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DECO FOR DIVERS

A Diver's Guide To Decompression Theory and Physiology

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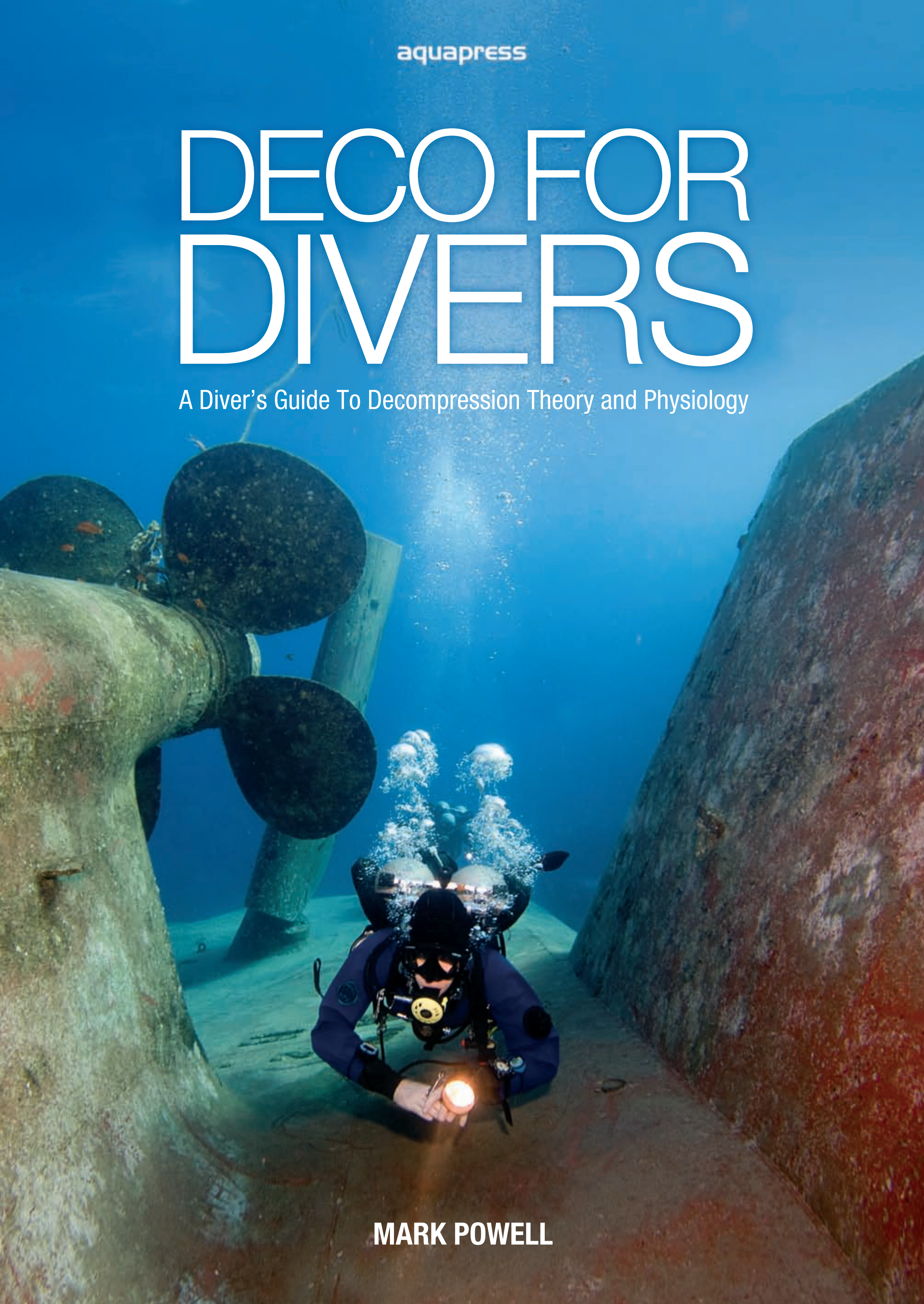

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Introduction

This book was written to provide an accessible source of information on decompression theory. It is aimed at divers who are interested in finding out a little more about the physiology and concepts of decompression. The idea initially took root when I first started trying to learn more about decompression theory in order to satisfy my own interest. There were a number of sources of introductory information giving the basics of decompression theory. Some of these are very good introductions to the subject and are well explained. However I found that if I wanted to find out any more about any aspect of the theory there was a shortage of follow-on information. The only option was to jump into the original source articles, research papers or conference proceedings. Often the original source material was highly detailed with each paper looking at great depth into a single aspect of the individual concepts. A further hindrance was that many of these original papers were published in quite obscure journals or as research reports. Journals such as the Undersea and Hyperbaric Medicine Journal or the Aviation, Space and Environmental Medicine Journal can only be found in specific research or university libraries. Many of the papers written by decompression researchers working for the British, US and other navys were published as internal research notes and were not available in even the most comprehensive libraries. I was frustrated by this gap between the introductory texts and the source material. What I wanted was an intermediate overview that went into more detail but wasn't written for academics or researchers. Unfortunately there was no such text available.

When I became a technical diving instructor I started teaching other people about decompression theory. I tried to give an overview of decompression theory at this intermediate level to give my students a better understanding of what was happening during decompression dives. This was always very popular amongst divers who, like me, had always wanted to understand more about the concepts and models underlying decompression theory. I was always being asked if I could recommend a good book which covered this area but as before,

Left: A pair of divers explore a Red Sea wreck there was no such text available. Over time I started giving out notes for the decompression theory portion of my courses and these notes started building. Initially they were just a few pages but the notes became more and more comprehensive and started to cover more and more areas. Eventually they grew into this book.

As I wrote this book I could have started almost every sentence with 'current thinking is' or 'we currently believe'. There are many theories as to the causes and mechanics of decompression but very few known facts.

"There is a false sense of security amongst recreational divers that decompression is a well understood science and that decompression illness can easily be avoided if you stick to your decompression tables."

This confidence is not shared by many decompression researchers. They realise that there is so much we still don't understand.

As we will see during the course of the book there are a number of quite different theories on various aspects of decompression theory. Not all of these theories can be correct. One of the major problems in giving a definitive explanation is that there is very little scientific evidence behind many of the theories. This problem of insufficient evidence can be seen where there are directly competing theories on a single issue. It is possible to find a paper on one aspect of decompression theory which is directly contradicted by another paper. Which one is correct? This problem is not unique to decompression research but is exacerbated by the fact that many studies are performed on test groups that are too small to be considered statistically significant. Tests are often conducted in less than ideal experimental conditions with test subjects being given control of the experiment and asked for a subjective view of the results. This leads to the situation where you can get contradictory results and often interested parties leap on the result that backs up their point of view without acknowledging other points of view.

Despite all the issues I have raised above, recreational diving is a very safe activity compared to other activities. Millions of dives are carried out each year using current decompression models with a very small incidence of decompression illness.

Many of the early advances in the field of decompression theory were driven by navy research scientists or medical officers. Haldane's development of the dissolved gas model through to Workman's development of the M-value idea was driven by military interest. In the 1960s and 1970s the discovery of oil reserves in deep water led to a significant interest in developing new diving techniques for deeper and longer dives. During this period the major oil exploration companies invested heavily in decompression research. With the increased use of remotely operated vehicles (ROVs) the interest in decompression research in the oil companies was greatly reduced. With the reduction in research in the military and commercial sectors the funding for decompression research has also been greatly reduced.

The increase in popularity of technical diving has raised the interest in decompression theory when pushed beyond the limits of recreational diving. Technical diving involves diving deeper than recreational limits for extended periods of time and using mixed gases other than air. Technical diving is pushing the boundaries of many aspects of diving and decompression theory is one such area. With the reduction in research on the military and commercial sectors it is becoming increasingly common for the needs of technical divers to drive decompression research.

Technical divers who are extending recreational diving concepts to technical diving decompression may be taking a much higher risk. Applying concepts tried and tested in the recreational diving range can produce unexpected or incorrect results when applied outside of their intended range. Decompression ideas that are valid within the recreational diving range are not necessarily valid beyond this range.

As an analogy we can consider a post natal clinic which measures the length/height of babies from birth to 6 months old. With enough measurements we can calculate an average height for ages from birth to 6 months. From this data we can extrapolate to 1 year, 2 years or more. However this extrapolation becomes increasingly inaccurate as the age is increased. The rate of growth slows down and then stops as we become older and so the relationship between age and height that applies from birth to 6 months becomes increasingly unreliable as we get older. Blindly extrapolating the data will result in a prediction that by age 21 we will be approximately 4m tall. Diving in the recreational range can be thought of as analogous to age 0 to 6 months in that we have plenty of data points for this range and can use these to accurately predict what will happen in this range. As we increase the depth and start to go into decompression diving then we are extrapolating past the 6 months point and so our predictions will start to become less reliable. In this range traditional methods of predicting decompression may still provide useable dive profiles but they are based on less than ideal assumptions. As we dive deeper and longer and move into the range of extreme technical dives then decompression predictions based on traditional recreational models can be compared to the predictions of a 4m tall, 21 year old.

Adopting the latest fashion in decompression theory still doesn't mean that the technical diver is free from risk. Divers who download one of the latest PC planning tools from the internet; use it to plan a dive and just blindly follow the plan it gives them are gambling with their health and more on the assumption that this piece of software is correct.

"Blindly following a set of tables, PC planning program or any other form of decompression planning without understanding some of the principles of decompression theory can be highly dangerous."

As I have explained I am a diver and a technical diving instructor. I am not a doctor or a decompression researcher. As such there is no original research or thoughts in this book. All I have tried to do is to bring together and explain the ideas and theories that have been proposed by others. In doing this I have necessarily had to summarise some of the core ideas. In some cases this process has taken an aspect of decompression theory which spans many articles and conference proceedings and summarises it in just a couple of paragraphs. In this case it is inevitable that much has to be left out and many of the ideas and explanations must be simplified. I have tried to simplify things to the point where they can easily be understood without loosing the key point.

In chapter one we start with a thorough review of the history and development of decompression theory. This chapter gives details on the life and work of some of the early researchers in this area as well as detailing the discoveries they are responsible for. Starting with Robert Boyle's experiments with a vacuum pump which provided the first documented occurrence of decompression sickness, the chapter moves through the research of the famous French scientist Paul Bert. The introduction of pressurised underwater working areas (Caissons) and the resulting discovery of Caisson's disease is detailed along with the experiences of workers involved in early Caisson construction projects. At about the same time, the first evidence of decompression sickness amongst divers was also documented.

The pioneering work of John Scott Haldane and his work for the British Admiralty in developing the first scientifically derived decompression tables sets the tone for future research on decompression theory. The contribution of the US Navy between the two world wars and in the early 1950s is described, as well as the significant contributions of Prof. Albert Bühlmann in Switzerland. Together, this research provides the basis of what we would consider traditional decompression theory.

In chapter two some of the key principles of decompression theory are explored. This combination of physical effects and their impact on our body provide an overview of exactly what happens to us when we breathe in a pressurized environment. Although dealing with concepts from physics and biology, this chapter is written in a descriptive style with no scientific jargon or complex equations.

Chapter three describes the various forms of decompression sickness, how they are caused and how they can be avoided. Various conditions, behaviours and environmental conditions that can increase the risk of decompression sickness are discussed. The medical effect of decompression sickness on the body, together with the treatment, both in a first aid and in recompression chambers, is discussed.

Saturation diving is discussed in chapter four. This type of diving is popular with commercial diving organisations but is not practical for the recreational diver. Saturation diving involves the divers staying on the sea bed until their bodies become saturated with the gas they are breathing, they can then work for indefinite periods – from days to weeks or even months – without incurring any further decompression penalties. This approach becomes cost effective for commercial divers undertaking long projects. Due to the interest in saturation diving amongst commercial and military organisations, a significant amount of research has been carried out in this area and in fact many aspects of decompression theory have arisen as a result of saturation diving research.

Chapter five discusses the use of Nitrox and its effect on decompression. Most recreational diving has traditional been carried out while breathing compressed air. Since the 1990s Nitrox, a combination of Nitrogen and Oxygen where the Oxygen content is higher than normal air, has become increasingly common. The use of Nitrox to reduce decompression obligations is discussed, as well as the use of an additional rich Nitrox mixture to speed up (or accelerate) decompression. Using the first of these techniques divers can spend up to twice as long on the bottom without having to go into decompression. With the second technique, divers can significantly reduce the amount of decompression they need to do for a given dive.

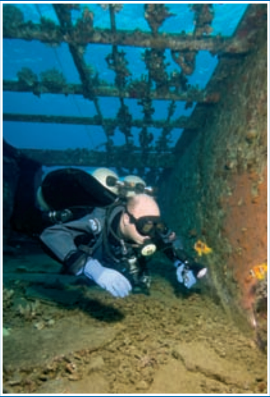
Modern approaches to decompression theory are summarised in chapter six. The emergence of inconsistencies in the traditional view of decompression which has led to the development of more recent theories are also discussed. More recent approaches, which can be described as deep stop or bubble model approaches, are covered in detail. The development of deep stops through both empirical trial and error as well as more scientific approaches is detailed. Empirical approaches such as Pyle stops are covered, along with the popular gradient factor approach. The work of researchers in the "tiny bubble" group, which has led to so called bubble models, is described as well as both the generic aspects of bubble models and some of the specifics of several of the more popular versions of bubble models.

For deeper diving, the use of Trimix – a mixture of Oxygen, Helium and Nitrogen – is becoming increasingly common. The introduction of Helium into the breathing mix provides significant advantages for deeper diving but introduces additional complications into decompression. Chapter seven gives a full discussion of all the factors involved in Trimix decompression.

A variety of other decompression models or approaches are discussed in chapter eight. Despite sponsoring the original research by JS Haldane, the British Royal Navy developed an alternative method of calculating decompression schedules. These tables were developed by the Royal Naval Physiological Laboratory and are known that RNPL tables. These tables adopt a quite different approach to decompression modeling to the traditional approach inspired by Haldane. The British Sub Aqua Club (BSAC) has also developed a set of tables based on an alternative model. The BSAC has never published the details of their model but by investigating the research of the scientist who developed them we can piece together some clues as to how they work. The US Navy has also looked at alternative models based on different assumptions as to how our body takes in and eliminates nitrogen. They have also put extensive effort into calculating decompression tables based on statistical or probability models.

For those who are interested in the details of the various decompression models discussed throughout the book, Chapter nine contains tables of the various key parameters as well as details of the mathematical models. All the mathematical details of the various models have been collected into a single chapter, providing a complete reference for those who would like to investigate the implementations of the various approaches. It also ensures that the rest of the chapters can remain relatively maths free which makes the main sections of the book more readable. For those who are not mathematically inclined, this chapter can be safely skipped!

In the main body of the text I have generally avoided giving specific references or including footnotes in order to avoid breaking up the flow of the narrative. The References and Further Reading section contains further reading on key areas of decompression theory as well as references to source material for each chapter.



Deco for Divers provides a comprehensive overview of the principles underlying decompression theory and physiology. Mark Powell has written a book that for the first time allows the average diver to fully understand the principles behind this fascinating and critical aspect of diving. As well as a thorough examination of air decompression the book also addresses decompression using nitrox and mixed gases. It is completely up-to-date and includes information on the latest developments including deep stops and advanced bubble models. Deco for Divers bridges the gap between introductory books and specialist scientific journals and is suitable for new as well as highly experienced divers.

This is a truly remarkable book which covers all the various theories of decompression and ascents for divers in a most readable and understanding manner. There is no other comprehensive book on decompression to my knowledge which is so easy to read and understand by the average recreational or technical diver.

Peter B. Bennett, Ph.D., D.Sc. Executive Director, UHMS. Emeritus Professor of Anesthesiology, Duke University Medical Center. Founder & 1st President, DAN

This is the most comprehensive and well-written text I've seen that attempts to explain decompression theory to divers.

Dr Richard Vann Assistant Research Professor in Anesthesiology, Safety Officer and Director of Applied Research at the Duke Hyperbaric Center, and Vice President for Research at DAN.

This book is a "must read" for those who have ever wondered about decompression tables and how they are created. It is a straight forward book and devoid of technical jargon. It starts with the scientific giants who developed the physics of the gas laws and the physiology of diving and ends with M-values and tissue bubbles. For the curious diver – and all divers should be – it will be money well spent!

Michael R. Powell, MS, PhD. NASA (retired), Medical Sciences Division, Johnson Space Center, Texas

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