for the first and a repetitive dive, even more than Mares M1. The optional safety stop was also displayed after the last obligate stop at 3 msw. Conservatism holds for deep dives (multilevel), shallow dives m, and very long dives. A penalty at a too fast ascent could not be established. This DC did not penalize any of our yoyo-simulations. It is suggested to lengthen NFTs by 4 to 8 hours.
This DC is recommended (with some minor remarks).

Smart Com, Pro, Z and Tec (UWATEC)
With respect to NDL this DC was very conservative for the first and repetitive dive. Applying a microbubble mode comprising a stop at 9 msw and higher is supposed to be not without some risk for DCS (on-gassing of many compartments) and one should be very critical in using them. It is much saver and more effective to shorten bottom time. Its response to *skipping a stop* is adequate (imposing a deeper stop). This DC should and does protect against *too fast ascents* (very adequately). For such an ascent over about half MDD the penalty is a deco-stop and an emergency ascent over nearly the whole MDD (from 45 to 6 msw) resulted in a stop and a dive prohibition. (This holds also for Aladin® Air). This DC also protects against decrease of body temperature (a little moderate) by shortening NDLs, or lengthening deco-times. This DC penalizes yoyo-simulations; our most heavy one with 7 min extra stop time and a dive prohibition of 13 h. For this DC it is suggested to lengthen NFTs by 4 to 8 hours according to the 12-24-36 hour rule. RBT is under study.
This DC is recommended (with some very minor remarks).

Galileo Luna (UWATEC)
Comaped to the Smart, a substantial improvement is the safety stop, making the dives more conservative, or less harmfull in case of not following the prescribed ascent profile or violating basic rules (too fast ascent, yo-yoing etc.). RBT and the heart rated feature is under study.
This DC is recommended.

Acknowledgement
The UWATEC test chamber is a precious gift of the firm HyTech at Raamsdonkveer, The Netherlands. Without this gift this research had been supposedly not realized. For this reason, the SDR is HyTech very grateful.
Suunto Benelux is acknowledged for providing a D6 and Vyper Air, UWATEC Benelux for a Galileo Luna with cardiometer..

Dankwoord
Het UWATEC testvat is een kostbare gift van de firma HyTech te Raamsdonkveer. Zonder deze gift was dit onderzoek vermoedelijk niet mogelijk geweest. De SDR is HyTech daarom zeer erkentelijk.
Suunto Benelux wordt bedankt voor het beschikbar stellen van een D6 en Vyper Air, UWATEC Benelux voor een Galileo Luna met cardiometer.
De SDR dankt de SRM voor de geboden gastvrijheid om de hectische temperatuurtesten met kokend water en grote partijen ijsblokjes in een bijna-waterballet uit te voeren.
De auteur dankt Ir. Harry van Grol voor zijn vele commentaar, dat de leesbaarheid van het rapport zeker ten goede is gekomen..

Abbreviations **Afkortingen**

DC	dive computer, duikcomputer
DCIEM	Canadian Forces Decompression Tables 1992
DCS	decompression sickness
DCZ	decompressieziekte
HF	herhalingsfacton
MDD	maximal diving depth (msw), maximale duikdiepte (msw)
M-value	maximal allowed compartimental inert gas tension (bar)
M-waarde	, maximaal toegestane inerte gasdruk in compartiment (bar)
NDL	no-deco limit, niet-decolimiet (min)
NFT	no-flying time (h or min)
NVT	niet-vliegtijd (h of min)
OI	oppervlakte interval
RBT	remaining bottom time (min), resterende bodemtijd (min)
RF	repetition factor
SDR	Stichting Duik Research
SI	surface interval (h and min)