A History of the Development of Decompression Tables

By
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January 10, 1981

U.H.M.S.

Undersea and Hyperbaric Medical Society
10531 Metropolitan Avenue
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UMS PUBLICATION NUMBER 47(DT)1-10-8

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JANUARY 10, 1981

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The selection, analysis, and reproduction of material for this report is supported by the Max and Victoria Dreyfus Foundation.

The original collection of the documents, the abstracting and key wording was supported by the Office of Naval Research under contract N000014-79-C-0435, with additional funds supplied by the U. S. Navy Bureau of Medicine and Surgery, Research and Development Command, and the National Oceanic and Atmospheric Administration.

PREFACE

The literature reported in this document was collected, abstracted and keyworded to fulfill the requirement of the Office of Naval Research program to alert involved individuals to the latest information in the field of hyperbaric and underwater activity.

The first analysis in the present form was published under the same title by the Undersea Medical Society on 18 February 1975. The present update is supported by The Max and Victoria Dreyfus Foundation.

The citations and abstracts are arranged alphabetically by the senior author's last name, and by date if more than one publication is by the same author.

The second part of the report consists of a number of different analyses which we believe the reader will find of interest in more fully understanding the development of this part of the field of underwater activity.

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1.
ADAMS, G.M.

Bone necrosis. Status report number 1.
Faceplate 5:20; Winter 1974.

A survey of dysbaric osteonecrosis is being carried out at the Naval Submarine Medical Research Laboratory in Groton, Conn. The diving populations with the highest percentage of this disease are Japanese shell divers, who do not use standardized procedures or consistent therapeutic methods. The populations with the lowest are the U.S. and Royal Navy divers, who follow both practises rigidly. In order to minimize the problem, careful adherence to accepted procedures of compression and decompression should be adhered to. Heavy regular use of alcohol is known to be a contributing factor. The absolute necessity of the diver's reporting of any or all symptoms during or following a dive is stressed. (MFW/UMS)

2.
AKERS, T.K. and W.A. Bares.

Experimental verification of computer-derived optimum diving profiles.
In: Abstracts of the Undersea Medical Society, Inc. annual scientific meeting. May 12-13, 1976. Undersea Biomed. Res. 3:A46-A47; Mar. 1976.

Abstract only. Entire item quoted: Biological modeling of decompression profiles has been known since Haldane and Hill. Two years ago, one of the above authors presented results of a digital computer-based simulation of a seven-compartment model, showing optimization of decompression to be a modified exponential curve. A series of decompression experiments on various-sized guinea pigs has been run since that time. All the guinea pigs were saturated to 21 and/or 11 Bars helium with 200 mm Hg pO_2 at 32°C and about 40% R.H. Animal size ranged from 150 gm to 800 gm, and most were on the rapid growth curve. Optimum decompression profiles were computer-derived for each specific weight range, centered on 150, 300, 500, and 800 gm. Each profile had been scaled for the animal size and weight as related to these parameters in man. All animals were successfully decompressed. Roles of the various parameters (weight, height, girth, fat content, age) and scale factors will be discussed.

3.
AKHLAMOV, N.A., Yu.M. Barats, Yu.N. Kiklevich and A.B. Khayes.

Underwater investigations of "Ikhtiandr" club.
In: Azhazha, V.G., ed. Some results and prospects for the use of underwater habitats in marine investigations, p.94-98. Moscow, Izdatel'stvo Nauka, 1973. Translated by U.S. Joint Publications Research Service, Oct. 23, 1974 (JPRS 63261).

In 1966 and 1967, the Donetskiy Club "Ikhtiandr" conducted in sequence two experiments including the submergence of underwater houses-laboratories and a study of the functions of the human organism existing for an extended time under unusual conditions in the ambient medium. In the authors' opinion, the problem of developing the continental shelf needs to be solved along the following four lines: 1) a study of the life activity of aquanauts; 2) the development of underwater habitats and systems of their support; 3) the development of technology and procedures for underwater activities; and 4) the creation of new instruments for underwater research. (Authors' abstract)

4.
ALBANO, G.

Etudes sur la decompression chez l'homme. Les valeurs critiques du gradient de pression a la remonte sans paliers.
First Int. Conf. Sub-Aquatic Med. Cannes 15-19 June 1960.

The author has verified experimentally, by means of dives repeated several times a day by scuba divers, the relative importance of decompression and the pressure gradient, taken as indicators of the tendency of dissolved nitrogen to liberate itself in gaseous bubbles in the human body. It was concluded that the magnitude of the decompression should be evaluated and calculated by means of the pressure gradient. (Author's summary translated by MFW/UMS)

5.

ALBANO, G.

Teoria del nucleo gassoso. Il gradienti di pressione nel controllo decompressione subacquea.
[Theory of the gaseous nucleus. The pressure gradient in the control of underwater decompression].
Folia Med. (Napoli) 48:910-931; Oct. 1965.

The bubbles causing decompression troubles develop in presence of gas supersaturated from pre-existing nuclei or newly formed nuclei. Generally speaking, the origin of these nuclei is related to local tension forces, provoked by muscle contraction (especially isometric contractions); however, in some tissues (S.N.C.) the formation of gas nuclei can be determined by electro-chemical phenomena. Each newly formed spheric nucleus is, however, destined to immediately dissolve again, unless a condition of supersaturation subsists, such as to determine its growth. Insofar as nuclei of a different form than spherical are concerned, there might subsist some condition of gas supersaturation which might permit their stability. If a pressure gradient (Dp) higher than the critical supersaturation level develops in the body, the gas nuclei will increase in volume by diffusion and will penetrate then in the vessels through the pores of the capillaries; there, they will get rid of the spherical nuclei which are less than 3.3 micron in diameter, so that a residual Dp of at least 213 mm Hg will be necessary in order that they might be allowed to grow further and cause embolism. This is the minimal necessary gradient in order that morbid manifestations might be observed even far from surfacing. Nevertheless, in order that the extravasal gas nuclei might start enlarging, a higher Dp is necessary, such as might be present at the time of surfacing. This Dp can be determined according to the various stops on the basis of the elements available for scientific investigation. (Author's abstract)

6.

ALBANO, G. and M. Columba.

Gas nucleation concept applied to decompression.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the fourth symposium on underwater physiology, p.193-204. New York, Academic Press. 1971.

The authors state that research carried out on 156 guinea pigs affected by decompression allowed them to make the following observations: (1) Only major areas in decompression give rise to gross bubble formation and to death. In these experiments postmortem histological findings show great and confluent gas bubbles in almost all tissues without manifest connections with blood vessels. (2) Localized damage ensues after precise and always reproducible patterns of exposure and decompression. This damage has special characteristics according to the specific tissue and animal species involved; some effects are also related to the sex of the animal, its body mass, and the degree of adaptation. Thus, in a selected group of animals it is possible to produce at will damage of the bones, the mesenteries, the spinal cord and the brain stem. (3) If an animal is killed some minutes after localized damage has occurred, there are indications of gas emboli with secondary thrombi on the arterial side. (4) However, if the animal is killed at the initial development of localized damage, one can often detect penetration into the vessels of small gas bubbles originating in the adjacent tissue mass. There follows a theoretical and mathematical discussion which shows how these four observations apply to man. (CWS/BSCP)

7.

ALEXANDER, J.M., E.T. Flynn, Jr. and J.K. Summitt.

Initial evaluation of revised helium-oxygen decompression tables.
U.S. Navy Exp. Diving Unit Rep. NEDU-RR-14-70, 101p. Oct. 23, 1970.
(AD 719 388)

Fifty-four man dives were undertaken to evaluate three representative tables from a revised set of HeO_2 schedules. These tables were calculated using the classical Haldane method and used the set of "M" values derived by Workman in 1965 as limits. A 33% incidence of decompression sickness occurred using surface decompression procedures. It was subsequently recommended that further testing of the schedules was unwarranted at this time. Further evaluation of the "M" values was recommended. (Author) (GRA)

8.

ALLIN, L., R.Y. Nishi and L.A. Kuehn.

The use of digital technology for diver monitoring and decompression research.
In: Program and abstracts. Undersea Medical Society Annual scientific meeting. May 13-16, 1977, Toronto, Canada, p.A33-A34. Undersea Biomed. Res. 4, Mar. 1977. Appendix A.

Abstract only. Entire item quoted: Technological changes in digital electronics and microprocessor development within the past few years have made possible the development of field-portable instrumentation for decompression research and real-time diver monitoring. Previously, diver-carried decompression computers were pneumatic-mechanical devices and to be marketable and small, were very simple and of limited use. Decompression computers based on more realistic decompression models were complicated, bulky, expensive and not commercially available. Decompression schedule generation usually required the services of a large general purpose computer. With current electronic technology it is possible to construct miniature low-powered digital computers which can quickly calculate decompression schedules for dive planning or analysis, or which can calculate the decompression status of a diver in real-time based on his actual pressure-time history. A family of such instruments, developed by the Defence and Civil Institute of Environmental Medicine in cooperation with private industry, is described. These include a desk-top calculator for analysing and generating decompression schedules, real-time decompression monitors for hyperbaric chambers or surface-supported dive operations, and a diver-portable personal decompression computer. The advantages and disadvantages of using digital electronic technology as opposed to pneumatic-mechanical technology are described. Some applications of these various types of digital decompression computers and their use in dive management will be outlined.

9.
ANONYMOUS
Sadko-2—a new Soviet underwater laboratory.
New Sci. 42:122; Apr. 17, 1969.

Entire item quoted: Successful trials of a new underwater laboratory have recently been described by the Soviet press agencies. The laboratory—christened Sadko-2—was designed by members of the Leningrad Hydrometeorological Institute and the Academy of Sciences, Acoustical Institute. It consists of two steep spheres. The upper one contains the living quarters and control panel, while the lower one acts as an anteroom where the crew can change out of their aqualungs and diving suits. The laboratory is served by either a surface ship or coastal port, and is supplied with gaseous breathing mixture from them through a flexible pipe. The Sadko-2 structure is fairly buoyant. It is held in position by a hanging ballast, and is also attached to a heavy anchor and the surface, the laboratory can be raised or lowered as required. The first trials of the Sadko-2 were carried out in the Black Sea last summer. The laboratory was lowered to a depth of 25 m, although members of the research team made individual dives down to 40 to 50 m. The main aim of the trials was to test special breathing mixtures and decompression tables worked out by the underwater research laboratory of the Leningrad Hydrometeorological Institute. The crew also measured the speed of the currents, the temperatures at various depths, as well as studying the underwater fauna and flora. The trials lasted ten days in all, including three days in the decompression chamber.

10.
ANONYMOUS
Ocean Systems to provide diving services to 1,500-Ft. depth.
Sea Technol. 15:9; June 1974.

The systems will be comprised of a decompression chamber complex of three chambers to support up to four divers to the maximum depth and for the long periods required for decompression. Two living chambers can be controlled independently for simultaneous decompression of two 2-man teams. The 1,500-ft. system provides support for saturation diving which at full bottom depth will yield about two hours bottom working time per diver team. The two hour limitation is believed to be the maximum time divers can effectively work because of the extreme environmental conditions found at that depth. The system will provide for heating of the diver, his breathing gas and the submersible chamber. . . . [Ocean systems has] planned a series of experiments in 1974 with manned exposures at 1,500 feet to develop the diving procedures which will include the saturation-excursion diving technique for this project. Divers will be maintained under a pressure much shallower than bottom depth. Special decompression schedules will permit deep excursions from this saturation base giving moderately long bottom times (up to two hours) with minimum decompression penalties incurred when coming back to the base depth. Ocean Systems has already developed this technique for diving to 1,000 feet. (Author)

11.
ANONYMOUS
Saturation excursion table limits extended.
Faceplate 5:24; Summer 1974.

The U.S. Navy Experimental Diving Unit has been developing new saturation-excursion diving tables. It has been found that excursions could be extended to much longer periods than had been thought safe, without incidence of decompression sickness. From three 300-foot saturation dives, excursions were made to 400 feet starting with two-hour dives and culminating in safe excursions of 24 hours. In a fourth dive, the divers first saturated at 300 feet and conducted a 24-hour excursion. They then went to 600 feet, saturated, and made two 24-hour excursions to 750 feet. They went finally to 1000 feet, saturated, and remained for 48 hours. Work capability was studied, and physiological parameters were monitored. Respiration, heart rate, serum enzyme and platelet studies were made. Findings will be published at a future date. (MFW/UMS)

12.
ANONYMOUS
New diving tables permit more rapid decompression.
Sea Technol. 16:17-19; Mar. 1975.

The author discusses the development of the decompression tables and submersible operations of the Harbor Branch Foundation, operator of the Johnson-Sea-Link lock-out submersible, and funder of a grant of the Duke University hyperbaric facility for the development of new tables. Divers used in the research were furnished by Oceaneering International, Inc. and International Underwater Contractors, Inc. Under the direction of Dr. Peter B. Bennett, a technique of mixing breathing gases allowing rapid compression and comparatively fast decompression without loss of function, has been developed. The decompression time after 30 minutes at 500 feet is reduced from 17 hours (U.S. Navy tables) to 12 hours. Slower initial decompression, elimination of oxygen breathing, and the addition of small amounts of nitrogen to overcome hpns are among the innovations. The dives here described took place in the Bahamas on 19 December. Two divers were locked out for 30 minutes at 500 feet, using Bio-Marine closed-circuit rebreathers. The Johnson-Sea-Link has a 1000 foot depth capability. It has two manned pressure hulls, one of which mates to a deck decompression chamber. Except for one plexiglass pressure hull for the pilot and observer, and the viewports of the second, it is constructed of aluminum. It carries sonar, VQC underwater telephone, FM transmitter, intercom, Doppler navigation system, mechanical arm, life support systems and closed circuit diving equipment. Cruise speed is from ¾ knot on two motors to 1¾ knots on five motors. Life support endurance is 5½ man days. The Johnson-Sea-Link 2 is nearing completion. It will have a greater depth capability. (MFW/UMS)

13.
ANONYMOUS
Alberta diving reminders.
Diver Underwater Adventure 4:27; Jan. 1978.

If the diver waits 12 hours after arriving at altitude before diving, he has become acclimatized, and need not consider himself in a repetitive dive group. But a dive from sea level to 5,000 feet would put him in group D, waiting two hours in group C. If he dove to 90 feet true depth (108 feet according to the Cross altitude tables) he would have 10 minutes bottom time. A capillary depth gauge should be used, along with the U.S. Navy dive tables. Since the gauge reads deep at altitude, it allows a margin of safety. Twelve hours should be waited after diving, and one should not dive at more than one altitude in one day. Depth gauges other than the capillary type read shallower than actual depth and this must be taken into consideration. One should wait for 12 hours after diving before flying or driving home over a mountain pass. If it is inconvenient to wait, flying is permissible when the diver has reached repetitive group D. If he has been doing no-decompression diving, this means he will be able to fly in 4½ hours. (MFW/UMS)

14.
BARES, W.A.
Optimum diving profiles.
Biomed. Sci. Instrum. 10:29-32; 1974.

A new dimension of versatility in diving simulation is accomplished which uses the digital simulator Continuous System Modeling Program (CSMP) to simulate a parallel seven-compartment diving model. Feedback to control decompression rate is incorporated into the model. Results show the optimum decompression profiles for the Haldane model to be segmented exponentials with each segment time constant determined by one controlling compartment "diving ratio." Comparison to conventional diving tables shows both perilous and overly conservative regions in traditional decompression. . . . A versatile simulation using CSMP to model a seven compartment parallel inert gas system for generation optimum diving decompression profiles is shown. The simulation can be used for short-time, saturation, and excursion diving decompression profile generation. (Author)

15.
BARES, W.A.

Digital simulation for determination of optimum diving profiles.

In: Aerospace Medical Association. Preprints, 1974 annual scientific meeting, p.203-204. Washington, D.C., Published by the Association, 1974.

Biological models in diving have pioneered physiological modeling since the days of Haldane and Hill et al. (1908). Most models have been parallel first order linear differential equations defining diffusive cases, with tabulated step solutions (diving tables) for decompression bases on experimentally determined time constants and "diving ratios" for avoiding "bends." A new dimension of versatility in diving simulation is accomplished which uses the digital simulator Continuous System Modeling Program (CSMP) to simulate a parallel seven-compartment diving model. Feedback to control decompression rate is incorporated into the model. Results show the optimum decompression profiles for the Haldane model to be segmented exponentials with each segment time constant determined by one controlling compartment "diving ratio." Comparison to conventional diving tables shows both perilous and overly conservative regions in traditional decompression. (Author's abstract)

16.
BARNARD, E.E.P.

Medical problems of very deep diving.

J. Roy. Nav. Med. Serv. 51:179-183; Summer 1965.

The area covered by the term Deep Diving is that which has been explored only experimentally, as yet, in pressure chambers, and lies between 300 and 800 feet for durations up to 4 hours at depth. Two problems of particular interest to a doctor are those of isolation and communication. The two main channels for information as to the condition of the divers are observation through small viewing ports and speech through a two-way communication link. The divers, due to distortion of the voice under pressure, can not make themselves heard, but they can hear and understand and give answers by use of sign language. The major problem of diving is still decompression sickness. This is discussed by the author; description of the Haldane tables is also given. Decompression sickness and the handling of it is discussed, and it is tentatively suggested that the solution will be found in the prevention of bubble growth. A discussion follows the paper. (EH/BSCP)

17.
BARNARD, E.E.P.

Medical aspects and decompression.

In: Experimental observations on men at pressures between 4 bars (100 ft) and 47 bars (1500 ft). Alverstoke, UK, Roy. Nav. Physiol. Lab., Rep. 1-71, p.114-137. 1971.

Oxygen partial pressure was limited to 0.45 ats, CO_2 partial pressure to 0.005 ats. Diagrams show the compression and decompression rates. During compression, stationary levels of 24 hours were observed at 600, 1,000 and 1,300 ft for adaptation purposes. During decompression from the 1,500 foot dive, recompression had to be employed early in the procedure because of labyrinth symptoms in subject No. 1. This recompression caused a rather severe compression syndrome in subject No. 2, who became confused and uncoordinated, although the recompression was actually slower than the original compression had been. When decompression was resumed, both subjects showed slight pain at 970 and 730 ft, which disappeared. At 26 ft subject No. 2 had a rather severe leg pain and recompression to 31 ft for several hours was employed. The pain returned when decompression was resumed and an attempt to combine oxygen-breathing with recompression was tried. After a few hours gradual decompression was resumed, and upon surfacing, subject No. 1 was still somewhat unsteady and subject No. 2 had an ache in his right leg. The subject has since apparently made a complete recovery. Subject No. 1, however, still suffered from poor balance two months later, and examination showed a "severe right labyrinthine lesion and the remnants of a spontaneous nystagmus." He will probably suffer a slight imperfection of balance permanently. In conclusion the author states that if rapid recompression cannot be used at great depths without resulting in compression syndrome, the chief curative agent in decompression accidents becomes restricted, precluding any assurance of cure. It may be that permanent physical damage is a risk of saturation diving at these depths. (MFW/BSCP)

18.
BARNARD, E.E.P.

Fundamental studies in decompression from steady-state exposures.

In: Lambertsen, C.J., ed. Underwater physiology V. Proceedings of the fifth symposium on underwater physiology, p.263-271. Bethesda, Md., Federation of American Societies for Experimental Biology, 1976.

The model upon which the current solution is based is as follows: Equal masses of gas are considered to be liberated by equal decrements of pressure, hence a linear term should be involved. Secondly, equal masses of gas occupy volumes which are inversely proportional to the pressure. The physical dimensions of such volumes of gas will be inversely proportional to some power of the pressure; for spherical bubbles, indeed, the radius would be inversely proportional to the cube root of the pressure. The underlying assumption which we believe to be supported by experiment is that this type of decompression always leads to the formation of intravascular gas emboli. The general method described—that of extrapolation followed by empirical adjustment and refitting of the curve with further extrapolation—represents a method of progressive refinement by which it should be possible to exclude unsatisfactory mathematical relationships, but which does not in itself suggest any particular solution. The decompression curve so far developed with its deep linear portion and its shallow curved section—shaped like a hockey stick—presents a striking similarity to the U.S. Navy schedules for these depths, but it remains to be seen whether future experiments will confirm this convergence. (Author)

19.
BARTHELEMY, L.
French naval activities in diving physiology.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the Third Symposium on Underwater Physiology, 23-25 March, 1966, Washington, D.C., p.34-43. Baltimore, Williams and Wilkins Co., 1967.

This presentation of French research in diving physiology is a report of the activities of Groupe d'Etudes et de Recherches Sous-Marines (GERS) for the period since the Second Symposium. Much of the work deals with developing new decompression schedules and elaborate diving schemes as a result of the need for handling very deep dives for long duration. Another part of the work deals with submersible diving chambers (SDC) of various kinds and with the special diving suits and new pieces of equipment developed. (CWS/BSCP)

20.
BASSETT, B.E.
Theory of air decompression for scuba instructors.
In: Proceedings of the Eighth International Conference on Underwater Education, Nov. 1976, San Diego, Calif., p.50-57. Colton, Calif., National Association of Underwater Instructors, 1976.

Instructions in the use of Air Decompression Tables often gives rise to many questions which cannot be answered from the information generally available to the Scuba instructor. As a result, many misconceptions regarding the tables have developed and been perpetuated. This presentation outlines the history of the development of safe decompression based on the findings of the English physiologist, J.S. Haldane, and discusses the subsequent development of the U.S. Navy Standard Air Decompression Tables. Application of the theory to problems related to sport diving will be emphasized. (Author's abstract)

21.
BASSETT, B.E.
And yet another approach to the problems of altitude diving and flying after diving.
In: Proceedings of the Ninth International Conference on Underwater Education, p.26-38. Colton, Calif., National Association of Underwater Instructors, 1977.

There have been a number of procedures and tables formulated and presented in the past for diving in high altitude lakes and for flying following diving. The most well known of these are the "Cross Corrections" and perhaps the newer approach presented in the NOAA Diving Manual. This presentation discusses these procedures and compares them to yet another approach presently being used to generate procedures and tables for these two related decompression problems. A status report on planned manned validation testing of these tables and procedures will also be presented. (Author's summary)

22.
BECKMAN, E.L., R.G. Masson and E.M. Smith.
Medical support program.
In: Miller, J.W., J.G. Van Derwalker and R.A. Waller, eds. Tektite II: Scientists-in-the-sea, p.IX-1 - IX-24. Washington, D.C., U.S. Department of the Interior, August 1971.

This report describes the organization, responsibilities, observations, and conclusions of the medical program. Included are descriptions of the staff, training requirements, physical facilities, examination and decompression procedures, the development of new decompression tables, and a review of some problems faced. In general it can be said that no serious medical problems were encountered. Of 915 man-days in the habitat, only 13 man-days in the water were lost because of medical reasons. A brief discussion of non-diving medical problems is included. [Appendix A gives Tektite 1 decompression table, Appendix B, the revised table for Tektite 2 (more oxygen breathing and more stops), Appendix C, the table for Minitat, and Appendix D, the treatment schedule for emergency or accidental decompression from 100 feet.] (Authors' abstract)

23.
BECKMAN, E.L.
Diving standards.
In: United States-Japan conference on natural resources development. Proceedings of the first joint meeting of the U.S.-Japan panel on diving and technology, Tokyo, 1972, p.104-115. Japan, Ministry of Agriculture and Forestry, 1972.

The author discusses the economic and safety problems of the diving industry in the United States, and emphasizes the difficulties of agreeing on regulations for decompression tables, for medical certification of divers, and for standards regarding equipment and procedure. The necessity of developing new decompression tables for industrial diving is noted. The U.S. Navy decompression tables are so conservative as to be prohibitive in cost, due to the extremely high wages received by divers. In spite of the conservatism of the Navy tables, there is a large incidence of osteonecrosis in former Navy divers who are now working in the industry. The author has been assigned the task of developing commercial decompression tables, and requests the cooperation of Japan in the testing of three tables. (MFW/UMS)

24.
BECKMAN, E.L. and E.M. Smith.
Tektite II. Medical supervision of the scientists in the sea.
Texas Rep. Biol. Med. 30:1-204; Fall 1972.

This report constitutes an entire special issue of the journal. The contents are as follows: I. Introduction; II. Saturation diving; III. Tektite I; IV. Evolution of project Tektite II; V. Medical staff and responsibilities, psychological monitoring; VI. The spectrum of medical supervision of the aquanauts; VII. Other medical and biological objectives; VIII. Tektite logistics; IX. Mission-by-mission experiences; X. The aborted 100-FSW (Minitat) Program; XI. Decompression tables; XII. General medical observations; XIII. Some preliminary psychological observations; XIV. Biochemical, hematological, and endocrine studies; XV. Conclusions. (MFW/BSCP)

25.
BECKMAN, E.L.
Development of criteria for improved safe work practices in the U.S. diving industry.
In: Trapp, W.G., E.W. Bannister, A.J. Davison and P.A. Trapp, eds. O_2. Fifth international hyperbaric congress proceedings, p.912-917. Burnaby, Canada, Simon Fraser University, 1974.

Present conditions indicate that almost every high pressure worker will be entitled to a compensation claim before he reaches retirement age. Thus, it is essential that legislation be adopted to protect both employer and employee. A committee of the National Institute for Occupational Safety and Health has made recommendations as follows: Specifications must be made as to safe limits of oxygen partial pressure and exposure, as to inert gas partial pressures, and as to medical qualifications for divers. The recommended treatment for decompression sickness consists of U.S. Navy treatment tables plus British Royal Navy Table 7, supplemented by heparin, dextran, and steroids. Regarding osteonecrosis, preemployment and annual roentgenographic bone surveys should be made; juxta-articular lesions prohibit employment, and the disease is to be considered an occupational hazard unrelated to negligence. As to diagnosis, ultrasonic bubble detectors and measurement of platelet function and blood coagulability are suggested. Supervisory personnel must be trained by the government in recognition and treatment of decompression sickness. Diving contractors responsible for reasonable care in prevention of decompression sickness, and for administration of proper treatment should it occur. Regarding equipment, the ANSI Z135 Committee recommendations were followed. As to prevention of decompression sickness, the Washington State Tables should continue to be considered standard until further research to improve them has been completed. Divers must remain within easy access of a chamber for a specified period of time after diving, and should wear identification indicating recent diving activity. They should not fly within two hours of a no-decompression dive, within 12 hours of a decompression dive, and within 24 hours of a saturation dive. These recommendations do not apply to altitudes below 800 feet, so that presumably transportation by helicopter would be safe. (MFW/UMS)

26.
BECKMAN, E.L.

Summary and recommendations for future research.

In: Beckman, E.L. and D.H. Elliott, eds. Dysbarism-related osteonecrosis. Proceedings of a symposium on dysbaric osteonecrosis, Marine Biomedical Institute, University of Texas Medical Branch, Galveston, Texas, February, 1972. p.243-246. Washington, D.C., U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, 1974.

In the author's opinion, the problems explored in this Symposium suggest that research attention and funding should be expended primarily in seeking answers in the following areas: (1) The epidemiological factors in osteonecrosis among both caisson workers and commercial divers. Such research would be greatly simplified by the establishment of a central registry for storing data on osteonecrosis and decompression sickness. (2) Development of an animal model for studying dysbaric osteonecrosis, the results of which can be used to evaluate: a) The relationship between clinical signs of dysbarism and the occurrence of osteonecrosis; b) The value of the Doppler ultrasonic bubble detector (or comparable device) in predicting that a particular decompression schedule is potentially productive of dysbarism and/or osteonecrosis; c) Development of decompression-schedule criteria to prevent dysbaric osteonecrosis and acute decompression sickness; d) Identification of pharmacological agents that are effective in preventing and treating osteonecrosis—e.g., oxygen at high pressures and low-molecular-weight dextran and heparin. (3) Evaluation of fluorine-18 and technetium isotopes for use in early detection and follow-up studies of the disease process, and relating isotopic bone-scan findings to roentgenographic findings. (Author)

27.
BECKMAN, E.L.

Recommendations for improved air decompression schedules for commercial diving.

Honolulu, Hawaii, Univ. Hawaii, UNIHI-SEAGRANT-TR-76-02, 64p. Oct. 1976.

Decompression schedules for air diving at depths of from 100 to 250 FSW with various times of work on the bottom were computed by Haldane, Workman, and Lambertsen techniques (Decom 1), after the method of Buhlmann (Decom 5), and after the scientific approach of Hills (Decom 8). The resulting dive tables were compared with depth and time diving schedules used by the U.S. Navy on one hand and those recommended by the British Royal Naval Physiological Laboratory on the other. The comparative evaluations disclosed that the U.S. Navy tables have significantly shorter decompression times and use more shallow decompression stops than do the other tables. It is recommended that the British Royal Naval Physiological Laboratory air diving tables of 1968 be adopted for use by the commercial diving industry in this country in an effort to provide greater safety to diving decompression practice. (Author's abstract)

28.
BEHNKE, A.R., R.M. Thomson and L.A. Shaw.

The rate of elimination of dissolved nitrogen in man in relation to the fat and water content of the body.

Am. J. Physiol. 114:137-146; 1935.

The inhalation of oxygen results in the elimination of dissolved body nitrogen in equilibrium with pulmonary nitrogen. The nitrogen content of a young, well developed man weighing 60 kgm is 840 cc., or 14 cc. per kilogram, 98 percent of which is eliminated with oxygen breathing over a period of 6 hours. If the assumption is made that the body is 70 percent water, then 400 cc. of nitrogen are dissolved in water and 440 cc. in the body fat and lipoids. Dividing 440 by the solubility coefficient of nitrogen in fat gives an estimate of 13.2 percent for the body fat, in contrast with 70 percent assumed for body water content. The fat from a well nourished dog of 12.2 kgm., extracted with carbon tetrachloride, comprised 15.4 percent of the body weight and the water 59.2 percent. If these values are multiplied by the respective solubility values of nitrogen in fat and water, the nitrogen content of the dog per kilogram is 14.2 cc., or approximately the same as that for man. Nitrogen elimination follows an exponential type of curve, the slope of which is a function of the cardiac output. The cardiac output in liters can be estimated by dividing the value for nitrogen eliminated during the first minute by the quantity of nitrogen dissolved per liter of blood. The rate of absorption and the time of elimination of inhalation anesthetics can be estimated from the nitrogen elimination curve on the basis of the ratio $\frac{\text{solubility in fat}}{\text{solubility in water}}$

During the decompression of divers who have been exposed for short periods (20 min.) to excess pressures, the fat and lipoids of the body act as nitrogen absorbents and serve as buffers against bubble formation. Under these conditions rapid decompression from relatively high pressures can be safely effected. (Authors' summary)

29.
BEHNKE, A.R.
The application of measurement of nitrogen elimination to the problem of decompressing divers. U.S. Nav. Med. Bull. 35:219-240; 1937.

The results of measurements of nitrogen elimination in man are presented, and their application to the problem of decompressing divers is discussed. Although decompression governed by the standard procedures is safe for short exposures in compressed air, decompression after prolonged exposures (over 75 minutes) may be followed by compressed-air illness. In an analysis of this problem it was concluded that the practice of abruptly halving the absolute pressure and the comparatively rapid lowering of pressure in the early part of decompression might result in nitrogen bubble formation. The retardation of nitrogen elimination from the body when bubbles are present in the blood was pointed out, and the danger of this condition while the pressure head of nitrogen in the tissues is high, was emphasized. The proposed method of decompression is based on the use of a single curve which represents the rate and quantity of nitrogen eliminated from the body as a whole. To minimize the possibility of bubble formation in the early part of decompression the practice was suggested of maintaining a constant relative difference (i.e. air pressure of 12 to 19 pounds, nitrogen pressure of 10 to 15 pounds) between the pressure in the body and the pressure in the lungs. The adoption of the proposed method of decompression in comparison with the standard procedure will shorten the time for short exposures in compressed air and lengthen the early stages of decompression after prolonged exposures to excess pressures. (Author)

29a.
BEHNKE, A.R., Jr.
Decompression sickness following exposure to high pressures. In: Fulton, J.F. Decompression Sickness. 53-89; 1951. Saunders. Philadelphia.

A remarkedly complete review of all aspects of exposure to hyperbaric conditions covering everything from primary pressure phenomena to treatment of decompression sickness. What makes the chapter pertinent to the present effort is the detailed treatment of the 'Principles Underlying Prevention of Decompression Sickness'. (CWS)

30.
BEHNKE, A.R.
Split shift and short shift decompression: New York State experience. In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October, 1965, p.192-198. Newcastle upon Tyne, Oriel Press, 1967.

Review of the New York State experience with compressed air workers is presented. Keays' East River report, in 1909, showed 557,000 decompressions with 3,692 cases of decompression sickness, and 20 deaths, at a working pressure of 42 p.s.i.g. With shorter working hours and longer decompression, Levy reported in 1922 that there were no deaths and only 680 cases from 1,361,000 decompressions. Further revision of the Industrial Code toward more safe decompression resulted in a negligible number of cases of decompression sickness in more than 1,600,000 decompressions. Various studies have shown X-ray evidence of bone necrosis in the tunnel workers even when no symptoms are reported. The split-shift decompression is not desirable. (CWS/BSCP)

31.
BEHNKE, A.R.
The isobaric (oxygen window) principle of decompression. In: The New Thrust Seaward. Trans. Ann. Conf. and Exhib. of Marine Technology Society, Washington, D.C. p.213-228, 1967.

The isobaric (oxygen window) principle of decompression embodies the assumption that the pressure of inert gas in tissues and blood stream should at no time exceed ambient pressure during decompression. Essentially in the capillaries there is an exchange of oxygen and inert gas. The fall in oxygen pressure in the capillaries creates a partial pressure vacancy designated as the oxygen window. The size of the window regulates the rate of diffusion of inert gas into the blood stream and its subsequent transport and elimination in the lungs. The higher the oxygen pressure in the gas mixture breathed up to 1500 mm Hg (2 atm), the greater the transport of inert gas. In current saturation diving operations, the rate of ascent during decompression has been in the range of 10 to 15 minutes per foot. This rate is consistent with an oxygen window that varies from 230 to 360 mm Hg, and with the slowest desaturating tissue with a half-time (helium) of 60 minutes. There appears to be no basis for the assumption that there are half-times for the slowest tissue (helium) as long as 300 minutes, and that inert gas during decompression is transported in a state of supersaturation devoid of bubbles. (Author's abstract)

32.
BEHNKE, A.R.
Some early studies of decompression.
In: Bennett, P.B. and D.H. Elliott, eds. The physiology and medicine of diving and compressed air work, p.226-251. Baltimore, Williams and Wilkins, 1969.

In the early nineteen hundreds there were two methods proposed for bringing men safely from high pressure situations to normal atmospheric pressure: the uniform slow reduction of pressure, and the stage method with progressive increase in time for the stops at the lower pressures or shallower depths. The development of an understanding of the etiology of decompression sickness related to bubbly formation enabled basic postulates to be made. Two concepts are the basis for the stage method of decompression; the first is that there are no bubbles liberated within the body unless supersaturation of 2.25 atmospheres is exceeded; and the second is that the time-course of nitrogen uptake for various parts of the body can be simulated by the use of a family of discrete, hypothetical half-time tissues (5, 10, 20, 40, and 75 min) to represent gas exchange in the whole body. These different tissue rates may be due to blood supply variability but are also related to fat content of the organs and the total body, as fat absorbs seven times as much nitrogen as water. Helium-oxygen diving was proposed in 1925 and has been studied thoroughly by the U.S. Navy and is now widely used for very deep diving. The original supersaturation ratio of 2.25 has been reduced to 1.7 to 1 and alteration of gas mixtures during decompression has been added with pure oxygen for the lower level stops. There have been many studies of the quantitative uptake and elimination of inert gases, and radioactive krypton has been used to demonstrate elimination during decompression. Both saturation dives and tunnel work use uniform decompression following initial reduction of pressure (often one-half). Essentially, the difference in the application of the two systems is whether or not exposures are short or long, relatively shallow or deep. (CWS/BSCP)

33.
BEHNKE, A.R.
Medical aspects of pressurized tunnel operations.
J. Occupational Med. 12(4):101-112; 1970.

The Washington State Tables represent an advance in decompression practice chiefly because crippling bone lesions have not been observed following the longer schedules. However, the incidence of bends is much too high at higher pressures. It should not be necessary to depend upon acclimatization to resolve this problem; the emphasis should be on bubble prevention. It is not feasible to extend decompression time. The recourse is three-fold: (1) Revise decompression to accord more time at the higher stops without necessarily increasing total time. (2) Institute some muscular exercise to ensure adequate blood perfusion of tissues of the now dormant lower extremities. (3) Introduce monitored oxygen inhalation initially during the terminal stages of decompression. Because of the importance of pressurized tunnel operations. it is mandatory that there be initiated the same type of methodical, computerized test programs that have made possible the safe exploitation of the more hazardous marine environment. (Author)

34.
BEHNKE, A.R., Jr. and J.P. Jones, Jr.
Preliminary BART tunnel results.
In: Beckman, E.L. and D.H. Elliott, eds. Dysbarism-related osteonecrosis. Proceedings of a symposium of dysbaric osteonecrosis, Marine Biomedical Institute, University of Texas Medical Branch, Galveston, Texas, February, 1972. p.25-40. Washington, D.C., U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, 1974.

The risk of decompression sickness is minimal if working pressure can be maintained below 11 psig; maintaining pressure below 17 psig minimizes the risk of dysbaric osteonecrosis. Engineering consideration should therefore be given to avoiding the use of compressed air altogether, or minimizing the pressure necessary in tunnel, caisson, or diving work. . . . To disqualify from work those applicants with antecedent dysbaric osteonecrosis or coexistent illnesses associated with avascular osteonecrosis, comprehensive preemployment examinations are essential—including special laboratory studies and roentgenograms. Bone lesions have been associated with the primary effects of nascent bubbles liberated during rapid decompression and with such secondary complications incident to bubble release as platelet aggregation, cellular clumping, release of lipids with embolic potential, and circulatory stasis. Predisposing factors are repeated decompressions, the pressure under which the individual has worked, and the number of attacks of dysbarism that he has experienced. During the past 50 years steps have been taken in New York State to reduce the incidence of dysbarism and the complication of bone necrosis by shortening hours of work. In both U.S. and U.K. experience, it has not been possible to limit the hazard of decompression sickness. . . . To circumvent future dysbarism-related injury in compressed-air work, two positive procedures are suggested: 1) O_2 decompression under conditions favoring isobaric N_2 elimination from tissues; and 2) residence in compressed-air habitats with pressure adjusted to that of the tunnel. The feasibility of these procedures has been demonstrated in diving practice, but they remain to be implemented in compressed-air tunnel operations. (From authors' summary)

35.
BEHNKE, A.R.
New format for pressurized tunnel operations with application to surface-depth diving (300-500 feet).
In: Proceedings of the first annual meeting of the North Pacific Branch of the Undersea Medical Society, 5-7 Sept. 1974. p.35-36. Avalon Calif. Univ. So. Calif. Santa Catalina Mar. Sci. Cent. 1974.

Abstract only. Saturation-excursion schedules for compressed air workers are presented, as follows:

Habitat Pressure		Work Shift Pressures*					
		8-hr. Shift		6-hr. Shift		4-hr. Shift	
psig.	ft.	psig.	ft.	psig.	ft.	psig.	ft.
0	0	10.7	24	11.6	26	13.4	30
4.45	10	16.5	37	17.8	40	20.9	47
8.9	20	22.3	50	24.1	54	28.1	63
13.4	30	28.1	63	30.7	69	35.6	80
17.8	40	34.3	77	37.0	83	43.2	97

*No-stop Decompression to Habitat Pressure Following Work Shift.

Decompression from Habitat Pressure of 17.8 psig

psig.	ft.		psig.	ft.		psig.	ft.		psig.	ft.		psig.	ft.
17.8	40	to	12.5	28	to	8.5	19	to	4.9	11	to	0	surface
		5 min.			180 min.			192 min.			324 min.		

An effective procedure in stubborn cases of decompression sickness is recompression to 40-50 ft. equivalent for a prolonged stay. For underwater dives to 500 feet or more, it is proposed that during decompression, following two hours of oxygen breathing at 40 feet, an air schedule similar to the above for habitat decompression be followed. The compressed air worker could remain at habitat pressure, or of decompressing to the surface and returning to work after a one-day interval. The diver could dive every other day of "elution clearance" of inert gas proved effective. (MFW/UMS)

36.
BEHNKE, A.R.
Prevention of osseous avascular necrosis in compressed-air workers.
In: Lambertsen, C.J., ed. Underwater physiology V. Proceedings of the fifth symposium on underwater physiology, p.201-215. Bethesda, Md., Federation of American Societies for Experimental Biology, 1976.

Osseous avascular necrosis is a major hazard of compressed-air (caisson) workers employed in civil engineering projects. The bone lesions have been associated with inadequate decompression and with liberation of intravascular bubbles. Important also are "foreign" body phenomena induced by the presence of nascent bubbles which give rise to platelet aggregation, cellular clumping, release of lipids with embolic potential, hemoconcentration, and blood stasis. Predisposing factors reported by British authority are the number of times a worker has been decompressed, the pressure level at which he has worked, and the number of attacks of decompression sickness he has sustained. During the past 50 years steps have been taken in New York to shorten hours of work in the effort to reduce decompression sickness and the chronic complications of bone necrosis. In both New York and England, it has not been possible to circumvent these hazards. Tables, compiled by the State of Washington, greatly extend decompression time. Experience with these tables (Seattle, 1964-67; San Francisco, 1967-69) has not shown a reduction of decompression sickness. Yet to date (1972) there has been no report of disabling bone necrosis. In order to eliminate future injury, two positive procedures have been outlined: 1) oxygen decompression with isobaric transport of N_2 from tissues; and 2) residence in compressed air habitats with pressure adjusted to tunnel work level. These procedures are routine in diving practice and await implementation in compressed air tunnel operations. (Author's summary)

36.a

BELL, R.L. and R.E. Borgwardt.

The theory of high-altitude corrections to the U.S. Navy Standard Decompression Tables. The Cross corrections.

Undersea Biomed. Res. 3:1-23; Mar. 1976.

The theoretical basis for the Cross high-altitude corrections to the USN Standard Decompression Tables is derived. Providing corrections are made for depth and ascent rate and if no decompression stops are made, a dive at altitude can be transformed to a dive at sea level for which the theoretical tissue responses are mathematically similar to the altitude dive. The transformation fails if decompression stops are required due to the fact that the stop criteria used in the USN Tables do not obey the same rule of transformation. It is shown that the failure of the high-altitude correction is expected to be conservative. (Authors' abstract)

36.b

BENNETT, P.B.

Recent advances in deep diving research.

In: Fifth annual international diving symposium, sponsored by the Association of Diving Contractors and the Marine Technology Society, Morgan City, Louisiana, January 1975, p.72-75.

This paper discusses the results of a unique research program at Duke Medical Center in support of the health and safety of the divers involved in the offshore oil industry. Unique because all the data is freely available and combines an unusual combination of private, university, government and commercial diving company research funds from the Harbor Branch Foundation, Florida, Duke University, National Institute of Health, Oceaneering International and more recently International Underwater Contractors. The work has involved all facets of a dive profile including compression at depth and decompression from bounce dives of 30 mins at 500 to 600 feet to saturation at 1000 feet. Studies were made of the High Pressure Nervous Syndrome (HPNS) when breathing trimix ($He/N_2/O_2$) or helium-oxygen and new theories of decompression evolved to permit safe decompression without decompression sickness or oxygen toxicity for example from 500 feet/30 mins in 727 mins and from 1000 feet in a saturation mode in 4 to 5 days. (Author)

36.c

BENNETT, P.B.

A review of strategies for deep oxygen-helium diving.

In: Association of Diving Contractors. Proceedings, International Diving Symposium '76, New Orleans, Jan. 1976, p.30-42. Published by the Association.

The author discusses methods by which the effects of the high pressure nervous syndrome (HPNS) can be mitigated, and also those by which decompression time from a saturation depth of 1000 feet or more can be shortened. There appears to be some adaptation to HPNS up to depths of 1500 feet, and symptoms wear off in about an hour. The rate of compression is also important, and should become slower with depth; it should also be done in stages. Excursion diving from saturation can sometimes mitigate HPNS. Individual susceptibility varies greatly. Commercial divers should be subjected to a standard selection dive to 600 ft at 100 ft/min for 15 minutes before being selected for very deep diving. Temperature appears to be a factor—heat increases and cold decreases the signs and symptoms. Addition of nitrogen to helium-oxygen mitigates HPNS. Smaller amounts of nitrogen plus a small amount of alcohol have also been tried with some success. The percent of nitrogen must be decreased with depth to prevent narcosis. Decompression profiles from the 1000 ft, 1312 ft. and 1525 ft. dives are described. Oxygen was adjusted to 0.6 ATA in every case. The decompression from 1000 feet was 5 days, from 1312 feet to

6 days 4½ hours, and from 1512 feet, 7 days. Trimix was changed to heliox at 850 feet in the first, at 1150 feet in the second, and at 1450 feet in the third. Tables and diagrams showing performance detriment due to HPNS and also illustration dive profiles are given. (MFW/UMS)

37.
BENNETT, P.B., R.D. Vann, J. Roby and D. Youngblood.

Theory and development of subsaturation decompression procedures for depths in excess of 400 feet.

In: Shilling, C.W. and M.W. Beckett, eds. Underwater physiology VI. Proceedings of the sixth symposium on underwater physiology, p.367-381. Bethesda, Md., Federation of American Societies for Experimental Biology, 1978.

During 1974, 89 simulated dives were made, each involving 3 or 4 divers from Oceaneering International, Inc. and International Underwater Contractors, Inc., to simulated depths of 500 to 650 ft for 30 minutes breathing oxygen-helium, with one of the divers working (VO_2 1-2 L/min) under cold water. Decompression procedures for the initial 6 months were based mainly on Haldane concepts with a matrix of 16 tissue half-times the maximum being 600 mins. The tables utilized 7% O_2/83% He at depth with a compression rate of 100 ft/hr. Correlations between the highest ratio of PN_2 + PHe/ambient for each depth exposed and the incidence of decompression sickness occur. This method has been found unsatisfactory for computation of such tables, requiring too much oxygen and over-long times due to procedures, in effect, involving treatment of sub-clinical bubbles generated deep. The procedure adopted for the latter six months relies on a combination of nil-supersaturation and Haldane concepts with as much as three times more time spent in the deep phases of the decompression and minimal or no use of oxygen at the shallow depths. The use of this concept of not permitting the generation of sub-clinical bubbles deep has permitted the development of shorter and safer decompression tables for 500 ft/30 mins (23 man dives, 7 wet working; 727 min decompression time with O_2/air), 600 ft/30 mins (20 man dives, 8 wet working; 1273 mins with air only). Tables for 550 ft and 650 ft are under test as are further tables of 60 min duration. (From Sixth symposium program and abstracts)

38.
BERGHAGE, T.E.

FORTRAN IV computer programs to facilitate analysis and calculation of decompression schedules.

U.S. Navy Exp. Diving Unit Res. Rep. 4068, 50p. June 1, 1968.

Four FORTRAN IV computer programs designed to calculate and analyze decompression profiles are described. All four computer programs are based upon the Haldane decompression model as presented by Workman (1965). Additional theoretical considerations and supportive data are outlined in an attempt to modernize the present model for use on surface dives to great depths. (Author's abstract)

38.a
BERGHAGE, T.E., Ed. Decompression Theory.

Seventeenth Undersea Medical Society Workshop. 29 WS(DT) Bethesda, Md.: Undersea Medical Society, 1979.

The papers in this workshop report are divided into three sections: Historical Development of the U.S. Navy's Decompression Model and Its Operational Limits; Current Status of Neo-Haldanian Assumptions (of gas uptake, pressure reduction, and gas elimination); and Workshop Contributions (papers by individual participants). The authors of workshop papers (R.C. Bornmann, T.E. Berghage, H. Yano, E.L. Beckman, A.R. Behnke, A.A. Buehlmann, B.G. D'Aoust, R.W. Hamilton Jr., D.J. Kenyon, R.E. Peterson, M. Freitag, M.R. Powell, B.A. Hills, D.E. Yount, R.D. Vann and P.K.E. Weathersby) discuss the implications of Haldanian assumptions for present-day decompression theory and assess the present state of the art of decompression theory.

39.
BERGHAGE, T.E. and G.C. Tolhurst.

Revised tables of appropriate oxygen percentages for selected partial pressures at various depths.
U.S. Navy Exp. Diving Unit, Rep. NEDU-RR-4-71. 90p. April, 1971.
(AD 724,282)

The report was written to promulgate a revised set of tables to allow rapid and easy conversion of water depth and partial pressure combinations into appropriate oxygen percent to be used by divers and diving supervisors. The tables were devised for use when making necessary conversions between depth in feet of sea water and pressure in terms of atmospheres absolute. (Authors' abstract)

40.
BERGHAGE, T.E., J.M. Woolley and L.J. Keatings.
The probabilistic nature of decompression sickness.
Undersea Biomed. Res. 1:189-196; June 1974.

Because of the variability that is associated with decompression outcome, it has been extremely difficult to assess the risk related to a given decompression profile. This study is an initial attempt to deal with the observed variability and improve the precision of the decompression model. Two hundred eighty-eight mice were explosively decompressed following a 15-min hyperbaric nitrogen-oxygen exposure to one of two pressures: 13.8 or 14.2 ATA. The results of these exposures were compared with theoretical estimates based upon the Binomial Probability Function. No statistically significant differences between the actual decompression results and the theoretical predictions were found. This preliminary study indicates that probability theory may be a means to quantify the variance found in decompression studies and improve the precision of the present decompression model. (Authors' abstract)

41.
BERGHAGE, T.E., F.W. Armstrong and K.J. Conda.
Relationship between saturation exposure pressure and subsequent decompression sickness in mice.
Aviat. Space Environ. Med. 46:244-247; Mar. 1975.

Despite the fact that the pressure reduction is acknowledged to be the single most cogent factor in producing decompression sickness, little has been done to define accurately the allowable limits beyond 2 ATA. This study provides some theoretical guidelines for future manned dives related to this problem. There were 324 albino mice used to define the relationship between saturation exposure pressure and the safe abrupt pressure reduction. The results from both the helium-oxygen and nitrogen-oxygen exposures support the idea of a linear, depth-dependent relationship between the saturation depth and the allowable pressure reduction. Support is presented for the use of a modified decompression ratio P_1/P_2 (P_1 = saturation pressure and P_2 = pressure following decompression) to account for the observed incidence of decompression sickness. An attempt is made, using the existing human data, to relate this empirical relationship to the operational dive setting. (Authors' abstract)

42.
BERGHAGE, T.E., P.A. Rohrbaugh, A.J. Bachrach and F.W. Armstrong.
Navy Diving: Who's doing it and under what conditions.
U.S. Nav. Med. Res. Inst., Rep. on Proj. MPN10.03.2040DAC9, 95p. Dec. 1975.

This statistical survey is a first attempt to assess the adequacy of the data available and to provide a rough statistical description of the environment, personnel, and procedures presently existing in current Navy diving operations. The survey is a joint effort between the Navy Safety Center and the Naval Medical Research Institute. The fleet diving log data for the 24-month period from January 1972 through December 1973 has been analyzed for this study. During this period 127,103 dives and 83 accidents (.0653%) were recorded. The results of this analysis have possible widespread application in policy decisions about diver personnel management, diver training, and future diving research. (From authors' abstract)

43.
BERGHAGE, T.E., J.A. Gomez, C.E. Roa and T.R. Emerson.
Pressure reduction limits for rats following steady-state exposures between 6 and 60 ATA.
In: Abstracts of the Undersea Medical Society, Inc. annual scientific meeting. May 12-13, 1976. Undersea Biomed. Res. 3:A29-A30; Mar. 1976.

Abstract only. Entire item quoted: The role of pressure reduction in the formation and growth of bubbles is universally recognized and its significance in decompression theory has been accepted. Yet the allowable limits of pressure reduction for man and animal is uncertain. This study sought to evaluate the pressure reduction limits for rats following steady-state exposures at pressures greater than one atmosphere. To define the relationship, 345 albino rats were exposed to 1 of 12 specified pressure levels between 6 and 60 ATA and then abruptly decompressed to a preselected reduced pressure level for observation. The pressure reduction levels were selected to determine for each saturation exposure level an ED-50 (i.e. effective dose that would produce decompression sickness in 50% of the animals). The results demonstrate three consistent findings: (1) there is a linear relationship (r = .99) between the magnitude of a safe pressure reduction and the saturation exposures between 6 and 43 ATA; (2) at pressures greater than 43 ATA, there is a qualitative change in the decompression sickness symptoms and a reduction in the precision of the mathematical relationship (r = .44); and (3) the magnitude of the pressure change required to increase the incidence of decompression sickness from 10 to 90% is directly related to the magnitude of the exposure pressure. The implications of these results for deep operational diving are discussed.

44.
BERGHAGE, T.E., G.S. Goehring and C. Donelson.
Pressure-reduction limits for rats subjected to various time/pressure exposures.
In: Program and abstracts. Undersea Medical Society annual scientific meeting, May 13-16, 1977, Toronto, Canada, p.A24. Undersea Biomed. Res. 4, Mar. 1977. Appendix A.

Abstract only. Entire item quoted: The most cogent variables in determining tolerable pressure-reduction limits are exposure pressure and time. Data previously reported suggest that the pressure-reduction limits after a saturation exposure increase as hydrostatic pressure increases. The present study explores the impact of the combined effects of exposure time and hydrostatic pressure on these limits. The study is divided into two phases: determination of pressure-reduction limits for 15 different time/pressure excursions from 1 ATA and determination of pressure-reduction limits for 5 different excursion times from 3 different saturation-pressure levels. The chamber gas mixture during all pressure exposures was 0.51 ATA oxygen, 0.79 ATA nitrogen, and the remainder helium. The subjects were 655 rats; during each pressure exposure 5 rats were exercised in a rotating cage. In Phase I excursion dives were made to 10, 20, and 30 ATA for 5, 10, 20, 40, or 80 min. In Phase II the animals were saturated at 1.3, 10, or 20 ATA for 60 min; each saturation pressure was followed by a 10-atm excursion dive of either 1, 5, 10, 20, or 40 min. After each exposure, the rats were abruptly decompressed to a lesser pressure for observation. The observation pressure levels were selected to establish an ED-50 (effective dose to produce signs of decompression sickness in 50% of the animals). Results suggest that neither the starting saturation pressure nor the differential excursion pressure alters the time required for an animal to reach equilibrium with the surrounding environment. The allowable pressure-reduction limits, however, vary with exposure pressure, excursion-pressure differential, and exposure time. These results will have a direct impact on the formulation of future decompression models.

45.
BERGHAGE, T.E., G.S. Goehring and C.V. Dyson.
Relationship between pressure-reduction magnitude and stop time during stage decompression.
Undersea Biomed. Res. 5:119-128; June 1978.

Stage decompression was investigated to learn whether the amount of time spent at the first stop is independent of the magnitude of the initial pressure reduction. The effects of 3 different stop times (5, 40, and 120 min) and 5 different pressure reductions (3, 6, 9, 12, and 15 atm) were explored in a 3 x 5 factorial design using 375 female albino rats. A two-step, single-stage decompression was initiated after a saturation exposure at 30 ATA. The second step of the decompression was varied to establish a dose-response curve from which a 50% "bends" point could be extracted. Data analysis and subsequent inferences are based upon these ED_{50} points. Results suggest: 1) the greater the initial pressure reduction the smaller the possible subsequent pressure reduction; 2) the decompression stop time required to reestablish equilibrium after a pressure reduction is 10 times longer than that needed to reestablish equilibrium after compression; 3) there is an optimum decompression stop time that takes maximum advantage of the gas exchange rate; 4) short decompression stops are detrimental for further pressure reduction; and 5) a strong linear relationship exists between the optimum time spent at a decompression stop and the magnitude of the prior pressure reduction. If confirmed by large animal and human studies, these results could have a major impact on future decompression profiles. (Authors' abstract)

46.
BERGHAGE, T.E., J. Vorosmarti, Jr. and E.E.P. Barnard.
History of recompression procedures.
Unbender 4:1,10-13; May 1979.

The authors believe it is the time to take a fresh look at recompression procedure in an effort to improve its efficacy. This article is intended as a starting point for such reevaluation. It should be considered a statementof-the-art document in that it covers the history of recompression procedures in the U.S. Navy and surveys the procedures used throughout the world. We hope this compilation of treatment tables, along with the brief History, will be helpful to the diving community. *The inclusion of a treatment table in this article is in no way meant to be an endorsement of the table for use in recompression therapy. In fact, some of the older tables in this report are downright dangerous.* [Treatment tables used in the past, and their modifications, are presented.] The one area in which a recompression treatment problem still exists is in the handling of decompression sickness cases in which the symptoms appear while the patient is still exposed to increased ambient pressure. Such cases often occur during deep saturation dives and excursion dives from saturation depths. Berghage (1976) reports that the initial recompression success rate in treating these cases is only about 35%. Future research efforts must focus attention on this problem area. (Authors)

47.
BERT, P.

Barometric pressure. Researches in experimental physiology.
Translated by Hitchcock, M.A. and F.A. Hitchcock.
Columbus, Ohio, College Book Co., 1943. Republished, Bethesda, Md., Undersea Medical Society, 1978. 1055p.

Paul Bert's book is a classic in the field, but for the purpose of this review we consider only that he was not convinced that the stage method of decompression was desirable: "I have remarked no great difference between the cases in which decompression was effected continuously at the rate of eight or ten minutes per atmosphere and those in which it was carried out by means of sudden jumps, with intervals of repose. The facts are not, however, sufficiently numerous to permit of deciding in favour of one or other of these methods." (CWS/UMS)

48.
BIERSNER, R.J.

Factors in 171 Navy diving decompression accidents occurring between 1960-1969.
Aviat. Space Environ. Med. 46:1069-1073; Aug. 1975.

Comparisons were made between the incidence of specific factors in U.S. Navy decompression accidents and the incidence of these factors in routine (nonexperimental) U.S. Navy operational dives. It was found that decompression accidents are disproportionately high among a) air dives less than 140 ft which have bottom times of 30 min or less and air dives greater than 140 ft which have bottom times of more than 15 min, b) Divers First Class, c) older divers, and d) dives which do not involve work or dives which require heavy work. Repetitive dives have a lower decompression accident rate than expected. Decompression accidents were not disproportionately high for any category of body build. These results indicate that the present U.S. Navy decompression tables are extremely safe (5 decompression accidents/10,000 dives), and do not appear to require modification. Future decompression research may be directed toward analyzing the relationship of work and aging to physiological processes involved in decompression. In addition, the present findings should be cross-validated using more recent accident and operational diving data. (Author's abstract)

49.
BONI, M., R. Schibli, P. Nussberger and A.A. Buhlmann.

Diving at diminished atmospheric pressure: air decompression tables for different altitudes.
Undersea Biomed. Res. 3:189-204; Sept. 1976.

Fifty subjects performed 106 simulated dives at a final ambient pressure of 0.7 at. (3000 m above sea level). One hundred and forty-three subjects performed 278 actual controlled dives at altitudes 900-1700 m above sea level. From the experience of these dives, air-decompression tables for altitudes 0-3200 m above sea level were calculated. Tables up to 2000 m above sea level were tested on humans under wet conditions. (Authors' abstract)

50.
BOODA, L.

Demands for commercial diving exceed available services.
Sea Technol. 15:20-24; May 1974.

The only diving company involved in training is Oceaneering International, whose subsidiary is the Commercial Diving Center. Other diver training schools are Santa Barbara City College; Highline College, Seattle; Divers

Institute of Technology, Seattle; Coastal School of Deep Diving, Oakland; Divers Training Academy, Fort Pierce, Fla.; Coastal Diving Academy, New York; Divemasters, Inc., Madison, Wisc.; Commercial Diving Training Division, Ocean Corporation, Houston, Texas; California Institution for Men, Chino (which trains prisoners). The total number of working divers in the United States at present is estimated at 1800 full-time, and 900 part-time. Technological advances in commercial diving systems, made by Ocean Systems, Inc., are summarized. The largest commercial diving company is Oceaneering International, of Houston, which owns nine subsidiaries, employs 300 divers, and owns a hyperbaric medicine research center in Houston. It operates 25 600-foot systems, and owns ten 1000-foot systems, now actually operating at 625 feet, but expected to go deeper. Another major company, both in hyperbaric medical research and in technological development, is Taylor Diving and Salvage. Recent experiments in rapid compression using three-gas breathing mixtures, carried out by Ocean Systems, by Oceaneering International, and by COMEX in France, are described. Ocean Systems ACCESS program compresses a diver rapidly to 1000 feet, holds him at depth for a one-half hour working period, and decompresses him immediately. Another technique is to select a holding depth from which excursions are made. Both of these techniques make cost-effective short duration working dives possible. The 1000 foot dive carried out at Duke with the collaboration of Oceaneering International is described. Some investigators are concerned over the density of the three-gas mixture, which might not work as well in actual open sea dives as it does in chamber dives. (MFW/UMS)

51.
BORNMANN, R.C.
Decompression after saturation diving.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the Third Symposium on Underwater Physiology, 23-25 March, 1966, Washington, D.C., p.109-121. Baltimore, Williams and Wilkins Co., 1967.

A good review of the stage type decompression for deep diving and a detailed account of experimental work with decompression at a constant rate of ascent. This type of decompression has been used in several of the long stay dives under the sea. Tables in the past have been constructed for a large range of decompression susceptibilities, but perhaps we can "develop tests to eliminate from deep diving the individuals who would be bends-prone"—over-age, overweight, physically unfit, and the diver who has already had the bends several times. Breathing oxygen as an aid in decompression is not the perfect answer as bends have occurred during oxygen breathing and it is a pharmacologically active agent. (CWS/BSCP)

52.
BORNMANN, R.C.
Decompression schedule development for repetitive saturation-excursion helium-oxygen diving. Chevy Chase, Md., Deep Submergence Syst. Off., Rep. RR-1-70, 96p. June 1, 1970. (AD-718, 907)

A twelve month program of saturation-excursion diving operations was carried out to test newly developed tables for repetitive, no-decompression excursions from helium-oxygen saturation exposures at depths between 150 feet and 600 feet. 1,126 excursions were performed in accordance with the tables. The extensive test program not only validated these tables but provided as well a massive confirmation of the conservative adequacy of the extrapolated M values of Workman in this depth range. The format for saturation final decompression was also modified and improved during this program. (Author) (GRA)

53.
BORNMANN, R.C.
Physiological considerations for deep helium-oxygen saturation diving.
In: Progress into the sea. Transactions of the symposium 20-22 October 1969, Washington, D.C., p.135-143. Washington, D.C., Marine Technology Society, 1970.

Design constraints for diving systems are described in terms of acceptable ranges for physiologically important values. Depth limits for the gas breathing diver are considered along with equipment requirements to attain such depths. New decompression tables are described. Saturation diving puts the diver under pressure for very long periods. Improved diving equipment is required to make him comfortable and efficient at work in the water. (Author's abstract)

54.
BORNMANN, R.C.

U.S. Navy experiences with decompression from deep helium-oxygen saturation excursion diving.
In: Scripps Institution of Oceanography. Human performance and scuba diving. Proceedings of the symposium on underwater physiology, La Jolla, Calif., April 10-11, 1970, p.51-62. Chicago, The Athletic Institute, 1970.

The author explains the Haldane half-time tissue approach to the question of inert gas tension. In Figure 1, he shows an exponential curve that represents the inert gas exchange in any tissue, pressure remaining constant. Figure 2 is a diagram showing Haldane's analysis of change in tissue tensions of air during an air dive to 168 feet. This diagram also demonstrates the stage method of decompression. Haldane's 2 to 1 ratio for safe supersaturation in ascent was found to be inadequate at greater depths. Other tables give the schedule for Sealab III, a 600-foot saturation dive: this uses a rate of 15 minutes per foot, with four-hour stops at 450, 350, 250, 150, 100 and 50 feet. Other standard decompression schedules for saturation dives are shown, in which the speed of decompression slows as the diver nears the surface. No-decompression limits in minutes for excursion dives from saturation are given. Other diagrams show increase in all representative half-time tissues during a 60-minute no-decompression excursion dive of 150 feet below saturation depths, and the speculative symmetrical replotting of maximum value increases with increasing saturation depth. The author emphasizes that, although the researchers have been successful so far in their daring and testing approach, it would be most helpful to be able to explain why an increase in permissible dives is possible as the depth becomes greater. More information is needed on the physical behavior of bubbles in body fluids, and the nature and timing of pathophysiologic reactions set in motion by the bubbles. (MFW/BSCP)

55.
BORNMANN, R.C.

Helium-oxygen saturation-excursion diving for U.S. Navy.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the fourth symposium on underwater physiology, p.529-536. New York, Academic Press, 1971.

Excursion diving from a saturation situation presents additional problems concerning length of time at excursion depth permissible without decompression. For example the tables allow a no-decompression excursion dive from saturation exposure at a depth between 300 and 600 FSW gauge depth of 270 min. at an excursion depth of + 50 ft; 150 min at + 75 ft; 100 min at + 100 ft; 75 min at + 125 ft and 60 min at + 150 ft. The above table was evaluated in a 10-week test program of saturation dives to 350 ft. Five 12-day dive cycles included one day for compression and equilibration, six days for excursion dive testing and five days for decompression. Computer analysis verified this no-decompression table and other excursion possibilities were added. This work is important in preparation for the future activities of the DSSP for excursion diving permits a fuller utilization of the saturation diving potential. (CWS/BSCP)

56.
BORNMANN, R.C.

U.S. Navy program.
In: Hong, S.K., ed. International symposium on man in the sea, Honolulu, July 1975, p.I-1 - I-6. Bethesda, Md., Undersea Medical Society, Inc. 1976.

Of the five million dollars at the disposal of the Navy's Undersea Biomedical Research Program, 60% goes to advanced development and 20% each for exploratory development and basic research. Roughly half of it goes to Navy laboratories (chiefly Naval Medical Research Institute at Bethesda and the Naval Submarine Medical Research Laboratory in Groton, Connecticut) and half to civilian research through contracts made with the Office of Naval Research. The purpose of the program is to provide biomedical knowledge in support of deep submergence operations and of the submarine fleet, and to be able to operate safely on the continental shelf (defined as 850 fsw maximum depth). Some of the problems currently receiving attention are: (1) the improvement of underwater breathing apparatus to be used with the current models of Deep Diving Systems (600-1000 fsw) and also with future models (up to 1500 fsw or deeper); (2) investigation of ways in which decompression schedules can be speeded up with safety; (3) the study of the pathogenesis and natural history of dysbaric osteonecrosis. (MFW/UMS)

57.
BORNSTEIN, A.
Weitere untersuchungen uber Herzschlagvolumen.
Z. Exp. Path. Ther. 14:135-150; 1913.

In studies of cardiac output in man, the first measurements of N_2 recovery during the course of oxygen inhalation were reported. (CWS/UMS)

58.
BOROM, M.P. and L.A. Johnson.
Decompression meter for scuba diving utilizing semipermeable membranes.
Aerosp. Med. 45:135-142; Feb. 1974.

This report describes the principles, construction, and operation of a prototype, wrist worn, automatic decompression meter for scuba diving developed at the General Electric Research and Development Center. This device is designed to automatically calculate the decompression schedules required during the course of any dive using compressed air. The device contains silicone rubber diffusion membranes as the controlling elements which permits it, unlike meters containing porous media as controlling elements, to compute properly the decompression schedules according to the model employed in the U.S. Navy Standard Decompression Tables. (Authors' abstract)

59.
BOVE, A.A., E. Hardenbergh and J.A. Miles, Jr.
Effect of heat and cold stress on inert gas (^{133}xenon) exchange in the rabbit.
Undersea Biomed. Res. 5:149-158; June 1978.

To determine the effects of heat and cold stress on tissue inert gas exchange, the rate of elimination of ^{133}xenon gas was measured in five anesthetized rabbits at normal body temperature, after cooling, and after heating. Core temperature fell from 38.3 ± 0.2°C to 37.1 ± 0.4 ($P < 0.02$) with cooling, and rose to 39.3 ± 0.3 ($P < 0.001$) with heating. Ear temperature fell 1.7°C with cooling, and rose 8.2°C with heating. To evaluate the rate of inert gas washout, the xenon elimination curve was converted to a log concentration vs. time plot and separated into an early and late washout phase, each of which was considered to be monoexponential. The slope of the two lines was calculated by linear regression as log percent concentration per min. These slopes were used as a measure of the rate of washout in units of min^{-1}. Although early and late washout rates generally responded in the same way under heat and cold stress, this was not uniformly true. For the ear, representing skin washout, the late washout rate increased threefold with heat stress (normal: 0.02 ± 0.005 min^{-1}; hot: 0.06 ± 0.004, $P < 0.01$), but cold stress also caused an increase (cold: 0.04 ± 0.005, $P < 0.01$). In skeletal muscle late washout decreased in the heat and rose in the cold (normal: 0.05 ± 0.003; hot: 0.03 ± 0.002, $P < 0.01$; cold: 0.08 ± 0.008, $P < 0.01$). The increased muscle washout in the cold was probably due to shivering. Late lung washout, representing whole body xenon elimination, increased in the heat and was unchanged in the cold (normal: 0.02 ± 0.008; hot: 0.05 ± 0.009, $P < 0.01$; cold: 0.02 ± 0.009). These data show that inert gas washout in skin skeletal muscle, and the whole body varies significantly from normal in hot and cold environments. This variability suggests that decompression tables may be in error when hyperbaric inert gas exposure is accompanied by either heat or cold stress. (Authors' abstract)

60.
BOYCOTT, A.E., G.C.C. Damant and J.S. Haldane.
The prevention of compressed-air illness.
J. Hyg. (Cambridge) 8:342-443, 1908.

1) The time in which an animal or man exposed to compressed air becomes saturated with nitrogen varies in different parts of the body from a few minutes to several hours. The progress of saturation follows in general the line of a logarithmic curve and is approximately complete in about five hours in man and in a goat in about three hours. 2) The curve of desaturation after decompression is the same as that of saturation, provided no bubbles have formed. 3) Those parts of the body which saturate and desaturate slowly are of great importance in reference to the production of symptoms after decompression. 4) No symptoms are produced by rapid decompression from an excess pressure of 15 pounds, or a little more, to atmospheric pressure, i.e., from two atmospheres absolute to one. In the same way it is safe to quickly reduce the absolute pressure to one-half in any part of the pressure scale up to at least about seven atmospheres: e.g. from six atmospheres (75 pounds in excess) to three (30 pounds), or from four atmospheres to two. 5) Decompression is not safe if the pressure of nitrogen inside the

body becomes much more than twice that of the atmospheric nitrogen. 6) In decompressing men or animals from high pressure the first part should consist in rapidly halving the absolute pressure: subsequently the rate of decompression must become slower and slower, so that the nitrogen pressure in no part of the body ever becomes more than about twice that of the air. A safe rate of decompression can be calculated with considerable accuracy. 7) Uniform decompression has to be extremely slow to attain the same results. It fails because it increases the duration of exposure to high pressure (a great disadvantage in diving work), and makes no use of the possibility of using a considerable difference in the partial pressure of nitrogen within and without the body to hasten the desaturation of the tissues. It is needlessly slow at the beginning and usually dangerously quick near the end. 8) Decompression of men fully saturated at very high pressures must in any case be of very long duration: and to avoid these long decompressions the time of exposure to such pressures must be strictly limited. Tables are given indicating the appropriate mode and duration of decompression after various periods of exposure at pressures up to 90 pounds in excess of atmospheric pressure. 9) Numerous experiments on goats and men are detailed in proof of these principles. 10) The susceptibility of different animals to compressed-air illness increases in general with their size owing to the corresponding diminution in their rates of circulation. 11) The average respiratory exchange of goats is about two-thirds more than that of man; they produce about 0.8 gram. of CO_2 per hour per kilogramme of body weight. 12) The mass of the blood in goats is six and a half or seven and a half percent of the "clean" body weight. 13) The individual variation among goats in their susceptibility to caisson disease is very large. There is no evidence that this depends directly on sex, size or blood-volume: there is some evidence that fatness and activity of respiratory exchange are important factors. 14) Death is nearly always due to pulmonary air-embolism, and paralysis to blockage of vessels in the spinal cord by air. The cause of "bends" remains undetermined; there are reasons for supposing that in at least many cases they are due to bubbles in the synovial fluid of the joints. 15) In our experiments bubbles were found post-mortem most freely in the blood, fat, and synovial fluid; they were not uncommon in the substance of the spinal cord, but otherwise were very rarely found in the solid tissues. (Authors' summary)

61.
BOYLE, R.
New experiments physico-mechanical touching the spring of the air and its effects (made for the most part, in a new pneumatical engine).
Oxford, H. Hall, 1660.

Robert Boyle, working in Oxford in the mid-17th century, is undoubtedly the father of the subject of experimental variation of atmospheric pressure. His observation of a bubble in a viper's eye has been noted many times. He wrote: "Another suspicion we should have entertained concerning the death of our animals, namely that upon sudden removal of the wanted pressure of the ambient air, the warm blood of those animals was brought to an effervescence or ebullition, or at least so vehemently expanded as to disturb the circulation of the blood, and so disorder the whole economy of the body." (CWS/UMS)

62.
BOYLSTON, R.R. and K.H. Smith.
Decompression techniques and dive profiles: drilling support, construction, pipelines, field maintenance and other tasks.
In: Lambertsen, C.J., S.R. O'Neil and M.L. Long. The human factor in North Sea operational diving. Proceedings of a symposium, London, Nov. 1976, p.59-62. Allentown, Pa., Air Products and Chemicals, Inc. 1978.

The first author discusses three types of diving: exploration, construction, and inspection. The first is of short duration, with little exertion required; the second is longer and much more strenuous; the third can be of long duration but requires no exertion other than swimming. Ideally, these different types should all have different decompression profiles. This author believes that decompression is not the most important thing about diving. Accidents and injuries in commercial diving seldom come from inadequate decompression. The second author discusses the technical development of decompression procedures. Aspects of the physical environments important in calculating decompression tables are: pressure, whether or not a bell is being used, whether a wet suit or a dry suit is being used, the type of breathing apparatus, temperature of the water, amount of exertion required to perform the task, and the experience and capabilities of the diver. Physiological aspects are still not completely understood. Figures 1, 2, and 3 demonstrate the effect of differing rates of ascent upon the production of bubbles, detected ultrasonically in goats. Figure 4 demonstrates the effect of decompression on the elimination of inert gases. Figure 5 demonstrates an isobaric switch at 132 fsw, and the continued low level bubbling following the gas switch. This is the type of information from which decompression tables are constructed for field use. (MFW/UMS)

63.
BRADNER, H. and R.S. Mackay, Jr.
Biophysical limitations on deep diving: some limiting performance expectations.
Bull. Math. Biophys. 25:251-271; 1963.

Decompression is treated according to the conventional Haldane model, but with continuously varying gas mixture, and continuous ascent. Analytical expressions are derived for the inert gas, tissue supersaturation, during dives with optimum gas mixtures. Analog computer results are used to show the supersaturation graphically, on dives of 300 ft. with 20 minutes on the bottom, and 1,000 ft. with 4 minutes on the bottom. The decompression times are much shorter than the times expected from U.S. Navy diving tables. (Authors' summary)

64.
BRAITHWAITE, W.R.
Systematic guide to decompression schedule calculations.
U.S. Navy Exp. Diving Unit, Rep. EDU 11-72, 13p. July 15, 1972.

This report is designed to be used in conjunction with Workman's presentation of the theoretical basis for the calculation of decompression schedules, EDU Report No. 6-65, to clarify the definitions and simplify the calculation procedure. An attempt has been made to explain verbally and graphically the basic concepts in areas known to be difficult for students of Workman's method. The report includes a step-by-step program designed to lead one through the calculations with a minimum of confusion, and a discussion of methods for shortening the time involved. The necessary tables and worksheet used in the calculations are also included. (Author's abstract)

65.
BRAY, J.M.
The hyperbaric link.
Oceanol. Int. 4:47-49; May/June 1969.

The physiological problems of "man-in-the-sea" are reviewed. The matter of breathing mixtures under high pressures, composed so as to avoid oxygen poisoning and nitrogen narcosis is discussed. The theory of saturation—the hyper-pressurization of the body to match ambient pressure by absorption of the gases in the breathing mixture—is explained. The need for lengthy decompression periods is emphasized. In the dive of short duration at moderate depth, the sea itself is often the diver's decompression chamber: he is raised in stages and allowed time to stabilize at each level. In group saturation dives of prolonged periods at great depths, personnel transfer capsules (PTCs) and deck decompression chambers, generally in connection with an ocean-floor habitat, are used. When a habitat is not used, the diver goes directly from PTC to ocean environment, both compression and decompression taking place within the PTC. Problems of construction and design are discussed, with particular emphasis on the many factors to be considered with regard to the decompression chamber. The complicated pressure locks, which make it possible to pass an object from outside the chamber, at atmospheric pressure, to within the chamber, where pressure is much higher, are described, as are the couplings that attach the PTC to the habitat and to the DDC. (MFW/BSCP)

66.
BUCKLES, R.G.
Etiology of decompression sickness: characteristics of bubble formation in vivo.
U.S. Nav. Med. Res. Inst. Res. MR005.04.0095 Rep.1, 30p. Aug. 9, 1967.

In order to permit the testing of new decompression procedures in a reasonable time frame, a scaled animal preparation has been developed. The techniques permits the direct observation of bubble formation in vivo under highly controlled environmental conditions. This report presents the basis for such scaling and describes the instrumentation system that has been developed. (Author's summary)

67.
BUCKLES, R.G.
The physics of bubble formation and growth.
Aerosp. Med. 39:1062-1069; 1968.
Also published as U.S. Nav. Med. Res. Inst. Rep. 3. 1968. (AD 678 008)

The literature on the physics of bubble formation, growth, and resolution is extensive but of quite limited value in the quantitative study of decompression sickness. Direct observation of in vivo bubble nucleation has eluded all investigators and the study of in vitro bubble nucleation has proven that theoretical constructs are far outweighed by unpredictable practical abnormalities within the fluid-solid environment. This paper presents our recent attempts to overcome some of the previous theoretical limitations to direct in vivo studies on bubble nucleation, growth, and resolution. A high resolution pressurized optical bench capable of pressurizing an animal to 40 atmospheres of positive pressure or down to hard vacuum has been developed at NMRI. It is capable of supporting a living hamster and has been designed so that its cheek pouch may be observed microscopically. Studies on hamsters exposed in increasing pressures of nitrogen (pO_2 = 0.2 atmosphere) have been carried out up to pressures of 7 atmospheres ata. Results show that bubbles do not nucleate in the pouch under conditions where they are formed elsewhere in the body and carried to the pouch by the circulatory system. Bubble resolutions once present in the pouch can be accomplished by recompression with nitrogen to minimal pressures. Bubble resolution studies indicate that in vivo bubbles are not resolved according to the simple mathematical models of spherical diffusion. Rather, their resolution is impeded by the formation of relatively impervious surfactant monolayer surrounding the bubble.

68.
BUCKLES, R.G. and D.L. Greenberg.
The use of analog computers for the analysis of decompression schedules.
U.S. Nav. Med. Res. Inst. MR005.04-0095 Rep.2. 1968. (AD 686 033).

The establishment of safe decompression schedules is still a major limitation on man's successful exploitation of the sea. Modern computers are being used to compute decompression schedules based on the multiparameter empiric models of inert gas uptake and distribution in vivo. This report presents the utility of using an analog computer to compute decompression schedules based on the model currently used in the U.S. Navy. Continuous ascent profiles are computed following any dive profile of up to four dive-and-hold maneuvers of less than 1000 feet. Direct accessibility makes the analog computer a powerful design tool for the evaluation of optimum schedules. The same program is also capable of computing inert gas tissue tensions during any dive profile as a means of comparing U.S. Navy criteria with the results of known dives from non-Navy sources. (Nav. Med. Res. Inst. Sum. Res. 1968)

69.
BÜHLMANN, A.A., P. Frei and H. Keller.
Saturation and desaturation with N_2 and He at 4 atm.
J. Appl. Physio. 23(4):458-462; 1967.

Forty-three subjects were exposed to 4 atm. (100 ft.) in 120 experiments of 3-72 hr. duration, by breathing air or a mixture of 80% He/20% O_2. Using a factor of critical oversaturation (surfacing ratio) of 1.6-1.0, the longest halftimes for N_2 were 420-480 min., and for He, 160-180 min. No "bends" appeared after decompression times according to these half-times. A practically complete saturation (> 99%) requires 64 hr. for N_2 and 24 hr. for He. The differences in the saturation speed for a constant blood flow in the slowest fatty tissue can be explained by the difference of the oil/H_2O solubility ratio for N_2 and He. Since in the experiments bends appeared mainly in water tissues, like muscles and joints, the difference in pressure equilibration for a given slow perfusion ratio seems to be determined by the molecular weight similar to a diffusion limited system. (Authors' summary) (© Biol. Abstr.)

70.
BÜHLMANN, A. and W. Waldvogel.
Decompression apres plongees de longue duree jusqu'a saturation sous 23 ATA.
[Decompression after prolonged saturation dives to 23 ATA].
Rev. Physiol. Subaquatique Med. Hyperbare 1:135-140; Oct./Dec. 1968.

The authors have employed their own decompression tables in a series of experiments consisting of simulated chamber dives to 23 ATA and underwater dives to 220 m. They reached the following conclusions: (1) Oxygen must be progressively increased during decompression, but the partial pressure of 1.0 ATA must not be exceeded. (2) Life is perfectly possible and normal at 23 ATA. Results of biological examinations made after decompression were identical to those observed before, with the exception of a slight polynucleosis. (3) Effective decompression time remains the same for all dives of more than six hours; therefore, dives of a few hours are not economically profitable. (Authors' summary translated by MFW/BSCP)

71.
BÜHLMANN, A.A.
The use of multiple inert gas mixtures in decompression.
In: Bennett, P.B. and D.H. Elliott, eds. The physiology and medicine of diving and compressed air work, p.357-385. Baltimore, Williams and Wilkins, 1969.

Between 1960 and 1962 it was demonstrated both in the sea and in dry pressure chambers that man could attain and work at depths of at least 1,000 ft (31.2 ATA). At present the main interest is in exposures of long duration or saturation diving. There are limits to the use of nitrogen as an inert gas for diving: narcosis, and at very high pressures resistance to flow. Oxygen would be ideal but it is extremely toxic at increased pressures. Hydrogen has some advantages but the risk of explosion is too great. Helium is the inert gas of choice. The molecular weight and the solubility coefficient make it the gas of choice. In a study of the half-time spectrum for helium and nitrogen, the use of nitrogen results approximately in a threefold prolongation of the half-time spectrum. In a lengthy summation the following factors were analyzed: descent time with the two different gases, variation of half-time with physical activity, variation of the supersaturation factors, corrections for possible differences between respiratory, alveolar and partial inert gas pressures, dives with exposure times to 120 minutes, exposures to 330 feet, exposures from 500 to 1,000 feet (16 to 31 ATA), and exposure times of four to 72 hours. "The rationale of the use of the technique of changing inert gases to shorten the decompression time is based on the concept that saturation and desaturation, especially in poorly perfused and fatty tissues, proceeds two to three times faster with helium than with nitrogen." (CWS/BSCP)

72.
BÜHLMANN, A.A., H. Matthys, G. Overrath, P.B. Bennett, D.H. Elliott and S.P. Gray.
Saturation exposures at 31 ATA in an oxygen-helium atmosphere with excursions to 36 ATA. Aerosp. Med. 40:394-402; Apr. 1970.
(Also published as Roy. Nav. Physiol. Lab. Rep. 6-70).

Three exposures each of several hours and one exposure of several days in a compression chamber at 31 ATA with an oxygen-helium atmosphere are reported. During the latter experiment three exposures of several hours were made at a pressure of 36 ATA. A relatively rapid rate of compression was used for the three short duration exposures to 31 ATA. Some symptoms of vertigo, nausea and tremor were noted. There was also a rise in pulse rate and blood pressure, an increase in urinary catecholamine elimination and a small decrement of psychomotor function. During and after the longer exposure to 31 ATA, for which a slightly slower rate of compression was used, and during the daily descents to 36 ATA, there was no significant alteration of fluid balance, catecholamine elimination, blood morphology and chemistry, ECG or psychomotor ability from the pre-dive control values. Decompression from the 80 hour exposure at 36 and 31 ATA was completed successfully in 88 hours for two subjects. The third had a minor episode of decompression sickness requiring an additional four and one-half hours before returning to the surface. (Authors' abstract)

73.
BÜHLMANN, A.A.
Decompression in saturation diving.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the fourth symposium on underwater physiology, p.221-227. New York, Academic Press, 1971.

The early diving experiments were based on the concept that "inert gas half saturation times are related to the perfusion of the tissues with blood; that the half-time for a given tissue and the rate of perfusion are determined by inert gas diffusion; and that diffusion depends on the physical properties of the particular gas, especially its molecular weight." Some of these concepts may need modification but they have worked successfully. Differences were confirmed between the saturation rates of He and N_2 by dives at 4.0 ATA where the longest half-time tissue seems to be 480 min for N_2 and 180 for He. Because of unknown diver activity the calculations were based on the longest N_2 tissue half-time being 640 min and the longest He being 240 min. And the supersaturation ratio was calculated on the more conservative 1.5:1 rather than the 1.6:1 suggested by Haldane. Mixed gas breathing during decompression (50% O_2 - 50% N_2 and air) rather than 21% O_2 - 79% He for saturation dives to 31 atm abs demonstrates that the method of "mixed-gas decompression" is as safe as the other methods and certainly conserves times. (CWS/BSCP)

74.
BÜHLMANN, A.A., R. Schibli and H. Gehring.
Experimentelle Untersuchungen uber die Dekompression nach Tauchgangen in Bergseen bei vermindertem Luftdruck.
[Experimental studies on decompression following diving in mountain lakes at reduced air pressure].
Schweiz. Med. Wochenschr. 103:378-383; Mar. 10, 1973.

Fifty subjects underwent 106 exposures of 17-120 min in a dry pressure chamber at a pressure of 4.2-5.2 ATA. They performed physical work on a bicycle ergometer followed by decompression at a pressure of 0.7 ATA corresponding to an altitude of 3000 meters. Thirty-five of the 106 simulated dives were performed as repeated dives at an interval of 40-45 min and a pressure of 0.7 ATA. In a second series 108 real dives, including 44 repeated, were performed in a lake at 1250 meters altitude without decompression symptoms. Decompression was calculated in the usual laboratory manner, having regard to diminished surface pressure without alteration to the N_2 halflife spectrum of 5-640 min or the oversaturation factors. These experiments without decompression symptoms offer the basis for decompression tables for different altitudes including rules for repeated dives. (English summary)

75.
BULENKOV, S.Ye., et al.
Illnesses peculiar to underwater swimming and adverse effects due to them. 6. Decompression illness.
In: Spravochnik plovtsa-podvodnika [Manual of scuba diving], p.181-183. Moscow, Publishing House of the Ministry of Defense, USSR, 1968. (JPRS 47,828)

The cause of decompression illness is "violation of the proper decompression regimen when surfacing from depths in excess of 12.5 m." A table gives the amount of time a diver can spend safely at depths of up to 40 m without decompression, but because of the limited air supply in the diver's tanks the safe permissible time can not be exceeded. Thus the only real danger from decompression illness is from diving with "air fed from the surface." The symptoms listed are standard: "cutaneous pruritis, pains in the muscles and joints, general debility, circulatory and respiratory disturbances, paralysis of the extremities, and loss of consciousness." Treatment is therapeutic recompression at once. And prevention is: observe underwater time for various depths; and observe the regimen for surfacing according to the decompression tables. (CWS/BSCP)

76.
BUSUTTILI, M.
The transatlantic connection.
In: National Association of Underwater Instructors. Proceedings of the tenth international conference on underwater education, p.86-89. Colton, Calif., Published by the Association, 1978.

What are the differences between the American and the European approach to diving; the differences in the equipment used, in instructional methods, and diving procedures? It could be concluded that there are, of necessity, as many similarities as differences but it is usually in the areas of difference that the most fruitful exchanges of ideas and information take place. This paper examines the differences and seeks to determine whether the differences hold any lessons for either side of the Atlantic, as well as attempting to encourage and develop the exchange for mutual benefit. (Author's abstract)

77.
CABARROU, P., U. Finkeldey, H.-D. Fust, H. Krekeler, K.-G. Muller and H. Oser.
Development and tests of heliox dives in excess of 100 m. Part 1.
Bonn-Bad Godesberg, West Germany, Institut for Flugmedizin, Deutsche Forschungs- und Versuchsanstalt fur Luft-und Raumfahrt. Rep. DLR-FB 75-48, 46p. 1975.

The authors distinguish two types of decompression profiles: the type m-profile with a medium pressure reduction and a long decompression-time and the type f-profile with a fast pressure reduction and a short decompression time. Except for the initial decompression phase the Δp-values of the f-profile are smaller than those of the m-profile. An analysis of available diving information leads to a new scope for the construction of new type f-profiles. 110m/60min, 135m/60min and 150m/30min Heliox-dives have been proposed and tested in a dry chamber and a wet pot. During the test of unsuccessful profiles, which had to be rejected, only slight decompression sickness symptoms of type I occurred; neither vestibular nor central nervous symptoms have been noticed. Series of successful profiles exist for 135m/60min/428min and 150m/30min/300min dives, each slightly modified. They may provide a new basis for the introduction of type f-standard tables. (Authors' summary)

78.

CABARROU, P., K.G. Mueller, H.D. Fust, H. Oser, H. Krekeler and U. Finkeldey.

Development of testing of heliox dives in excess of 100 meters.

In: Shilling, C.W. and M.W. Beckett, eds. Underwater physiology VI. Proceedings of the sixth symposium on underwater physiology, p.383-388. Bethesda, Md., Federation of American Societies for Experimental Biology, 1978.

In our Institute a possible reduction of the decompression time due to a change in the type of the decompression profile has been investigated. There exist two different types of Heliox-profiles in excess of 100m. The common type of profile shows a medium pressure reduction and partially an inacceptably long decompression time. A new type of profile was tested by Cabarrou and Hartmann in 1968. These profiles are characterized by an extreme initial pressure decrease and by a relatively short decompression time. During the initial phase of such a profile the fast tissues (half time $t_h < 20$ min) are stressed by a supersaturation ΔP up to 40 m. This phase is followed by a recovery phase for the fast tissues. Here medium supersaturations are applied to the tissues with medium half times ($20 \leqslant t_h \leqslant 80$ min). In the final phase the slow tissue ($t_h \geqslant 100$ min) can be treated with mild supersaturations in spite of the short decompression time. On this basis we developed a 135m/60 min profile (decompression time $t_D = 428$ min) and a 150m/30 min profile ($t_D = 300$ min). The main features of these profiles were an initial pressure reduction of approximately 2:1 within 7-8 min, followed by a stop of 10-15 min. To accelerate the helium elimination breathing mixtures with high oxygen partial pressure have been used. The calculated profiles have been tested successfully in a dry chamber and in a wet pot. By these new profiles the limit of economic surface diving can be shifted towards greater depths. (From Sixth symposium program and abstracts)

79.

CAMPBELL, J.A. and L. Hill.

Concerning the amount of nitrogen gas in the tissues and its removal by breathing almost pure oxygen.

J. Physiol. 71:309-322; 1931.

The gaseous nitrogen content of bone marrow fat of an animal (ox, horse, sheep) breathing air is about 5 c.c. per 100 c.c. fat: the results agree with Vernon's figures for cod-liver oil, olive oil and lard. Brain tissue contains about 1 c.c. nitrogen per 100 c.c. tissue. The more easily removable nitrogen (200-300 c.c. under normal atmospheric pressure) in the human body is removed in a few minutes by breathing oxygen. After exposure to +1 and +2 atmospheres of ordinary air, the amount removed in the same time is about doubled and trebled respectively. (Authors' summary)

80.

CAMPBELL, J.A. and L. Hill.

Studies in saturation of the tissues with gaseous nitrogen. I. Rate of saturation of goats bone marrow in vivo with nitrogen during exposure to increased atmospheric pressure.

Q. J. Exp. Physiology 23:197-210; 1933.

1) The rate of saturation of bone marrow with gaseous nitrogen in goats breathing air at +3 atmospheres pressures has been studied. It is 25 percent saturated in one hour, 60 percent in four hours, and about 90 percent in eight hours, when the fat content of the marrow is about 90 percent. 2) This slow rate is shown to be due to a) low circulation rate through marrow, b) high fat content diminishing the rate of diffusion. 3) Some data re: saturation at some other pressures, e.g. +1 and +2 atmospheres, are also recorded. The nitrogen content depends upon the fat content of the marrow, the excess pressure and time of exposure to this pressure. (Authors' summary)

81.
CARTER, R.C.
Pioneering inner space: the Navy Experimental Diving Unit's first 50 years.
U.S. Navy Exp. Div. Unit, Rep. 1-77, 31p. 1977.

This history starts with the testing of Haldane's tables and the publication of the first diving manual in 1915. New diving dress was developed, and depth capability was quadrupled. Submarine salvage was carried out. Helium breathing mixtures were developed. The Navy Experimental Diving Unit was established as a permanent facility in 1927, with submarine escape and rescue as its first objective. The Momsen Lung and the McCann Bell were developed. No-decompression limit tables and a helium-oxygen surface supplied decompression table were compiled. The first medical staff arrived in the mid 1930's. More intensive work was done on helium-oxygen tables. The SQUALUS was salvaged, along with its crew. A closed circuit oxygen scuba was developed for combat swimmers. Much experimentation with oxygen toxicity was carried out during World War II. NEDU became involved in testing of aircraft pilots' pressure suits and breathing apparatus. The neoprene wet suit was developed. The pneumofathometer was invented. During the 1950's and 1960's, NEDU continued to improve decompression and treatment tables. They became involved in saturation experiments, such as SEALAB, and dives carried out with Duke University. They have carried on an exchange program with the Admiralty Experimental Diving Unit in the U.K., and have conducted joint saturation dives. They have made their facilities and knowledge available to Canadian divers. Their 1000-foot dive yielded understanding of respiratory heat loss. In 1973, they carried out a successful 1600-foot saturation dive at Taylor Diving and Salvage. In 1975 NEDU moved from the Washington Navy Yard to Panama City, Florida, where there exists the world's largest hyperbaric complex. There they continue to develop improved diving systems and to evaluate diving equipment. (MFW/UMS)

82.
CASTELLINO, N., S. Fatti and R. Pallota.
Considerations on some tables for prevention of gas embolism under water.
Folio Med. (Napoli) 47:1097-1120; Nov. 1964.

The authors mention first, briefly, the physical and biological principles governing the nitrogen solubility in different tissues of the body. They present some tables for the gradual air decompression applied by the U.S. Navy in the prevention of gaseous embolism underwater. (Authors' summary)

83.
CATTON, M.J.
Three stage decompression.
In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October, 1965, p.185-191. Newcastle upon Tyne, Oriel Press, 1967.

There was an opportunity in some British work to vary the decompression procedures. The standard procedure used was to rapidly (2 to 9 minutes) drop the pressure to one-half the absolute pressure; they then shifted to a slow phase at a steady rate of 8 to 11 minutes per pound. A modified three-stage procedure was a rapid drop to 14 p.s.i.g. over 2 to 6 minutes followed by a drop to half the absolute pressure over 2 to 10 minutes, and then the slow drop at 8 to 11 minutes per pound. The latter method cut the bends rate from 2.6% to 1.3%. In addition the cases experienced were less severe. (CWS/BSCP)

84.
CATTON, M.J.
The decanting method of decompression.
In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October, 1965, p.206-216. Newcastle upon Tyne, Oriel Press, 1967.

Decanting consists of rapid decompression of the workers to atmospheric pressure in the locks attached to the working chambers, which is followed as quickly as possible by recompression in a more spacious chamber where the full recompression procedure is carried out. Six stages of the procedure can be differentiated, all of which can be modified in a number of ways: rapid decompression to atmospheric pressure; transfer time; recompression to above working pressure; soaking at 1 to 2 p.s.i.g. above working pressure; the rapid drop phase; and the slow phase of decompression as given in the standard tables. Decanting was shown to carry no greater risk of bends than direct decompression (CWS/BSCP)

85.
CATTON, M.J.

Prevention of decompression sickness by special procedures.

In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October, 1965, p.185-191. Newcastle upon Tyne, Oriel Press, 1967.

The clinical impression of a reduced number of less severe bends cases following the introduction of a three stage decompression is confirmed by the reduced bends rate and by the reduction in the proportion of men affected by bends. The periods of work studied are comparable in length, pressure, range, shift work conditions and selection of the men. Variations in the details of decompression are noted. In the standard decompression the intermediate stage is likely to improve the results while the experimentation with the length of both rapid drop stages in periods E and G may have adversely affected the results. Details of the full decompression procedure comparing bends cases with normal decompressions in each period suggest that improvements in technique can be made, mainly in setting the optimum times for the rapid drop stages. The variation in introductory shifts is not likely to affect the results favorably. (Author's conclusions)

86.
CECH, I.

Los progresos del buceo moderno.
[Progress of modern diving].
Mar Pesca 14:12-15; 1966.

This is a brief general review, summarizing the historic development of diving since the Cousteau-Gagnan invention of the self-contained compressed air apparatus and outlining possibilities of future human activities under the sea, with creation of submarine habitats for prolonged underwater living. The basic physiology of the respiratory process is briefly considered and problems of pressure and decompression are noted. Reference is made to decompression tables prepared by the Cuban Ministry of Armed Forces, 1963. It is stated that according to these tables decompression period is 9 hours 56 minutes, with the observation that the different national tables vary in accordance with the margin of security taken as the basis for the calculation. Pre-Continent I and Pre-Continent III, conducted by J.-Y. Cousteau in the Mediterranean, are briefly reviewed and the significance of electronic computation for the future development of submarine medicine is mentioned. (MP/BSCP)

87.
CHOUTEAU, J.

Saturation diving: the Conshelf experiments.

In: Bennett, P.B. and D.H. Elliott, eds. The physiology and medicine of diving and compressed air work, p.491-504. Baltimore, Williams and Wilkins, 1969.

Saturation diving is the most recent technique for exploration of the sea, and came about because the ordinary short dive with return to the surface after a short period of work required too much time for decompression. However, once complete saturation of the body with the gas mixture being breathed has occurred the decompression time is constant regardless of the length of stay on the bottom. This may be expressed as:

$$\text{The economic time of a dive} = \frac{\text{Time at depth}}{\text{Time at depth 3 decompression time}}$$

It will be seen that for long periods of exposure the ratio will increase and tend to return toward unity. Animal work had shown that the inspired oxygen partial pressure should not exceed 309 mm Hg (0.41 ATS), and that the specific gravity should not exceed more than two or three times that of air at atmospheric pressure. In Conshelf I, a human experiment, these conditions were met and the men lived in the underwater house, Diogene, for seven days and worked four hours per day at 35 ft (2.06 ATA) and were brought back to the surface without incident except for some anxiety during the early part of the experiment. In Conshelf II there were five subjects and the depth was 31 feet and the duration was 30 days. Two of the five lived at 87 feet for six of the days. There were many excursion dives to greater depth during the daily work periods. The only problem was skin disease and otitis externa from the moist heat. Conshelf III consisted of animal experiments carried out at a depth of 640 feet, human pressure chamber experiments at 383 feet (10.95 ATA). They worked daily for four hours and made excursion dives to 426 feet. There were no serious problems. "It is considered that only the problems of respiratory function and hemodynamics require further study before further even deeper experiments may be performed by man." (CWS/BSCP)

88.
CIRIA UNDERWATER ENGINEERING GROUP.
Oxy-helium saturation diving tables. Report UR-11.
Alverstoke, Hants. Admiralty Mar. Technol. Establ. Physiol. Lab., Feb. 1978. 27p.

The decompression procedures given in the report are for saturation diving in depths between 50 and 305 metres. The tables are given in 50 metre intervals to 250 metres, plus a 305 metre (1000 foot) table, with notes on the use of the tables and action to be taken to treat decompression sickness. Excursion diving procedures from the stored saturation level are described, with the excursion limits presented in tabular and graphical form. [Appendixes consist of: 1) Summary of saturation tables; 2) Oxy-helium saturation diving to 305 metres–therapy; 3) Oxygen and carbon dioxide table; 4) Excursion dive limits and maximum limits table.] (Authors' summary)

89.
CLARKE, D.
Five years of undersea living.
Triton 21:126-130; May/June 1976.

The author gives an account of the various experiments that have been carried out from the underwater habitat Hydro-Lab, which was emplaced two miles off the southern shore of Grand Bahama Island in 1971. The habitat is supplied with utilities from unmanned life support barge on the surface. The breathing mixture is compressed air. Since 1971, 100 missions involving 340 diving scientists have been carried out. Many of the experiments have served a double purpose, in that while the scientist is carrying out a research project in marine biology, he himself is serving as the subject of physiological studies carried out by monitoring techniques. Gradually missions were lengthened, saturation depth increased, and tables were compiled that made deeper excursion dives possible. Sonic dopplers were used to check bubbles. During the earlier dives, it was discovered that divers could go to 200 feet from saturation at 42 feet, or to 250 feet from saturation at 60 feet, without experiencing nitrogen narcosis, as they would have done had they gone to these depths from the surface. This narcosis adaptation finding led to the planning of Project SCORE, the scientific exploration of the Continental Shelf, using Hydro-Lab, Johnson Sea-Link and a sub-igloo habitat as a refuge. Excursions were made from the sub to 250 feet, and from the habitat to 200 feet. (MFW/UMS)

90.
CROCKER, W.E.
Investigation into decompression tables. Report IX. Revised tables.
Prepared for the Underwater Physiology Subcommittee of the Royal Navy Personnel Research Committee, Medical Research Council, 1957.

The need for new diving tables is restated and a further attempt to produce a workable system is described. The revised system draws freely upon the experience of previous trials and certain of the principles developed by other workers, namely Hempleman and Rashbass are adopted. Empirical evidence as to the limits of safe decompression has, however, been the main basis of the tables. Trials consisting of 111 chamber experiments and 246 sea dives were satisfactory. A few schedules which were found to be suspect, have been extended by the addition of five minutes to the final stop. (Author's summary)

91.
CROCKER, W.E. and H.J. Taylor.
A method of calculating decompression stages and the formulation of new diving tables. Part B of Report III. Investigation into the decompression tables. Prepared for the Decompression Panel of the Royal Naval Personnel Research Committee, Medical Research Council. 1952.

As a result of experiments on goats exposed to higher pressures than those described in previous reports in this series, the findings became so variable that it was found impossible to decide on safe decompression ratios for the various tissues. Recently Hempleman (1952) has made a new theoretical approach to the problems of decompression and it was decided to use this theory in conjunction with the experimental work described, to formulate new Diving Tables. This has been done and the tables successfully tested. This report is, however, only a preliminary one and further work is in progress. (Authors' summary)

92.
D'AOUST, B.G., R. White, R.J. Buczek and J. Mahoney.
Time at given supersaturations as ascent criteria.
In: Proceedings of the first annual meeting of the North Pacific Branch of the Undersea Medical Society, 5-7 Sept. 1974. p.37. Avalon, Calif., Univ. So. Calif., Santa Catalina Mar. Sci. Cent., 1974.

Abstract only. Excerpt quoted: Information available in the literature and the results of more recent field and laboratory work on fish mortality due to air supersaturation has emphasized the importance of time and has prompted us to analyze several dive profiles which have produced bends in our laboratory (and which are in use in commercial diving). The cumulative sum of (time X supersaturation) is calculated for each compartment during and after the entire dive. The results often show crossover points in any one dive where a nonlimiting tissue (i.e., specific half-time) using ΔP as an ascent criteria can become limiting using a cumulative sum of time multiplied by ΔP as above; also more than one tissue can show similar values. These results indicate that such a parameter is both physically and physiologically more revealing and predictive and it is suggested that this technique might be most effectively used in conjunction with the use of empirically derived criteria of bubble formation under a variety of physical conditions.

93.
D'AOUST, B.G., K.H. Smith, H.T. Swanson, R. White, L. Stayton and J. Moore.
Prolonged bubble production by transient isobaric counter-equilibration of helium against nitrogen.
Undersea Biomed. Res. 6:109-125; June 1979.

The production of systemic gas bubbles by isobaric counter-equilibration of helium against 5 atmospheres saturated nitrox (0.3 ATA O_2 in both mixes) in awake goats was demonstrated. Sixteen animal exposures (8 dives, 2 animals per dive) to a sudden isobaric gas switch from saturation on N_2 to He were conducted; 8 saturation occurred at 132 fsw and 8 at 198 fsw. Central venous bubbles were detected acoustically by means of a Doppler ultrasonic cuff surgically implanted around the inferior vena cava of each animal. Bubbles occurred from 20 to 60 min after the switch in both the 132 fsw and 198 fsw exposures, but were not always present in the 132 fsw exposure, and did not persist for as long. Bubbles or other Doppler events were often detected for the entire isobaric period—12 h—following the gas switch in the 198 fsw exposures. Decompressions were conducted according to the USN saturation tables and were uneventful, with only occasional bubbles. Supersaturation ratios calculated to have occurred for a considerable period after the gas switch were approximately 1.15 (tissue gas tension π, divided by ambient hydrostatic pressure, P) with maxima at 1.26 for the faster tissues. These values are limiting ones in USN decompression *only* for the slower tissues. In general, therefore, these results argue for reducing the permissible ascent criteria for the faster tissues—assuming bubbles are to be avoided—and allowing more time at stops for nonsaturation decompression. Gas switches from a more soluble to a less soluble and/or more rapidly diffusing gas should therefore be avoided until physiological limits are well worked out. (Authors' abstract)

94.
D'ARRIGO, J.S. and Y. Mano.

Bubble production in agarose gels subjected to different decompression schedules.
Undersea Biomed. Res. 6:93-98; Mar. 1979.

The relative effectiveness of seven different (military, commercial, and experimental) decompression schedules in reducing bubble formation within aqueous gels has been evaluated quantitatively under rigorously controlled conditions. Specifically, visual counts have been conducted of the bubbles formed in highly purified agarose gels subjected to the different decompression schedules. The order of effectiveness among these schedules in reducing bubble formation in the agarose gel samples was as follows: Model 1 > Royal Naval Physiological Laboratory ≈ French Ministry of Labor ≫ Yount et al. > Japanese Department of Labor > United States Navy > French Navy. It was concluded that the depth at which slow decompression commences is a major factor, along with the total decompression time, in determining the extent of bubble formation. (Authors' abstract)

95.
DAVIS, R.H.

Deep diving and submarine operations. A manual for deep sea divers and compressed air workers.
London, St. Catherine Press, 1962. 693p. plus index.

This is the most recent edition of a standard handbook on the subject. Part I deals with diving equipment and technology (suits, breathing apparatus, decompression chambers, observation chambers, diving bells, etc.), the physics and physiology of diving, techniques of diving decompression tables, breathing mixtures, first aid escape from submarines, and use of tools and explosives underwater. Part II, entitled "Secrets of the deep," deals with the historical and adventurous aspects of diving. Seven appendices include such subjects as "Maximum depths for diving apparatus," "Submarine escape," "The greatest ocean descents" and "Holger-Nielson method of resuscitation." (MFW/BSCP)

96.
DECOMPRESSION SICKNESS PANEL, MEDICAL RESEARCH COUNCIL.

Decompression sickness and aseptic necrosis of bone. Investigations carried out during and after the construction of the Tyne Road Tunnel (1962-1966).
Brit. J. Ind. Med. 28:1-21; Jan. 1971.

This paper describes investigations into the health of compressed air workers during and after the construction of a road tunnel under the River Tyne. Altogether 641 men were exposed to the compressed air environment over a period of approximately 31 months. The maximum working pressure was 42 psig (289.6 kN/m^2), and the overall decompression sickness rate for work at pressures of 18 psig (124.1 kN/m^2) and above was 2%. Radiological examination of the chest was carried out on 183 men to detect lung cysts but only one was found. Thus lung cysts were not shown to be a common factor in the causation of decompression sickness but the possibility of small subradiological collections of trapped air being involved was not excluded. Radiological examinations of the shoulders, hips and knee joints were carried out on 171 men. There was evidence of aseptic necrosis in one or more bones of 44 men (26%). Fifteen of the men with definite lesions of aseptic necrosis of bone and seven of the men with suspected lesions had never worked in compressed air before this contract. The remaining 14 men with definite lesions and the eight with suspected lesions had worked elsewhere in compressed air prior to this contract, but a definite lesion in one of these men and a suspected lesion in another can almost certainly be attributed to their work in compressed air on this contract. Although most of these men were still symptomless three years after the end of the compressed air work, four were partially disabled even after surgical treatment. There was a statistically significant correlation between a man's fatness as measured by the Harpenden skinfold caliper and the number of attacks of bends which he subsequently suffered, but there was no correlation between fatness and the development of a bone lesion. Although it appeared that at first sight decanting was associated with a lower bends rate than conventional decompression, detailed statistical analysis showed this to be a false relationship. Nevertheless, decanting is no more liable to give rise to the bends than conventional decompression. After carrying out a therapeutic compression there is a distinct advantage to be gained by stopping the rapid phase of decompression at half the maximum gauge pressure required for the relief of symptoms instead of half the absolute pressure. Observations were made on the effect of minor divergences from the statutory decompression table, dermatitis in tunnellers, and noise levels at the working face and the medical locks.

Evidence is presented to suggest that timed decompressions should start when the working pressure reaches 14 psig (96.5 kN/m^2). At present the Medical Research Council Decompression Sickness Panel organizes periodic radiological examinations of the major joints of compressed air workers on a voluntary basis through its Decompression Sickness Central Registry at the University of Newcastle upon Tyne. It is felt that compulsory radiography of the joints of all compressed air workers should be introduced as part of the statutory regulations for work in compressed air. (Authors' abstract)

97.
DECOMPRESSION SICKNESS PANEL, MEDICAL RESEARCH COUNCIL.
A medical code of practice for work in compressed air.
London, U.K., Construction Industry Research and Information Association, Rep. CIRIA 44, 90p. Feb. 1973.

The Code sets out recommendations for the medical treatment and supervision of compressed air workers. Appendices include the new Decompression (Blackpool) Tables, and also other proposed and existing working documents. An Annexe compares the recommendations in this Code with the Statutory Instruments (1958). (Authors' summary)

98.
DECOMPRESSION SICKNESS PANEL, MEDICAL RESEARCH COUNCIL.
Experience with a new decompression table for work in compressed air.
London, Construction Industry Research and Information Association, TN 59, 33p. July 1974.

The results of using the 1966 Blackpool decompression tables during the Dungeness B contract are compared with the results of using the 1958 British Tables during the Tyne Road Tunnel contract. The percentage of decompression sickness and of bone necrosis was less with the new tables, but it is felt that the findings are not conclusive because of the many difficulties inherent in comparing incidence of decompression sickness in nonidentical circumstances. Comparison also is made with the Washington State Tables (first used in 1964). No bone necrosis has occurred with these tables, but it must be noted that the exposures were more moderate than those experienced with the British Tables. (MFW/UMS)

99.
DeLAUZE, H.G.
Deep-diving for the offshore industry and its future in the next decade.
In: Proceedings of a meeting of the Society for Underwater Technology, Ltd., London, Jan. 5, 1970, 26p. Published by the Society.

The author starts with a clear and reasonably detailed discussion of the physiological problems connected with diving. A list of safe, "no decompression" times at depths from 16 m to 180 m are given. The work of Ocean Systems in the United States, SSOS (subsidiary of Shell) in Italy, and Comex in France, in developing decompression tables and hyperbaric chambers is praised. Comex, at time of writing, was handling one-third of the world market in operational and industrial diving. The diving turret is used to lower the diver to the work site, where he then pressurizes the capsule to the ambient atmosphere; when the task is finished he re-enters, is brought to the surface where the turret is mated to a decompression chamber. The technological details of these facilities are described. The short duration deep dive, the "bounce" dive, can be made with safety only ten times in a month; this works out to about three to six hours of bottom time in a month. The development of saturation diving and the surface saturation technique are discussed. The early experimental Ludions 1, 2 and 3 are described. The divers lived at 95 m and worked at 150 m (simulated) for four hours each day in Ludion 3. Janus operated at the same depths. The divers were pressurized to 16 bars when they went to work site pressure, and were decompressed to 10.5 bars when they returned to the habitat pressure. In discussing inert gas narcosis the author states that the narcotic properties of gases are not related to their densities, as previously thought: this is indicated by the narcotic effects of the extremely light hydrogen. The operative factor is believed to be their pharmacodynamic activity–their grease/water solubility ratio. By this ratio, helium and neon demonstrate the lowest values, and they are in fact the least narcotic of gases. Helium may contribute to the phenomenon of excitation at high pressure because it is an excitant, while the other inert gases are depressants; it is also possible, however, that the excitation is caused by the pressure itself, and helium simply fails to obstruct it. It has been discovered that in very deep dives, the high pressure nervous syndrome (hpns) can be modified by substituting hydrogen for helium, or by adding nitrogen to it. The deep Physalia dives, carried out by the author and Dr. Brauer, culminated in a depth of 365 m using an oxygen-nitrogen-helium mixture; these experiments demonstrated that man could live and work effectively at 300 m. At the time of writing, it was believed that the safe limit with heliox was around 360 m. These experiments showed that the higher the pressure, and the faster the rate of compression, the more marked were the CNS effects. Manifestations of the hpns are described; primarily, they are 1) helium tremor, 2) decline of vigilance, and 3) modifications in the EEG, consisting mainly of the onset of sleep traces and increased theta wave activity. The chief distinction between heavy gas narcosis and the hpns is the marked EEG modification of the latter, which serves as a valuable alarm signal before outward symptoms are manifest. The Hydra experiments were designed to test the use of hydrogen. Despite long preparation, they were not entirely successful. The forced curtailment, by cold, of the excursion from the turret into the bell, caused the CO_2 level in the turret to become excessive. Further tests of hydrogen using animal subjects and isolated organs were designed to develop fundamental knowledge regarding the biological power of inert gases. Future plans are outlined, including long-duration hydrogen dives in the sea. Planned habitats and submersibles are described. (MFW/BSCP)

100.
DeLAUZE, H.G.
The present and projected capabilities of the diving industry in the support of offshore petroleum production.
Ind. Med. Surg. 41:12-19; Nov. 1972.

The author touches briefly upon some of the research and achievements of COMEX, as well as those of American and British groups. It is stated that the problem of cold is well on the way to being solved, as was indicated by the Beluga experiment and by the Labrador dives for Tenneco, in which ten dives of more than an hour's duration were made to 600 feet depths in -20°C water. The lack of universally accepted, published decompression tables for deep dives is pointed out. Each company seems to have its own approach to this problem, when international cooperation would probably result in a better solution. There is a question as to whether the oil industry will require saturation diving; the author believes not for drilling exploration, but if diving assistance is to be used in production, saturation would be the most efficient method. Depth limits due to breathing resistance are discussed. For medium to heavy work, requiring 100-200w, the limit for compressed air is 200 feet, for helium-oxygen 1,500 feet and for hydrogen-oxygen, possibly 3,000 feet; in the last case, limitations from pressure per se might interfere. For light work, the depth limits would be greater, but it is not yet understood to what extent pressure effects would be limiting. COMEX is planning a dive to 2,000 feet, undertaken with a very slow compression rate and a long stay at 1,500 feet. The large (17-foot) hyperbaric sphere of COMEX, with a pressure limitation of 1,000 feet, is described. It is used for training divers for experiments such as the Janus II open sea saturation dive to 840 feet. The closed-circuit hookah gas recovery system and the preheating unit, which heated the gas to 37°C, both used in Janus II are described. The same heating unit was used successfully in the Labrador exploration. In the eight-day Janus II, divers usually put in three hours bottom excursion working time. Physalia V culminated in about three hours at 1,700 feet, with a very brief jump to 1,706 feet. The profile of this dive is shown. There were stays of about 24 hours at 1,150 and 1,510 feet. The compression rate was fast to 355, slow to 1,150, fast to 1,310, slow to 1,510, fast to 1,610, and slow to 1,700. (MFW/BSCP)

101.
DeMATOS, A.
Emergencias em medicina submarina.
[Emergencies in underwater medicine].
Brazilian Navy, Submarine Force, 1973. 103p.

This publication of the Brazilian Navy contains chapters on the following subjects: Man in the underwater environment; Physiological changes caused by diving; Physical aspects of diving; Barotrauma; Air embolism; Decompression sickness; Inert gas narcosis; Oxygen toxicity; Carbon dioxide poisoning; Injuries caused by marine life; Drowning; Breath-hold diving. Each subject is dealt with briefly, but well illustrated by diagrams, drawings and tables. It is interesting to note that the treatment tables of Van der Auer and the oxygen treatment tables of Workman and Goodman are given as appendices to the decompression chapter. (MFW/UMS)

102.
DeSANCTIS, V.A.
DCM: il nuovo decompressimetro multiplo.
[DCM: the new multiple decompression meter].
In: Proceedings of the first national symposium of the Italian Committee on Underwater Research, Rome, 11-12 Oct. 1974, p.121-131. Published by Il Subacqueo.

A new device for calculating appropriate decompression schedules is described. The equipment simulates the behavior of 4 tissues under the gas and pressure conditions given. As an automatic device, it has 3 advantages for the sport diver or researcher: 1) Instant by instant, the variables of depth and time are taken into account. 2) The diver or operator is not called upon to perform calculations or to remember certain data. 3) Decompression can be conducted in small, closely-spaced stages, or even continually. The theoretical bases and the functioning of the instrument are described. (MEMH/UMS)

103.
DIETER, K.H.
On a mathematical theory of decompression.
IEEE Trans. Bio. Med. Eng. (BME) 14(2):124-146; 1967.

A theory is presented on the decompression procedure required after diving and on the accumulation of gases in the blood and in tissues during a dive. It is postulated that the decompression procedure must be such that at no time the partial pressure of the dissolved gases exceeds the external pressure. It is shown that the partial pressure of dissolved nitrogen is a weighted average of the external pressures to which the diver has been exposed previously. To make allowance for the partial pressure of dissolved oxygen, however, requires a more complicated formulation. A theory is in good agreement with published diving tables. (Author's summary) (© BA)

104.
DUFFNER, G.J. and H.H. Snider.
Effects of exposing men to compressed air and helium-oxygen mixtures for 12 hours at pressures of 2-2.6 atmospheres.
U.S. Navy Exp. Diving Unit Res. Rep. 1-59, vi + 14p. Sept. 18, 1958.

Five enlisted navy divers, age 21-34 years, were exposed for 12 hours in a recompression chamber to increasingly greater pressures until they contracted decompression sickness. The pressure in all cases was reduced at a rate of 25 ft. (11.12 lbs) per minutes. The exposures were performed first while breathing compressed air and then later 80% helium - 20% oxygen. Greater exposures were tolerated with the HeO_2 mixtures than with air. The differences amounted to pressures equivalent to 3, 4, 6, 10, and 14 ft. of sea water. (1 ft. = 0.445 p.s.i.) Data on helium elimination disclosed that a large fraction (over 50%) of the dissolved helium is contained in a tissue component which desaturates very rapidly (half-time 1.5 - 5 min.). The existence of a slow component (half-time 95-115 min.) appears likely. The use of helium-oxygen mixtures in mixed gas SCUBA and the utilization of a single mathematical expression to compute decompression stops are considered feasible. (Authors' abstract)

105.
DWYER, J.V.
Calculation of air decompression tables.
U.S. Navy Exp. Diving Unit Res. Rep. 4-56, 35p. Nov. 29, 1955.

This report presents the theory of air decompression in didactic form, including definitions, theory of exponential saturation, and theory of tissue ratios. The report provides a procedure for step-by-step calculation of decompression schedules, together with the necessary tables and worksheets. The discussion touches on other methods of calculation, on one use of this method, and on the probable validity of this method. The recommendations are for programming a computer and for using the report as a text. (Author's abstract) (LC/STD-Bull 9)

106.
DWYER, J.V.
Calculation of repetitive diving decompression tables.
Research Report 1-57, U.S. Navy Exp. Div. Unit, Washington, D.C. 1956.

Problem: Calculate suitable tables for repetitive dives. Findings: 1) Tables for 10, 60, 180, and 720-minute surface intervals have been calculated. 2) Suitability of these tables remains to be determined by test dives. 3) Certain aspects of the calculation procedure need improvement. Recommendations: 1) Test the 720-minute table. 2) Modify the calculation procedures to make the table adequate. 3) Find the satisfactory minimum number of repetitive tables. 4) Request certain specific modifications to the calculation procedure (6.2.0 (4)). (Author's summary)

107.
EATON, W.J.
Investigation into decompression tables. A practical approach to the evaluation of safe decompression procedures.
Rev. Physiol. Subaquatique Med. Hyperbare 2(1):8-15; 1970.

Following an air exposure to 160 feet for one hour and then decompression according to the U.S.N. standard decompression table for that exposure, some goats suffered decompression sickness. Using different decompression routines for the exposure to 160 feet for one hour, these same goats can be decompressed in substantially less time than that required by the U.S.N. decompression table. It is possible in some goats to provide a more dangerous situation by lengthening the decompression time following a "saturation" or "near-saturation" dive. It is suggested that these results are most simply explained by assuming that bubble growth is initiated at the moment of decompression. Attempts to limit the research for decompression profiles within the constraints of present biophysical frameworks are premature. (Author's abstract)

108.
EDEL, P.O.
Delineation of emergency surface decompression and treatment procedures for project Tektite aquanauts.
Aerosp. Med. 42:616-621; June 1971.

Project Tektite will require that four scientist-aquanauts live for two months in a habitat at a depth of 42 FSW in Lameshur Bay, St. John, Virgin Islands, during which time their breathing mixture will be 91% N_2-9% O_2. A series of experiments involving 12 test subjects was therefore conducted to determine to what degree of safety the scientists can make a "no-decompression" ascent to surface from the habitat, and the maximum surface decompression interval they can safely undergo. Recompression-decompression schedules were calculated for treatment of these subjects after their exposure to surface intervals of various lengths of time. All subjects were successfully treated according to these tables. A safe surface interval of 15 min and use of the recompression-decompression schedules that were developed as a result of this experimentation are recommended for incorporation into the Project Tektite operational procedures. (Author's abstract)

109.
EDEL, P.O.
Report on Project Hydrox II.
Harvey, Louisiana, Michel Lechler, Inc., Final Rep. on Contract N00014-73-0233, 76p. Aug. 15, 1974.

Since the world's supply of helium resources is diminishing, future deep diving operations may depend on substitutes for helium in breathing mixtures. On the basis of its physical constants, hydrogen would seem to be the most promising replacement for helium as an oxygen dilutant in breathing mixtures for human exposure to very high pressures. The experimental program involved four volunteer diver-subjects each of whom was exposed, on two separate occasions, to breathing mixtures of 97% H_2 - 3% O_2 and 97% N_2 - 3% O_2 at 7.06 atmospheres absolute (ATA) during an exposure period of 113 minutes for a total of 24 dives. Each subject was exposed to each breathing mixture during the program. During the exposures a work load was performed by the subjects and performance measurements were made.

In addition, blood and urine samples were collected, a mass spectrograph analysis was made of the divers' inspired and expired breath, speech studies were conducted, pulmonary function measurements were made, and a Doppler flowmeter was used to monitor the presence of bubble formation in the divers' blood stream during decompression. The subjects' responses to decompression profiles for the three oxygen dilutants were evaluated to provide provisional values with regard to hydrogen concerning uptake and elimination time for gas transport in the human body. (Author's abstract)

110.
ELINSKII, M.P.
Decompression disorders after exposure to 'safe pressure' or 'safe altitude.'
Voennomed. Zh.(7):60-63; July 1970.
(Translation U.K., Def. Res. Inform. Cent., DRIC-3035. Jan. 1973) (AD 756,263)

From experimental studies and clinical observations cited, it is clear that decompression starting from 2.25 atm abs or less and also ascents to an altitude of less than 8000 m may lead to the appearance of gas bubbles in the blood and sometimes cause severe decompression sickness. Such cases are probably not always spotted because of the widely held view that disorders do not occur with such pressure drops. The problem raised in this paper seems to be of practical importance because if decompression sickness may arise after exposure to a depth of 12.5 m, this points to the formation of gas bubbles large enough to cause embolism. From this it follows that uninterrupted ascent from these depths is not always harmless, particularly as 'occult' gas bubbles may be formed leading to subclinical forms of decompression sickness. In the second place saturation of the organism with nitrogen and other gases at a pressure of 2.25 atm abs may not be taken as an index of safe supersaturation, both now and hitherto calculations of tables for stepwise decompression are based on the assumption that a pressure drop in the ratio of 2.25:1 does not cause disease. It is possible that the need to reduce the factor with increasing depths is primarily due to a false concept of the complete safety of ascending from a depth of 12.5 m. (GRA)

111.
ELLIOTT, D.H.
Some factors in the evaluation of oxy-helium decompression schedules.
Aerosp. Med. 40:129-132; Feb. 1969.

For short dives when the diver has finished his task at the bottom well within saturation time it is obvious that the optimum decompression route back to the surface must take the minimal time compatible with the prophylaxis of decompression sickness. The current approach is to calculate, upon the basis of a suitable mathematical hypothesis, a series of decompression schedules for certain depths and durations of dive. Such Diving Tables are tested by a naval experimental diving unit and, if trials are successful, issued for general use. An analogue computer carried by the diver is no more than the instantaneous solution of the mathematical model for one particular occasion and, while it has a number of practical advantages over a series of tables printed in a manual, the decompressions of current models still require to be tested in the sea. (Author's abstract)

112.
ELLIOTT, D.H.
Man underwater. 3. His return to the surface.
Underwater Sci. Technol. J. 2:4-10; Mar. 1970.

The author explains the need to eliminate dissolved gas from the blood so that supersaturation will not cause bubbles to form which may damage tissue and cause decompression sickness. The no-stop curve (the line between safety and hazard in dives without decompression stops) is illustrated, plotted on time and depth. It is noted that this is not infallible for all individual cases. The diver may either ascend in stages, using stops, or ascend gradually; the first method is considered easier to control. Decompression schedules, while very useful, are also not infallible. It is recommended that a safety margin be used in utilizing tables. It is noted that in the case of oxy-helium tables, there are a greater number of variables than in compressed air tables; the chief of these is the percentage concentration of the constituent gases. The analogue compression computer is mentioned, and it is stated that this also does not guarantee safe decompression, since no allowance is made for individual differences. In tailoring a decompression schedule to the individual dive, factors such as the diver's age, his experience, the strenuousness of the work performed during the dive, and the water temperature must be considered. Saturation diving is explained, and it stated that decompression schedules for saturation dives are much easier to work out than those for individual dives of short duration. The problem of bone necrosis is mentioned, and it is stated that until some technique is developed for detecting bubble formation in bone, there is no way to satisfactorily assess the safety of the decompression tables in use; this form of decompression sickness, which can have very serious disabling consequences, does not manifest itself until months and even years have passed. Pulmonary barotrauma is described; this occurs usually after fast ascents, particularly if the diver holds his breath, and may be fatal. Also, gas may be trapped in the lungs by a plug of mucous, which can cause the same effect of forcing air bubbles into the bloodstream, and this mechanism occurs independently of any decompression schedule used. The problem of diagnosis is discussed, and it is emphasized that all symptoms should be assumed to be those of decompression sickness until proved otherwise. Treatment by recompression is discussed, and a method is recommended by which the diver is recompressed to 60 ft on compressed air, then given oxygen to breathe; if further recompression is needed, the atmosphere is changed to one of oxy-helium and recompression to the necessary depth for relief of symptoms is carried out. (MFW/BSCP)

113.
ELLIOTT, D.H.
The role of decompression inadequacy in aseptic bone necrosis of naval divers.
Proc. Roy. Soc. Med. 64:1278-1280; Dec. 1971.

As a result of analyzing the statistics revealed in a radiological survey of 305 naval divers, it is concluded that there is a positive relationship between the presence of radiological lesion and a history of decompression, also between positive lesion and experience of experimental diving with compressed air, and experimental deep diving with helium. ("Experimental" in this case refers to dives in which the decompression schedules used were not of proven adequacy.) (MFW/BSCP)

114.
ELLIOTT, D.H.
Incidence of osteonecrosis in Royal Naval divers.
In: Beckman, E.L. and D.H. Elliott, eds. Dysbarism-related osteonecrosis. Proceedings of a symposium on dysbaric osteonecrosis, Marine Biomedical Institute, University of Texas Medical Branch, Galveston, Texas, Feb. 1972, p.7-8. Washington, D.C., U.S. Department of Health, Education and Welfare, National Institute for Occupational Safety and Health, 1974.

The author gives a brief summary of the subject, going back historically to 1941, when K.T. Grutzmacher, in Germany, reported the first case of osteonecrosis in a diver. Surveys in the British Navy have revealed no cases of osteonecrosis in divers under 30, and 8% in those over 30. In Japan, there was found to be a 15% incidence in professional divers under 30, and a 76% incidence in those over 30. Adhering to conservative decompression procedures appears to be the surest method of controlling or preventing the disease. The highest incidence, 28%, was found in divers who had experienced decompression sickness while diving with helium-oxygen. (MFW/UMS)

115.
END, E.
Rapid decompression following inhalation of helium-oxygen mixtures under pressure.
Am. J. Physiol. 120(4):712-718; 1937.

1) After breathing a helium-oxygen mixture under pressure, two subjects have been uneventfully decompressed in less than one twenty-third of the time required when compressed air is breathed. 2) Attention is called to several possibilities of helium-oxygen mixtures as a substitute for compressed air for men working under increased pressures. (Author's summary)

116.
FAIRCHILD, E.J.
Role of the National Institute for Occupational Safety and Health.
In: Beckman, E.L. and D.H. Elliott, eds. Dysbarism-related osteonecrosis. Proceedings of a symposium on dysbaric osteonecrosis, Marine Biomedical Institute, University of Texas Medical Branch, Galveston, Texas, Feb. 1972. p.239-240. Wash., D.C., U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, 1974.

The question of the need for new decompression tables as a safeguard against osteonecrosis is brought up. It is felt that the Department of Labor could place a priority on the establishment of new decompression standards, as they have in the past adopted existing consensus standards with respect to other occupational hazards. The author recommends that the expertise of those present at this symposium be brought to bear toward the development of the best possible diving standards. (MFW/UMS)

117.
FARHI, L.E., W.T. Edwards and T. Homma.
Determination of dissolved N_2 in blood by gas chromatography and (a-A)N_2 difference.
J. Appl. Physiol. 18:97-106; 1963.

By combining vacuum extraction in a Van Slyke chamber and separation of the extracted gases in a gas chromatograph, it is possible to determine N_2 content of 1.5 ml of blood or other biological fluids in less than 10 min. The 95% confidence limits are 0.44% on either side of the mean of the triplicate analysis—or 2.4 mm PN_2 in arterial blood when breathing room air. Application of the method to the problem of arterial-alveolar N_2 difference yielded the following data: 1) N_2 solubility in whole blood at 37.3 C varied from 0.0125 to 0.0129; 2) N_2 solubility in urine is inversely related to urine specific gravity, confirming Klocke and Rahn's data; 3) changes in arterial N_2 content were reflected in arm superficial venous blood and urine N_2 only after a considerable period of time, indicating that either of these will give an excellent indication of the mean PN_2 over a period of time; 4) there is no systematic difference between venous blood and urine PN_2; 5) the (a-A)N_2 difference in nine normal subjects varied from 3.7 to 13.1 mm Hg. (Authors' abstract)

118.
FELD, J.N. and C.J. Lambertsen.
Optimal choice of inert gases to be breathed for minimum-time decompression scheduling.
In: Aerospace Medical Association. 1972 annual scientific meeting, Bal Harbour, Florida, May 1972. Preprints, p.220. Published by the Association.

The time required for decompression after exposure to elevated pressures depends on the properties of the inspired inert gases. It is possible to safely reduce the required decompression time by purposely alternating inert gases and/or using mixtures of inert gases in the breathing media. A flexible computerized program has been developed for calculating decompression schedules of varying inspired breathing gas compositions. The inert gas pattern to be breathed throughout the dive can consist of several inert gas mixtures. By employing mathematical optimization techniques, the amount of time to breathe each of these mixtures and the composition of these mixtures can be optimally chosen so as to minimize decompression time without violating physiological constraints. (Author)

119.
FIFE, W.P.
Professor Hills' amazing decompression breakthrough.
In: National Association of Underwater Instructors. Proceedings of the sixth international conference on underwater education, October 1974, San Diego, Calif. p.159-167. Published by the Association, 1975.

Haldane built his decompression tables on the theory that one should decrease the pressure on the body as much as possible in order to get rid of the dissolved gas. If his equation showed dissolved gas up to 4 ata, he should ascend to 2 ata and remain until his equation told him the tissue had only 2 ata pressure. Current thinking is that bubble "seeds" are in the body at all times, in which case, bubbles would

would develop long before the diver reached the first stop. Therefore, by the old concept, decompression tables really constituted treatment tables that treated decompression sickness acquired on ascent to the first stop. The author has attempted to develop tables with deeper stops, shorter stops near the surface, and shorter total decompression time. Often the 10-foot stop is eliminated entirely. For example, a diver who goes to 100 FSW for three hours decompresses in 98 minutes by the author's table, and in 203 minutes by the U.S.N. tables. The Navy table's first stop is at 40 feet, while the Fife table shows short stops at 80, 70, and 60 feet, and one of 20 minutes at 50 feet. Although they have been tested on pigs and on men, these tables are still in the experimental stage. (MFW/UMS)

120.
FIFE, W.P., M.J. Mezzino and R. Naylor.
Development and operational validation of accelerated decompression tables.
In: Shilling, C.W. and M.W. Beckett, eds. Underwater physiology VI. Proceedings of the sixth symposium on underwater physiology, p.359-366. Bethesda, Md., Federation of American Societies for Experimental Biology, 1978.

It now seems clear that asymptomatic bubbles appear in the body long before the diver reaches the first decompression stop called for by the U.S. Navy schedules. If these bubbles do, indeed, appear, then it would seem logical that long ascents to shallow first stops would not be desirable. In fact, quite the opposite would be true. We have tested this in the following manner. We first developed conventional tables in which about 50% of our animals suffered bends. We then arbitrarily removed time from the shallow stops, placing it at deeper stops. When we found these profiles free of bends we removed time from the shallow stops without adding it to deeper stops. We were, thus, able to reduce by nearly 50% the total decompression time shown in the Navy Exceptional Exposure tables for the same bottom time. In our initial tables we allowed an ascent of no more than 60 feet between stops. Using computers we now have constructed a family of decompression profiles which follow this concept. These initially were tested on the standard commercial pig which was our animal model. When we obtained a clean, no-bend profile on the pig, a similar profile was tried on man. In no instance have we had bends appear in man if the pig showed no symptoms. Our tables now have been in commercial use on more than 1000 operational dives with both air and heliox. The deepest dives have been to 410 feet for 30 minutes. Decompression time for this profile is approximately 425 minutes. In general it appears to us that divers using these new tables complain less of fatigue than when using previous profiles. (From Sixth symposium program and abstracts)

121.
FLEMMING, N.C.
Operational diving with oxy-helium self-contained diving apparatus.
In: Lythgoe, J.N. and J.D. Woods, eds. Symposium of the Underwater Association for Malta 1965, p.3-13. Published by the Association, n.d.

This report describes geological diving work started in spring 1964, the problems which were encountered resulting from nitrogen narcosis, and the development of self-contained oxy-helium partial recirculation equipment to solve the problems. Decompression tables for dives of 15 minutes at 100, 125, 150, 175 and 200-ft were evolved and tested successfully at sea with no bends in 35 sea dives. Psychological tests showed that the divers performed significantly better on oxy-helium at 200-ft than on air at the same depth. Use of the oxy-helium sets at 175-ft in the English Channel enabled the completion of the geological research whixh had not been completed on air. (Author's summary)

122.
FREITAG, M. and R.W. Hamilton, Jr.
Comparison of U.S. Navy air decompression tables by gas-loading analysis.
Undersea Biomed. Res. 1:175-179; June 1974.

A gas-loading comparison has been made between the U.S. Navy standard air decompression tables and the surface decompression tables using either oxygen or air. The results of these comparisons between the same depth-time schedules show that in all cases, for the compartment half-times used, the gas loadings at the end of the surface decompression with oxygen tables are less than or equal to those of the standard air decompression table. A similar comparison between the surface decompression with air decompression in this range these positive gas tensions can be avoided, and thus the bends could be circumvented. Problems occurred in using this method to depths beyond 130 m. At a 150 m/30-min-dive bends appeared three hours after decompression; a recompression to 162 m had to be applied. An analysis of the gas tensions indicates a too long exposure to overtensions during the first steps, the effect of which could not be counterbalanced by any treatment at lower depths. Indications were that a decompression schedule no longer can be constructed alone by controlling the values of the gas tensions in the compartments by M-values. The history of a compartment and especially the duration of exposure to overtensions become important. On the basis of these ideas new decompression schedules in the range of 150-200 m are proposed. (Authors' abstract)

128.
GILLIS, M.F.

Research on deep submergence diving physiology and decompression technology utilizing swine: evaluation of swine as a hyperbaric analog to man and detection of emboli by use of the ultrasonic doppler flowmeter.

Richland, Wash. Battelle Mem. Inst., Tech. Prog. Rep. on Contract N00014-69-C-0350, 25p. July 6, 1970. (AD 708,748)

Sixteen miniature swine of similar size performed 83 dry chamber air dives, using no-stage profiles with linear ascent and descent rates of 60 ft/min depths of 60 to 180 ft and bottom times up to 120 min. Surface intervals always exceed 48 hr. Signs considered diagnostic of bends were lameness, persisting for 15 minutes or more and relieved by recompression, and/or acute, progressive respiratory distress, and/or central neurologic signs, e.g. paralysis. Bends was not observed at 60 ft with bottom times up to 120 min; a 60% incidence was recorded for 1400 ft/60 min and a 16% incidence for 180 ft/20 min. Doppler flowmeter studies have shown that individual glass microballoons of 80-150 micra diameter are easily detectable in the thoracic caudal vena cava, and that 40 micra balloons, while difficult to detect individually, are easily detected when injected in large quantities. Severe caval air embolism has been recorded following 180 ft/15 min excursions without bends signs, confirming that significant gas embolism can exist in the absence of such signs and showing the value of the Doppler flowmeter for embolism detection. (Author's abstract) (Aerosp. Med. Biol.)

129.
GILLIS, M.F.

Research on deep submergence diving physiology and decompression technology utilizing swine: evaluation of swine as a hyperbaric analog to man and detection of emboli by use of the ultrasonic doppler flowmeter.

Richland, Wash. Battelle Mem. Inst. Final Report, 50p., May 20, 1971. (AD 724,765)

Attempts to define the no-decompression air limits for miniature swine were complicated by individual variance and bends tolerance development, but based solely on clinical signs, they appear more resistant to bends than man except perhaps at depths beyond 140 feet. Although 100 feet/90 minutes, 140 feet/60 minutes and 180 feet/30 minutes produces an 80% incidence of bends, they generally tolerate dives from 60 to 180 feet for bottom times three times greater than the no-decompression limits for man. Temporary signs of middle ear distress are seen almost exclusively on ascent. (Author's abstract) (GRA)

130.
GIVEN, R.R., V.M. Pilmanis, B.E. Bassett and A.A. Pilmanis.

A feasibility study of a temperate shallow-water habitat site off Santa Catalina Island, California.

HYDRO-LAB J. 3:114-124; 1975.

A 350-min experimental dive was made in temperate waters off Catalina Island, California, in order to 1) define thermal limitations of long-duration scientific diving and 2) to conduct a biological survey of a proposed underwater habitat site. Since no satisfactory decompression tables for such an extended and specialized dive profile was calculated and used, safety of the dive profile was reinforced by use of in vivo underwater ultrasonic bubble detection. Body core temperature, subjective thermal sensation and performance in the biological survey were used to define extent of thermal stress. The results were compared to results of similar thermal studies performed in tropical waters around HYDRO-LAB. It was concluded from results that 1) the nonstandard decompression profile was useful and safe, 2) the customfitted wet suit used provided adequate thermal protection for long-duration dives in temperate waters, and 3) from the standpoint of marine biology, the proposed habitat site affords excellent potential. (Authors' summary)

131.
GOLDING, F.C., P.D. Griffiths, H.V. Hempleman, W.D. Paton and D.N. Walder.
Decompression sickness during construction of the Dartford Tunnel.
Br. J. Ind. Med. 17:167-180; 1960.

A clinical, radiological and statistical survey has been made of decompression sickness during the construction of the Dartford Tunnel. Over a period of two years, 1,200 men were employed on 8-hour shifts at pressures up to 28 pounds per square inch (psi). There were 689 cases of decompression sickness out of 122,000 compressions, an incidence of 0.56%. The majority of cases (94.9%) were simple "bends." The remainder (5.1%) exhibited signs and symptoms other than pain and were more serious. All cases were successfully treated and no fatality or permanent disability occurred. In two serious cases, cysts in the lungs were discovered. It is suggested that these gave rise to air embolism when the subjects were decompressed and pulmonary changes may contribute more than hitherto believed to the pathogenesis of bends. Some other clinical features are described, including "skin-mottling" and an association between bends and the site of an injury. The bends rate is higher for the back shift (3 p.m.-11 p.m.) and in the night shift (11 p.m.-7 a.m.) than for the day shift. In the treatment of decompression sickness it appears to be more satisfactory to use the minimum pressure required for relief of symptoms followed by slow decompression with occasional "soaks," than to attempt to drive the causative bubbles into solution with high pressures. During the contract the decompression tables recently prescribed by the Ministry of Labour were used. Evidence was obtained that they could be made safer, and that the two main assumptions on which they are based (that sickness will not occur at pressures below 18 psi, and that a man saturates in four hours) may be incorrect. It is desirable to test tables based on 15 psi and 8-hour saturation. The existence of acclimatization to pressure was confirmed; it is such that the bends rate may fall in two to three weeks to 0.1% of the incidence on the first day of exposure. Acclimatization is lost again, with a "half-time" of about seven days, if a man is away from work. A study of bone damage in compressed air work has been started. In certain radiographs abnormalities have been seen which may represent an early stage of caisson disease of bone. (Authors' abstract)

132.
GOODMAN, M.W.
Living and working within earth's oceans.
New York J. Med. 70:1181-1194; May 15, 1970.

An excellent review of historical and research aspects of man under the sea with 48 references to the literature. The material was presented under the following headings: Employment of man-in-the-sea; Sea water as an environment for man and his machines; Problems related to ventilatory dynamics; Oxygen in diving; Narcosis, performance decrement, and introduction of oxyhelium in diving; Decompression and saturation diving: "you only pay when you leave"; Engineering problems of deep diving and high-pressure helium atmospheres; Closed-circuit mixed-gas breathing apparatus: diving systems and "hardware": Submersibles; and Science and capabilities–the possible and practical. (CWS/BSCP)

133.
GORANSON, A., C. Lundgren and G. Lundin.
A theoretical model for the computation of decompression tables for divers.
Nature 199:384-385; July 27, 1963.

Thirty years ago the abstractor of this short article did the early work on different histological types of tissues as representing different elimination rates for the calculation of safe decompression after a prolonged stay under high pressure. The authors of this article "present a more fruitful approach to the problems of inert-gas exchange" in that they consider the body as composed of an unlimited or very large number of fractions as regards nitrogen-elimination rates and have set up an elaborate formula, requiring a computer to calculate, for determining each individual decompression. (CWS/BSCP) schedules and the standard air tables showed 25 schedules following surface decompression using air in which at least one compartment had a final gas loading greater than the same compartment for the same depth-time schedule using the standard air tables. It seems reasonable that the repetitive procedures designed for the standard air tables can be used with surface decompression tables in all cases where surface decompression is done with oxygen and in certain cases where air is used. (Authors' abstract)

123.
FRUCTUS, P.
Aspects medicaux de la plongee profonde a saturation. These.
[Medical aspects of the deep saturation dive].
Marseilles, Faculte Mixte de Medecine et de Pharmacie de Marseille, 1968. 92p.

The author first reviews hyperbaric physiology, discusses the physico-chemical properties of gas under pressure, then analyzes the experiment called Ludion II, which was carried out by two groups of divers, one which lived at 9.5 ata, and the other of which worked 4 hours a day at 13 ata. The divers were under surveillance at all times, at work and at rest. No significant physiological changes were apparent, and no undue nervous or physical fatigue resulted. All tests indicated that the organism adapted well. However, future investigators are urged to concentrate on several problems: the stress of conditioning; the narcosis that appears at 300 meters, even with use of helium; the phenomena of agitation connected with the chemical properties of inert gas; the increase of density of breathing mixtures at high pressures, which brings about a diminution of the respiratory output. It is noted that decompression schedules are still hypothetically based, and that the exact nature of the behavior of gas in the tissues is still unknown. The harmlessness of the underwater environment is not completely assured, since experiments so far have been of short duration, and tests too imperfectly codified. (MFW/BSCP from author's conclusions)

124.
FRUCTUS, X.
Generalites sur l'operation Janus II.
[General observations on the operation Janus II].
Bull. Medsubhyp. 4:17-18; Dec. 1970.

This operation involved two teams of three divers each in saturation dives at 200 m with excursion-work at 250 m according to the "Ludion" procedure, April-Sept. 1970. The operation was in two parts: 1) preliminary laboratory physiological and technical studies, and 2) a marine party with a labor force and daily work of three men at 250 m for eight hours. Part 1, among other results, confirmed the traumatizing effect of rapid pressurizations and defined a curve of compression for saturations at great depths; produced a new procedure of decompression which is faster and more comfortable than those previously used; controlled the tolerance of submarine workers at pressures of 21 and 26 ATA under helium at PiO_2 of 420 and 520 mb; posed bacterial and mycotic problems with attempts at solution; delivered protective equipment against heat loss of divers in immersion at great depths, in particular by reheating inhaled gases. Part 2 benefited from good marine conditions, found in the Bay of Ajaccio which met the conditions of 250 m depth in a region where the surface equipment could be assured of a sure anchorage, sheltered from strong winds and near enough to the coast for logistical support. Description of equipment and position and of the individual divers is given. The open sea operations (eight working days at 830') demonstrated that even in the Mediterranean, where mean submarine temperature is about 13°C, efficient work is possible only when the divers are protected by heated undergarments and breathing mixtures preheated to 38°C. The work performed comprised applied petroleum practices. The divers demonstrated that soldering and cutting were feasible and could be done at 250 m of depth. Fatigue was felt on the fifth working day; a rest period on the morning of the sixth gave them their "second breath." The operation totaled 26 hours of underwater time in the submarine turret [bell] at depth, with 16 hours 56 min of work by one diver and 17 hours 40 min by the other; 13 dives were made, averaging two hours per stay in the turret and two hours 40 min of work per dive. The apparatus for protection against the cold, in spite of some defects in the prototypes, constituted the major element of the technique developed (MFW/BSCP)

125.
FRYER, D.I.
Evolution of concepts in the etiology of bends.
Aerosp. Med. 39:1058-1061; Oct. 1968.

The author gives a brief resume of the history of man's understanding of decompression sickness, going back to Robert Boyle, in 1660, who first inquired into the possible value of experimental variations of atmospheric pressure; he mentions early and infrequent use of diving bells and diving suits from the 17th century up to the time of the Industrial Revolution, when technical progress made possible the use of altered atmospheric pressure in therapy and of compressed air as an aid to underground workers. Some of the numerous theories on the cause of decompression sickness put forward during the 19th century are described, with emphasis on the crucial work of Paul Bert, considered the founder of modern understanding of the subject. Bert was convinced that the underlying mechanism of supersaturated blood was gaseous embolism following the feeling of gas bubbles; he made specific recommendations concerning minimum decompression periods. The tendency, during the 19th century of the practicing medical profession to lag behind the physiologists in the understanding of decompression sickness is noted. Credit for clarifying the general confusion of ideas is given to Haldane, Boycott and Dumant, upon whose 1907 report the entire modern system of regulation of compressed air and diving practices is founded. Advanced post-war developments noted include multiple (as opposed to single) decompression ratios, the importance of the extra-vascular bubble, and the complication of decompression tables caused by the use of new gas combinations. In recent years, one basically new idea put forth by D.N. Waldon and his associates is that some cases of presumed decompression sickness might in fact be of pulmonary barotraumatic origin; another, from Le Messurier and Hills in Australia, concerns the discrepancy between the sum of gas partial pressures and total ambient pressures, which applies to the body mass, from which concept they have proposed an entirely new basis of calculation of ascent procedures aimed at the avoidance of supersaturation. (MFW/BSCP)

126.
FULTON, J.F.

Decompression sickness. Caisson sickness, diver's and flier's bends and related syndromes. W.B. Saunders Company, Philadelphia and London. pp.438, 1951.

This book is of interest from a historical standpoint. The contents are indicated by the chapter headings: I. Historical Introduction, John F. Fulton; II. The Clinical Nature of High Altitude Decompression Sickness, Eugene B. Ferris, Jr., and George L. Engel. With a note on Psychologic Reactions by John Romano; III. Decompression Sickness following Exposure to High Pressures, Albert R. Behnke; IV. Physical Factors in Bubble Formation, E. Newton Harvey; V. Animal Experiments on Bubble Formation, Part I. Bubble Formation in Cats, E. Newton Harvey, Part II. Bubble Formation in Frogs and Rats, L.A. Blinks, V.C. Twitty and D.M. Whitaker; VI. Decompression Sickness: Physical Factors and Pathologic Consequences, Isidore Gersh and Hubert Catchpole; VII. Constitutional Factors Affecting Susceptibility to Decompression Sickness, John S. Gray; VIII. Environmental Factors Affecting Decompression Sickness, Part I, A Physical Theory of Decompression Sickness, Leslie F. Nims, Part II. Role of Exercise, Temperature, Drugs and Water Balance in Decompression Sickness, S.F. Cook; IX. Preoxygenation and Nitrogen Elimination, Part I. Review of Data on Value of Preoxygenation in Prevention of Decompression Sickness, J.B. Bateman, Part II. Gas Exchange and Blood-Tissue Perfusion Factors in Various Body Tissues, Hardin B. Jones; X. Preselection Tests, Franklin M. Henry and A.C. Ivy; XI. Decompression Sickness in Actual Flights, C.A. Tobias; XII. Explosive Decompression, Fred A. Hitchcock; Addendum, Robert B. Livingston. (CWS/UMS)

127.
FUST, H.D., K.G. Muller, H. Oser and S. Ruff.

Development of decompression tables for short term 100-200 meter dives.

In: Hesser, C.M. and D. Linnarsson, eds. Proceedings of the first annual scientific meeting of the European Undersea Biomedical Society, Stockholm, 13-15 June 1973. Forsvarsmedicin 9:502-506; July 1973.

[An M-value is the maximum value of the partial pressure of dissolved inert gas which can be tolerated in specific compartments of the human body and will permit the diver safely to ascend to the next stop.] The main features of these tables, based on Workman's M-values, were a rather fast initial decompression with overtensions up to 35 m and a slow decompression in the range of depths between 20-0 m. The analysis of the gas tensions at 130 m/60 min-dives showed the following: Some compartments had been exposed to medium overtensions during the first steps; later on the overtensions became negative. During unsuccessful dives they became positive again in the range of depths between 15-0 m. This was correlated with the occurrence of bends. A possible explanation is the formation of a silent bubble produced in the beginning of the decompression which grows to a critical size at 15-0 m. By a slower

134.
GOTOH, Y. and I. Nashimoto.
[Decompression bubbles in caisson workers].
Jap. J. Hyg. 32:529-533; Oct. 1977.

A total of 152 precordial detections of decompression bubbles was carried out in 91 caisson workers with the Doppler Ultrasonic Bubble Detector. The results were as follows: 1) Most of the bubble signals appeared and attained to their maximum grade within 60 minutes after decompression. 2) The appearance or increase of blood bubbles was accelerated by clenching the fist or raising arms above the shoulder height. Many workers, however, dislike these movements for fear of suffering from decompression sickness. 3) Of 152 detections, bubble signals were heard in 88 (58%). They were heard in all cases of decompression sickness which required treatment (13 bends and 3 chokes). On the other hand, 48 cases with bubble signals were asymptomatic. 4) The occurrence and grade of decompression bubble signals at successive jobs seemed to depend on the decompression schedules. (Authors' abstract)

135.
GRAVER, D.
A decompression table procedure for multi-level diving.
In: Proceedings of the Eighth International Conference on Underwater Education, Nov. 1976, San Diego, Calif., p.126-131. Colton, Calif., National Association of Underwater Instructors, 1976.

The sport diving community is unfairly penalized when using the U.S. Navy decompression tables for multi-level diving. A new procedure for using the standard tables without the penalty involved has been developed from a variation of table procedures after investigation into an article on multi-level diving which used new tables. The new procedure has been mathematically verified. Further information is requested to confirm the validity of the new technique. (Author's abstract)

136.
GRAVER, D.
Multi-level decompression table procedure update.
In: Proceedings of the Ninth International Conference on Underwater Education, p.91-96. Colton, CA, National Association of Underwater Instructors, 1977.

The idea of multi-level diving without being penalized for the deepest depth for the entire dive, was put forward by C.L. Smith, who also proposed new tables to be used for the procedure. The tables lacked the credibility of the Navy tables, however, By combining this idea with the procedure for obtaining residual nitrogen time for shallow dives by determining the equivalent bottom time from the no-decompression table, it is possible to develop the multi-level procedure using the standard U.S. Navy tables. The diver must figure his repetitive group for a time and depth whenever he changes depth during a dive, then use that designation to obtain an equivalent bottom time for a new depth. This method had been used in commercial diving, unbeknownst to the author, but was new to sport diving. Dr. Bruce Bassett has validated the procedure through his own calculations, and Dr. Robert Workman says that one can use U.S. Navy table 1-13 to get equivalent bottom times at depths from 40 to 190 feet. Since this technique was first described at $1Q_8$, numerous instructors and divers have verified the procedure. The Duke University Medical Center Hyperbaric Unit is seeking funding to carry out studies to obtain scientific confirmation. If this can be done, the procedure can be published and recommended for sport divers. (MFW/UMS)

136.a
GRAY, J.S.
Prevention of aeroembolism by denitrogenization procedures.
National Research Council. Report 123 on Aviation medicine. 1942.

Conclusions: 1) Breathing 100% oxygen for 45 minutes before a 2 hour flight at 38,000 in an altitude chamber markedly reduced the incidence of severe symptoms of aeroembolism (from 30.3% to 5.8%) in aviation cadets and slightly reduced the incidence of mild symptoms (from 32.3% to 28.8%). 2) Breathing 100% oxygen was most effective in preventing symptoms of bends and chokes and had comparatively little effect on gas pains. 3) The inclusion of exercise for the first ½ hour of the 45 minute periods of breathing oxygen exerted no additional protective effect.

137.
GREENE, K.M., R.E. Peterson and C.J. Lambertsen.
Decompression from saturation exposures.
In: Lambertsen, C.J., R. Gelfand and J.M. Clark. Predictive Studies IV. Work capability and physiological effects in He-O_2 excursions to pressures of 400-800-1200 and 1600 feet of sea water, p.G2-1 - G2-18. Philadelphia, Pa., Univ. Pennsylvania Med. Cent., Inst. Environ. Med., 1978.

The major considerations involved in choosing the approach to decompression from saturation exposures in this program included selection of ascent rates, use of nitrogen-oxygen (air) breathing to speed helium elimination, and use of oxygen on approaching atmospheric pressure to speed all inert gas elimination. Since decompression sickness has occurred principally at shallow depths, following both relatively slow and rapid deep saturation-decompressions, it was decided to pause for 24 hours at 200 fsw, a pressure slightly greater than the zone within which saturation-decompression DCS is common. It was expected that this maneuver would allow resolution of asymptomatic bubbles and elimination of excess dissolved gas. Decompression could then be resumed with what was expected to be a risk of decompression sickness closer to that associated with shallower saturation-decompression. The slow, essentially linear decompression pattern of ascent rates followed by the U.S. Navy schedule was not selected, since this method was no more effective than faster procedures in preventing bends in its single trial deeper than 1000 fsw. Most other schedules employed to date begin decompression with a relatively rapid rate which is decreased significantly during ascent. This approach, which was derived empirically in U.S. Navy trials, relates to the general concept that the diver's tolerance to excess inert gas (ΔP) increases with exposure depth. This concept was used for the design of the excursion-decompression schedule for this Predictive Study and was also employed as the basis for computation of these saturation-decompressions. (Authors)

138.
GRIFFITHS, H.B., K.W. Miller, W.D.M. Patib and E.B. Smith.
On the role of separated gas in decompression procedures.
Proc. Roy. Soc. (Biol):178(1053):389-406; 1971.

Experiments were made on the incidence and time of onset of decompression sickness in mice exposed in single or repeated exposures to raised pressures of N_2 or He. If a first (conditioning) exposure to pressure is followed five min later by a second (test) exposure, the incidence of sickness is considerably higher than that for either exposure alone, or for a single exposure equal in length to the sum of the other two exposures. The same result is obtained if the conditioning exposure is to saturation. Sickness produced by repeated exposures has a shorter latency of onset than after single exposures. These results are explicable on the basis of asymptomatic bubble formation after decompression. This latent susceptibility to decompression sickness initially increases with time after decompression, reaches a maximum, and then declines. The rate of decline is faster than can be accounted for on the basis of the decay and local reabsorption of bubbles. Gas bubbles may be also removed by passage from the tissues through the venous system to the lungs. The degree to which very short second exposures to pressure (lasting only a few seconds) give rise to the symptoms of decompression sickness cannot be explained on the basis of the kinetics of bubble growth. These symptoms could also arise from compression by the second exposure of bubbles in the tissues, allowing them to enter the venous system and pass to the lungs, where, if expanded by decompression before elimination, they give rise to severe decompression sickness. These observations are in direct conflict with the principles on which current decompression tables are based. The relative success of the latter must be attributed to the empirical manner in which the tables were constructed and modified in the light of experience. The theory that separated gas may be present in symptomless decompressions is supported and the question of gas transport to the lungs as a factor which should be taken into account in the design of decompression tables is discussed. (© BA)

139.

GROOM, A.C., R. Morin and L.E. Farhi.

Determination of dissolved N_2 in blood and investigation of N_2 in blood and investigation of N_2 washout from the body.

J. Appl. Physiol. 23:706-712; 1967.

The magnitude of the N_2 store of the body and the exchange of N_2 between the body and its environment were investigated in anesthetized dogs, breathing 100% O_2, in the absence of cutaneous transfer of N_2 from the atmosphere. For this study, the concentrations of dissolved N_2 in mixed venous and arterial blood were measured at various times after the start of O_2 breathing. Since the results presented are critically dependent on an adequate (and heretofore unavailable) method of analysis, the latter, which allows the measurement of low N_2 concentrations with an accuracy equivalent to ± 1.0 mm PN_2, is described in detail. The kinetics of N_2 washout were equivalent to those from a simple three-compartment model. The "compartments," representing 69.1, 23.5, and 7.4% of the total N_2 store, gave desaturation half-times of 117, 13.5, and roughly 1.5 min, respectively, equivalent to perfusion by 8.7, 24.8, and 66.5% of the cardiac output. The total N_2 store of the body was 22.5 ± 3.1 (SE) ml N_2 (STPD) $\cdot$ kg^{-1}. (Authors' abstract)

140.

GROSSMAN, R. and H. Kucher.

The application of computers to decompression problems of mixed gas scuba diving.

In: Flemming, N.C., Ed. Science diving international. Proceedings of the 3rd scientific symposium of CMAS, p.174-178. London, British Sub Aqua Club, 1973.

The purpose of this presentation is to review the computational aspects of decompression from particular air dives (e.g. repetitive diving, diving at altitude, and saturation excursion diving), and more especially from mixed gas Scuba diving. In the first section some decompression programs are described and results presented. The second section is devoted to a mathematical analysis of modern mixed gas techniques. Special attention is paid to the function of semi-closed rebreathing sets (that is, to the settings of the pressure-reducing valves and gas flow jets), and to the variability and stability of breathing mixtures and correct mixture flow rates. Complete computing algorithms for decompression calculations are presented in the third section in the form of ALGOL-60 procedures. The details of the decompression calculation program for constant-flow and variable-flow mixed gas devices are analyzed. In the final section some new mathematical statements for Haldane coefficients depending on tissue half-times and tissue inert gas tensions have been made. These statements produce nonlinear differential equations for the calculation of ascent profiles after saturation exposures. (Authors' abstract)

141.

HALL, A.L. and R.D. Galvin.

Technical notes. Effects of temperature manipulation and alteration of inert gases during decompression.

Aerosp. Med. 40:434-435; Apr. 1969.

Control of temperature during decompression introduces a significant change in the production of the bends. Addition of nitrogen or argon to the ambient atmosphere drastically increases the incidence of bends during decompression. (Authors' summary)

142.

HALL, P.

The miniature pig as a model for the study of decompression.

In: Aerospace Medical Association. 1972 annual scientific meeting, Bal Harbour, Florida, May 1972. Preprints, p.221-222. Published by the Association.

Diving for work or sport is increasing rapidly in the mountains of the western U.S. In the central Rocky Mountain region the only readily available decompression tables are the U.S. Navy sea-level tables and a theoretical table which uses a Boyle's Law factor to convert depths at altitude to "equivalent" depths below sea-level. This table is set out so that for any depth at any altitude up to 10,000 ft. one can enter the U.S. Navy tables at the calculated equivalent deeper depth and decompress for the indicated times at

the calculated shallower stops. The concept of a proportionality factor which would enable the diver at altitude to use established sea-level decompression tables is very attractive. This simple application of Boyle's Law might seem to be the obvious first approach, but the resulting theoretical table has not been rigorously checked. The author did preliminary testing on the miniature pig, chosen as a model because of its many physiological similarities to man. There is a growing need to develop a set of acceptable air decompression tables for altitude divers. In view of the hazards of decompression at altitude, the miniature pig should be a useful tool in the development of such tables. (Author)

143.
HAMILTON, R.W., Jr., J.B. MacInnis, A.D. Noble and H.R. Schreiner.
Saturation diving at 650 feet.
Ocean Systems Technical Memorandum B-411, Tonawanda, New York, 1966. 192p. and 3 appendices.

Ocean Systems, Inc. has conducted the deepest, longest chamber dive on record. Two divers, Arthur D. Noble and Robert W. Christensen attained an equivalent depth of 650 feet for 48 hours and two minutes. This dive was conducted between August 6 and 14, 1965 at Ocean Systems' Diving Research Facility at Tonawanda, New York, in an effort to demonstrate for the first time that man can function for extended periods of time at the pressure prevailing at the deep boundary of the continental shelf. Detailed medical, physiological and psychological measurements taken in the course of this dive show beyond a reasonable doubt that man can reside for prolonged periods of time anywhere on the continental shelf without acute or latent detriment to his health and without a significant impairment of his functionality. The ultimate physiologic and psychologic depth limit of man's existence in the sea remains to be determined in future experimentation. (Authors' summary)

144.
HAMILTON, R.W., Jr. and H.R. Schreiner.
Putting and keeping man in the sea.
Chem. Eng. 75:263-270; June 17, 1968.

This is a concise survey of the problems of man-in-the-sea. Breathing problems are explained as follows: Oxygen partial pressure must be reduced as the depth increases; nitrogen has a narcotic effect, and helium disrupts vocal communication and has a severe cooling effect; neon, though very heavy, may be practicable for future use, in combination with helium; hydrogen is being studied. Fire is an ever-present hazard in pressure chambers because of the increased combustibility of most fabrics under high pressure. Supplying heat in waters of below 50°F constitutes a problem that has not been satisfactorily solved. Fungus infections result from excessive humidity in underwater habitats; means of controlling this are briefly discussed. Poor visibility due to darkness and turbidity makes underwater work difficult, and the work area sometimes impossible. Portable chambers, filled with clear water, placed over the work area, are possibly practicable. Special tools for use underwater have been developed; they are operated by cryogenic gas, which may do double duty as a breathing mixture. A new welding technique that involves fitting a chamber over the pipe has been developed, and is workable at 600 feet; the maintenance of a nontoxic atmosphere is a chief difficulty here. Decompression techniques, and the question of using oxygen to speed up decompression, are discussed. Current decompression tables are only good for up to 400 feet depth at ½ hour; new procedures are being developed. Various types of "one atmosphere" research submersibles are described. To solve all the existing problems that stand in the way of effective exploitation of the undersea environment, the authors state, numerous disciplines must cooperate; these include many branches of medical science, equipment engineering, mathematics, biochemistry and pharmacology. (MFW/BSCP)

145.
HAMILTON, R.W., Jr., D.J. Kenyon, M. Freitag and H.R. Schreiner.
NOAA OPS I and II: Formulation of excursion procedures for shallow undersea habitats.
Tarrytown, N.Y., Union Carbide Tech. Cent., Environ. Physiol. Lab., Rep. UCRI 731, 179p. July 31, 1973.

This is a report on operational experiments whose purpose it is to develop and refine procedures for working from a shallow habitat. The program was 1) to construct a matrix of ascent-limiting M-values based on several hundred diversified dive logs, 2) to compute no-stop excursion limits for various times and depths (both ascending and descending), and 3) to verify the resulting tables. [An M-value is the maximum value of the partial pressure of dissolved inert gas which can be tolerated in specific compartments of the human body and will permit the diver safely to ascend 10 ft to the next stop.] The authors devised an efficient method for extracting and utilizing data from previous dives, using a combination of computer and manual methods. Tables were computed using the new matrix and the decompression model which in this case comprises 11 gas loading compartments; the longest limiting half-time used was 480 minutes. Three subjects in two 14-day dry chamber experiments tested this matrix in twice-daily excursions from normoxic saturation at 30, 60, 90 and 120 fsw, and ascents ranged from 30 to 65 fsw above the habitat depth; excursion times ranged from 8 minutes to 6 hours. Air was breathed on excursions. Results show that this approach produced highly successful tables on the first attempt. Extensive physiological experimentation and medical surveillance was conducted in cooperation with researchers from the U.S. Naval Submarine Medical Research Laboratory. Among the findings was the demonstration that habituation at 90 fsw provides relief from narcosis when subjects are subsequently exposed to 250 fsw of air. (Authors' abstract)

146.
HAMILTON, R.W., Jr., D.J. Kenyon, H.R. Schreiner and P.O. Edel.
Computation and testing of no-stop decompression procedures for use from saturation in a nitrogen-oxygen habitat.
In: Aerospace Medical Association. 1973 annual scientific meeting, Las Vegas, Nevada, May 1973. Preprints, p.239-240. Published by the Association, 1973.

This is a report on NOAA OPS I and II, first in a new series of operational experiments whose purpose it is to develop and refine decompression procedures for working from a shallow undersea habitat. The program can be described in four phases: a) to search out, review and analyze available relevant data on decompression with nitrogen as the inert gas, b) to use this data base for computing a set of tables describing depth-time limits for no-stop (e.g. "no decompression") excursions from various habitat depths (both ascending and descending), c) to verify these tables, and d) to evaluate health and performance aspects of these environmental exposures. Throughout the entire experiment extensive physiological, psychological, biophysical and biochemical surveillance was carried out in cooperation with the U.S. Naval Submarine Medical Research Laboratory. Ultrasonic methods applied to seek evidence of bubble formation, both Doppler and through-pass techniques being tried. Performance tests and evoked brain responses were used to follow the course and degree of adaptation to nitrogen narcosis of the divers. Mass spectrometric analysis was used to study the rate of nitrogen washout from the diver's lungs. Ecological, dental, immunological and microbiological parameters were monitored throughout the program, as well as biochemical factors in blood, urine and saliva. Psychological surveillance was also maintained. There seems to be a definite adaptation to narcosis in divers saturated at 90 and 120 fsw, less in those saturated at 60 and 30 fsw. From 90 and 120 fsw, their performance at 200 and 250 fsw showed little decrement from control levels, but at 300 fsw there was still a substantial effect of nitrogen narcosis. (Authors)

147.
HAMILTON, R.W., Jr., M.R. Powell, D.J. Kenyon and M. Freitag.
Neon decompression.
Tarrytown, N.Y., Union Carbide Tech. Cent., Environ. Physiol. Lab., Tech. Mem. CRL-T-797, 16p. Dec. 1974.

During the current contract year this Laboratory has conducted a feasibility program on the applications of neon in mixed-gas diving. The neon source studied was a by-product of the manufacture of atmospheric gases; it is composed of 25 percent helium, 75 percent neon, and we refer to it as Neon 75. To develop the decompression tables, we applied modifications of classical theory to existing diving data, mainly experience with helium. The resulting decompression schedules proved to be unexpectedly troublesome in causing sensory problems and delayed effects—whether designed for helium or neon—and satisfactory decompressions could be achieved only if oxygen breathing was included. The planned array of tests over a range of depths and times (150-400 fsw and 30-120 min) was set aside, and efforts were concentrated on producing a dependable table for 250 fsw/60 min. This was accomplished. At least for this depth/time situation, neon appears feasible as a diving gas and seems to be about equivalent to helium in decompression efficiency. Other studies showed divers are comfortable over a broader temperature range in neon, and speech is substantially more intelligible. (Authors' abstract)

148.
HAMILTON, R.W., Jr.

Development of decompression procedures for depths in excess of 400 feet.

Ninth Undersea Medical Society Workshop, Wheeler Industries, Washington, D.C., February 21-23, 1975. Bethesda, Maryland, Undersea Medical Society, 1976. 27p.

Following the introductory statements, the contents of the workshop are as follows: Systems constraints: A. Diver work, B. The scope of deep jobs, C. Diver environment, D. Diver equipment and operations, E. Lockout submersibles. Sub-saturation decompression procedures: A. Development and tests of heliox dives in excess of 100 meters, B. Helium-oxygen diving in the Swedish Navy, C. Current decompression research at Virginia Mason, D. Current work at the University of Zurich, E. Decompression work at Tarrytown, F. The zero-supersaturation approach to decompression, G. Theory and development of sub-saturation decompression procedures for depths in excess of 400 feet. Saturation decompression: A. Current work at Alverstoke, B. Recent U.S. Navy experiments in saturation-excursion diving, C. Current work at the Institute for Environmental Medicine. Operational experience: A. Operational results of Tarrytown Lab's work, B. The LUDION procedure for operational saturation diving, C. U.S. Navy operational experience. Treatment: A. Decompression sickness in the Bay Area Rapid Transit Project (BART), B. U.S. Navy incidence and treatment of decompression sickness in saturation diving, C. Treatment experiences at Duke University, D. Treatment experiences in the North Sea, E. The North Sea Hyperbaric Center. Selected research topics: A. Decompression studies with ultrasound, B. Use of other gases: hydrogen and neon. The workshop concluded with a critique, a plea for further research, and a presentation of a chart comparing the profiles of eight currently used 500 ft/30 min. decompression tables. (MFW/UMS)

149.
HAMILTON, R.W., Jr., R.E. Peterson, K.H. Smith and M. Beckett.

The challenge of writing a standard for decompression.

In: Program and abstracts. Undersea Medical Society annual scientific meeting, May 13-16, 1977, Toronto, Canada, p.A52. Undersea Biomed. Res. 4, Mar. 1977. Appendix A.

Abstract only. Entire item quoted: The development of occupational safety standards for commercial diving has been complicated by the question of what to do about decompression. This involves several factors: the proprietary handling of most commercial tables and the results of their use, the air of mystery about table development and the resulting undue reliance on "the computer," the difficulty of making an *a priori* judgment of table safety and of defining adequate laboratory testing, and a situation of relatively few safety problems as a result of tables themselves but a great attention to decompression tables in the public eye. We have been involved with U.S. Government agencies and other institutions in an effort to arrive at a standard for decompression which will be effective in protecting divers from decompression sickness but which recognizes the realities involved. Such a rule must not consider any arbitrary incidence of decompression sickness as "acceptable," must recognize the state of the decompression art as it now exists, must not create inappropriate liabilities, and in our case had to conform to the constraints of the U.S. OSHA law. From the start we recognized the empirical nature of decompression table development and that results must be the ultimate criterion for judging table safety. Through many iterations we arrived at a plan calling for: records keeping, analysis of all cases of decompression sickness, comparison of results with a set of performance criteria which can be updated as experience develops, prompt corrective action if indicated, and encouragement for operators to make small corrections and apply them directly to field operations. The decompression rules are backed up by other requirements which assure that when decompression sickness does occur it will be treated promptly and adequately, with minimal risk to the diver.

150.
HAMILTON, R.W., Jr., R.E. Peterson, K.H. Smith and M.E. Kent.

The challenge of writing a standard for decompression.

In: United States-Japan Cooperative Program in Natural Resources. Proceedings of the fourth joint meeting of the panel on diving physiology and technology, May 9-11, 1977. Buffalo, N.Y., p.38-43. Rockville, Md., Manned Undersea Science and Technology, NOAA. [1978].

We have been involved in an effort to develop occupational safety standards for diving. Decompression is a particularly difficult topic because tables often are proprietary, and it is not possible to evaluate the safety of a given procedure by computation alone. The only true method of judging tables is from experience in their use. The approach we recommend calls for adequate treatment capability records keeping, analysis of all cases of decompression sickness, comparison of results with a set performance criteria, and when necessary, correction of the tables. Small changes may be applied directly to field operations. (Authors' abstract)

151.
HANSON, R. deG.
Decompression sickness in civilian divers.
Med. Serv. 59:77-80; Summer 1973.

Most cases resulted from repetitive dives. In general, recompression therapy sufficed. One case is described in detail. Neurological symptoms occurred 15 minutes after two 15-minute dives to 130 feet, and developed over the next two days, consisting of back pain, leg pain, a headache, difficulties in urinating, and some cutaneous anesthesia. Treatment was not initiated until 84 hours after onset of symptoms. Initial recompression to 60 feet cured bladder problems and numbness. After nine days in hsopital, the pain subsided (treatment not specified). This survey shows that only a small proportion of divers practicing repetitive diving of short duration suffer from decompression sickness. It is concluded that the Royal Navy decompression tables are too conservative. There is a brief discussion of the calculation of tables, and a comparison of Royal Navy tables and U.S. Navy tables. The desirability of educating divers into decompressing on their last dives is noted. (MFW/UMS)

152.
HARTER, J.V.
Early dives pave way to progress.
Offshore 38:34-35; Aug. 1978.

The author traces the progress of deep diving and of the development of decompression tables, starting with the 1000-foot dive in 1962 under the direction of Hannes Keller, in which two men were lost. In 1965, Dr. Val Hempleman and Surgeon Commander David Elliott developed techniques for 600-foot intervention (or bounce) diving, working from the British diving ship RECLAIM off Toulon, France. In the United States, Captain Robert Workman at the Navy Experimental Diving Unit, and Drs. Heinz Schreiner and R.W. Hamilton for Ocean Systems, worked with chamber dives of 300 and 650 feet. Then came the development of saturation diving under the direction of U.S. Navy Captain George Bond in the Sea Lab experiments. This technique was first used commercially by Marine Contractors and Westinghouse, Inc., at Smith Mountain Dam in Virginia in 1965. Excursion diving from saturation was then developed by Allen Krasberg, and through the late '60's and early '70's many new records were set in experimental dives by industry, the Navy and by the laboratories at Duke University and the University of Pennsylvania. Dr. Christian Lambertsen of the University of Pennsylvania and Dr. X. Fructus of Comex, in France, were particularly active in this field. These experiments enabled the commercial diving industry to meet the increasing depth requirements of the offshore oil industry. Diving contracting companies such as International Underwater Contractors, Taylor Diving, and Comex have been instrumental in furthering deep diving techniques. At the present time, man-in-the-sea is the best available system for underwater tasks, and research has rendered such activity relatively safe and harmless to the human organism insofar as any nonreversible damage is concerned. (MFW/UMS)

153.
HARVEY, C.A.
Decompression tables in relation to dysbaric osteonecrosis.
In: Beckman, E.L. and D.H. Elliott, eds. Dysbarism-related osteonecrosis. Proceedings of a symposium on dysbaric osteonecrosis, Marine Biomedical Institute, University of Texas Medical Branch, Galveston, Texas, February 1972. p.47-54. Washington, D.C., U.S. Department of Health, Education, and Welfare, National Institute of Occupational Safety and Health, 1974.

In areas of developing dysbaric osteonecrosis, bone marrow probably exchanges inert gas slowly. Lesions have developed even with tables of apparent safety—as evaluated in terms of incidence of dysbarism or by a simple exponential gas-exchange model (as used in the modified Haldane perfusion-limited model). Inequality in gas uptake and elimination, as well as the low tolerance of bone for inert-gas supersaturation, may precipitate development of lesions when present-day decompression tables are followed. Showers of silent embolic bubbles during repeated decompressions may also be contributory factors, possibly because of secondary changes in blood constituents. Reflex circulatory and toxic changes in bone from an elevated PO_2 need further evaluation. Inert-gas exchange rates and the consequences of mixing or switching inert gases should also be studied in many tissues. A reasonable approach to the modification of current decompression practices might reasonably include 1) more positive consideration of tissues with longer half-times; 2) reduction of supersaturation in those tissues; and 3) greater emphasis on the inequality of inert-gas uptake and elimination. Of possible importance, as well, would be efforts to decrease the separation of gas from solution into a gas phase (silent bubbles) by using deeper decompression stages, by closer adherence to the O_2 window principle of decompression, and by monitoring with ultrasonic technicques—particularly in repetitive diving. (From author's summary)

153.a

HARVEY, E.N., A.H. Whitley, W.D. McEnroy, D.C. Pease and D.K. Barnes.
Bubble formation in animals. II. Gas nuclei and their distribution in blood and tissues.
J. Cellular and Comparative Physiology 24:23-34; 1944.

1) Removal of gas nuclei may be accomplished by centrifuging, filtering, boiling or high hydrostatic pressure (1000 atmospheres). The efficiency of each method depends on the size and shape of the nucleus. Techniques are described as well as the precautions for maintaining hydrophobic surfaces nucleus free. 2) A pompholygometer technique has been developed to sample fresh drawn blood for gas nuclei. Not even gas micronuclei have been found, indicating complete freedom of plasma as well as red and white cell surfaces, platelets, blood "dust" and oil globules from a gas phase. Gas nuclei are therefore believed to be attached to or form on the walls of the blood vessels, where they grow under proper conditions and only break loose as minute bubbles. 3) All excised tissues can be pressurized to from 8,000 to 16,000 lbs. $in.^2$ and will form no bubbles at the vapor pressure of water but with many, especially connective tissue, bubbles appear when crushed, cut or pulled in two. 4) Microscopic observation indicates that even at 1 atmosphere pressure minute bubbles form in prepressurized connective tissue as a result of local high negative pressures due to mechanical tension. 5) These in vitro experiments offer a possible explanation of the mechanism of bubble formation during muscle contraction or tissue injury. (Authors' summary)

154.

HAWKINS, J.A., C.W. Shilling and R.A. Hansen.
A suggested change in calculating decompression tables for diving.
U.S. Nav. Med. Bull. 33:327-338; 1935.

An analysis of 2,143 experimental dives has been made in which it is shown that the saturation of the 5- and 10-minute tissues has no bearing on the production of caisson disease. It is also shown that the 20-minute tissues may have a saturation ratio of 3 to 1 without the development of caisson disease. The method of calculating a decompression table has been given, together with its relation to tissue saturation and desaturation in connection with the production of caisson disease. The findings obtained from these experimental dives have been used as a basis for calculating decompression tables. These tables reduce the time of decompression following dives of short duration. New decompression tables have been calculated without considering the desaturation of the 5- and 10-minute tissues, and allowing a ratio of 2.8 to 1 for the 20 minute tissues, and 2.0 to 1 for the 40- and 75-minute tissues. (Authors' summary and conclusions)

155.

HAWKINS, J.A. and C.W. Shilling.
Helium solubility in blood at increased pressures.
J. Bio. Chem. 113(3):649-653; 1936.

Solubility coefficients of helium in whole blood of normal dogs equilibrated at atmospheric pressure were found to vary from 0.083 to 0.089, and in ox bloods from 0.080 to 0.091. The amount of helium dissolved by whole blood under helium pressures varying from 1 to 6 atmospheres (absolute) has been found directly proportional to the helium pressure according to Henry's law. (Authors' summary)

156.
HAXTON, A.F.

A proposed revision of the British decompression table.

In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October 1965, p.177-184. Newcastle upon Tyne, Oriel Press, 1967.

As the result of difficulty experienced with the British decompression tables there was a complete recalculation. For example, the case for 40 p.s.i.g. working pressure, calculation for full saturation employing the step-by-step method of decompression showed that decompression was 18% too slow at the beginning and 23% too fast at the end. The work was carefully done, and it is recommended that the British table be modified. (CWS/BSCP)

157.
HELLER, R., W. Mager and H. von Schroetter.

Luftdruckerkrankungen mit besonderer Berucksichtigung der Sogenannten Caisson-krankheit.

[Compressed air sicknesses, with particular emphasis on the so-called caisson's disease]. Vienna, Alfred Holder, 1900.

This massive volume, containing 219 figures and 11 tables, is divided into two sections: a historical and technical part (primarily physical in emphasis), and a physiological and clinical section. Topics covered include middle ear and central nervous system effects of pressure, symptoms and signs of pressure-related disorders, the pathogenesis of pressure-related conditions, preventive and therapeutic measures, and a discussion of residual effects. (MBK/UMS)

158.
HEMMINGSEN, E.A.

Supersaturation of gases in water: absence of cavitation of decompression from high pressures.

Science 167:1493-1494; Mar. 13, 1970.

It is stated that knowing the susceptibility to cavitation for various gases would be helpful in developing better gas mixtures and decompression procedures. It is here demonstrated that very high supersaturations can be produced without cavitation at atmospheric pressure. Table 1 shows the maximum supersaturation without cavitation, the saturation at which massive cavitation begins, and the solubility of argon, oxygen, helium and nitrogen. Using a 1.1 mm capillary, argon and oxygen cavitated at 135-140 atm, nitrogen at 170-185 atm, and helium had not yet cavitated at 270 atm. Changing the diameter of the capillary did not greatly alter results for nitrogen. These figures are in inverse proportion to the gas solubility; this would indicate that concentration rather than tension is the determining factor. The author suggests that, for this reason, Haldane's tables might need modification for gases other than nitrogen. (MFW/BSCP)

159.
HEMPLEMAN, H.V.

A new theoretical basis for the calculation of decompression tables. Part A of Report III. Investigation into the decompression tables.

Prepared for the Decompression Panel of the Royal Naval Personnel Research Committee, Medical Research Council, 1952.

A new theoretical treatment of the problem of nitrogen exchange in tissue is presented. The blood is considered as a well-stirred fluid and the tissues as immobile solvent layers. Suggestions are made as to the way the theory may be used for the calculation of diving tables. "These experiments help to prove the main point to be stressed in this contribution, namely, that the body cannot be regarded as various well-stirred fluids separated from the blood by a membranous layer, and that to talk of a tissue possessing a certain partial pressure of nitrogen is meaningless, except when equilibrium is reached. (Author's summary, augmented by CWS/UMS)

160.
HEMPLEMAN, H.V.

Further basic facts on decompression sickness. Report VIII. Investigation into the decompression tables.

Prepared for the Underwater Physiology Subcomittee of the Royal Naval Personnel Research Committee, Medical Research Council, 1957.

1) An attempt is made here to establish some basic facts necessary for the calculation of safe diving tables. 2) Goats were exposed for six hours to an absolute pressure P_2 and then decompressed rapidly to an absolute pressure P_2 at which pressure they were watched for six hours for signs of decompression sickness. The value of P_2 (for a given P_1) which was just safe was thus established. 3) The above experiment was repeated on a single animal with the time interval at P_1 reduced from 6 hours to 25 minutes. 4) Decompressing goats from values of P_2 greater than 83 ft. seawater pressure (absolute) proved to be more difficult than current ideas would have anticipated. 5) For the experiments described under 2 above it was established that P_1/P_2 is a constant independent of P_2. 6) For the experiment described under 3 above it was established that P_1/P_2 is a constant differing in value from 5 above independent of all values of P_2 greater than atmospheric pressure. 7) It is concluded that P_1/P_2 is a constant ratio for any fixed dive time, provided P_2 is greater than atmospheric pressure and that the value of P_1/P_2 is a maximum for short dive times and a minimum for long dive times. It is also concluded, 4 above, that the uptake and elimination of gases from the body may not be reversible processes when ambient pressure changes are also involved. 8) In the light of the conclusions given above it is possible to state that present methods of calculating diving tables are incorrect. (Author's summary)

161.
HEMPLEMAN, H.V.

An extension of the experimental findings of Report V of this series. Report X. Investigation into decompression tables.

Prepared for the Underwater Physiology Subcommittee of the Royal Naval Personnel Research Committee, Medical Research Council, 1961.

Several experiments are described designed to distinguish between a single-tissue (Hempleman, 1952), and a multiple-tissue (Haldane, 1907) for "bends" formation. (Author's summary)

162.
HEMPLEMAN, H.V.

Experiments in safe decompression.

In: Eaton, B., ed. The undersea challenge. Proceedings of the Second World Congress of Undersea Activities, p.60-63. London, The British Sub-Aqua Club, 1963.

The inadequacy is discussed of decompression schedules which would permit safe diving over a range from one hour at 300 feet depth to many hours at 30 feet depth. Goats are used as experimental animals because they suffer attacks of "the bends" which are very similar in their site and outward signs to those suffered by man. The similarity in sensitivity to an attack of "the bends" is shown in tabular form where the depth-time relationship of the two species for no-stop dives is compared. The resemblance is very close for times up to 6 hours but diverges beyond that time. Individual animals have widely differing performances. Tests to select resistant divers must bear in mind the type of diving involved. Techniques of deep diving using helium-oxygen mixtures are discussed. Decompression procedures are discussed also. Aseptic necrosis of bones occurred more frequently amongst compressed air workers than amongst divers. The factors operating to produce this disorder are still being studied. (ART/BSCP)

163.
HEMPLEMAN, H.V.

Tissue inert gas exchange and decompression sickness.

In: Lambertsen, C.J. and Greenbaum, L.J., Jr., eds. Underwater physiology. Proceedings of 2nd symposium, pp.6-13, 1963. Nat'l. Acad. Sci., Nat'l Res. Council, Wash., D.C.

A theoretical study of saturation and desaturation of inert gas by both percussion and diffusion processes, as applied to tissues with high vascularity and those with few capillaries. The use of oxygen in relation to inert gas is discussed.

164.
HEMPLEMAN, H.V.

Decompression procedures for deep, open sea operations.

In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the Third Symposium on Underwater Physiology, 23-25 March, 1966, Washington, D.C., p.255-266. Baltimore, Williams and Wilkins Co., 1967.

Working with goats and with man breathing helium-oxygen mixtures under pressure a study was conducted both to provide further facts regarding the etiology of decompression sickness, and also to enable safe decompression procedures to be devised for deep dives in the open sea. Four main principles were established for calculating schedules: body tissues effectively saturate in 4 hours; stage decompression, ratio cut-back can be used to extend the general ideas in calculating air tables; there is an irreversibility in the uptake and elimination of the gas responsible for decompression sickness; and oxygen and oxygen rich mixtures do not confer the benefit expected when breathed during decompression. In addition there are a number of general controls which must be maintained on the diver: schedules must be tested on acclimated men and also on unacclimatized men; a schedule is not considered successful unless 10 trouble free dives are performed by 10 different divers; atmosphere control must be accurate; the diver must be kept warm even at sea in order to match chamber dives; hard work on the bottom is essential to provide a good test of the tables; pressure measurements (depth) at sea are often inaccurate; and work during decompression must be reduced to the minimum. (CWS/BSCP)

165.
HEMPLEMAN, H.V.

British decompression theory and practice.

In: Bennett, P.B. and D.H. Elliott, eds. The physiology and medicine of diving and compressed air work, p.291-318. Baltimore, Williams and Wilkins, 1969.

Careful records have been kept for the past ten years of all cases of decompression sickness in all major pressure workings and only 0.04% of decompressions have been followed by severe decompression sickness. About 1% of those working under compressed air have some mild to severe pains in the joints. Work can be performed for periods between eight and 12 hours at pressures less than 14 psi gauge (31 ft: 0.095 ATA) with not less than a two minute decompression with only rare cases. The Haldane stage decompression with modifications is used in decompression. They have also found evidence of acclimatization to compressed air work. They have found that for a given exposure to pressure the incidence of bends increases at greater pressures. For deep sea diving there is a similarity in the overall picture for air diving. Testing decompression tables is a difficult business and must be carefully planned and controlled. A suggestion which was successfully tested, that a simple, single-tissue approach provides a satisfactory solution to the decompression problem, has influenced the British thinking since 1952. A series of assumptions are made both of a qualitative and quantitative nature. Solution in algebraic terms is shown to be unmanageable and 16 pages of a proposed graphical solution is presented. It is rather devastating after plowing through this material to read: "This (the graphic method) has led to difficulties and has long since been abandoned in favour of using accurate numerical solutions. . . ." A return to the stage method or ratio principle has occurred with all tables being calculated using a variable decompression ratio rather than a fixed ΔP value. The formulae is r(ratio) = 400/P + 180, where P = absolute pressure in pounds per square inch at which a saturation exposure has occurred. Thus at 100 ft (4 ATA), approximately 60 psi absolute, the ratio is 400/240 = 1.67. Helium diving has been experimented with and "there is a growing conviction that the Haldane 'stage' method of decompression is more desirable." (CWS/BSCP)

166.
HEMPLEMAN, H.V. and C. Trotter.
Deep diving experiments at R.N.P.L. (May-October, 1963) and sea testing (November-December, 1963).
Prepared for the Underwater Physiology Subcommittee of the Royal Naval Personnel Research Committee, Medical Research Council, 1964.

1) Two hundred chamber dives using oxy-helium breathing whilst at depth are described. 2) Satisfactory schedules for dives of 16 minutes duration at 300 feet, 400 feet, and 500 feet were established in the pressure chamber. 3) These dives were tested in a total of 54 sea dives and were found to be in need of modification for satisfactory use at sea. 4) The implications of these findings for the theory and practice of oxy-helium diving are discussed. (Authors' summary)

167.
HEMPLEMAN, H.V. and C. Trotter.
Theoretical consideration underlying the deep diving experimental work during the period March 1964 to February 1965 at the Royal Naval Physiological Laboratory.
Prepared for the Underwater Physiology Subcommittee of the Royal Navy Personnel Research Committee, Medical Research Council, 1965.

1) A total of 159 simulated oxy-helium dives on 14 men at depths ranging from 35 feet to 800 feet have been completed. 2) It is shown that helium saturates the body in about 4 to 6 hours. 3) The Haldane stage method of decompression is effective, and no gain was seen from a continuous reduction in pressure method. 4) Oxygen-rich mixtures when used in the final stages of decompression did not influence the safe rate of decompression. (Authors' summary)

168.
HEMPLEMAN, H.V. and C. Trotter.
An account of oxy-helium diving experiments carried out at the Royal Naval Physiological Laboratory from January to April 1965 and subsequent sea testing in the Toulon area during April, May and June 1965.
Prepared for the Underwater Physiology Subcommittee of the Royal Naval Personnel Research Committee, Medical Research Council, 1967.

1) For 'dry' chamber diving, a simple successful method for calculating schedules for oxy-helium dives to depths as great as 800 feet is given. 2) Schedules calculated as in 1 above, when attempted at sea, gave eight cases of decompression sickness requiring therapeutic recompression from 46 dives. 3) An appraisal of the differences between the 'dry' diving and sea diving is given. It is concluded that the breathing apparatus and temperature conditions at sea are two major factors which need to be brought closer to 'dry' chamber practice. 4) It is suggested that for the next series of experimental helium dives at sea, the breathing system should be radically revised, thermal protective suits provided, and a selected team of divers kept in regular diving practice. (Authors' summary)

169.
HEMPLEMAN, H.V. and W.J. Eaton.
Nitrogen and helium, a comparison of decompression requirements.
In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October 1965, p.199-205. Newcastle upon Tyne, Oriel Press, 1967.

Helium gas is used with oxygen as the breathing mixture for deep diving in order to reduce or eliminate the effects of nitrogen narcosis. Helium saturates tissue much more rapidly than nitrogen, in some experiments at least twice as fast. Acclimatization to helium diving was shown to occur. Decompression schedules should be changed to accommodate for the speed of saturation and for reduced solubility of helium in tissues. The idea of a fixed ratio independent of pressure must be abandoned, and also the idea of using the same tissue half-times for the ingoing gas and outgoing gas must be changed. (CWS/BSCP)

170.
HEMPLEMAN, H.V.

Decompression theory: British practice.

In: Bennett, P.B. and D.H. Elliott. The physiology and medicine of diving and compressed air work; Second Edition, p.331-347. Baltimore, Williams and Wilkins Co. 1975.

"The complexities of physics and physiology involved in the aetiology of decompression sickness are so great that attempts to formulate detailed quantitative analyses of the phenomena will only succeed by a happy accident. . . . Given these circumstances it is first necessary to examine the generally accepted facts that have arisen from various sources. Hopefully, these data will lead to the establishment of a set of ideas which can be used to calculate decompression procedures in a wide variety of conditions." This survey covers the following subject areas: Basic decompression data (the many forms of decompression sickness, effects of various breathing mixtures, compression and decompression pressure relationships, latency period for bends, treatment of bends, variety of susceptibility among individuals, adaptation, the incidence of osteonecrosis and its relationship to bends, "safe" diving data which form a gross preliminary test of ideas); A physical model for calculation purposes; Testing decompression schedules; Aetiology of the bends. It is stated in the conclusion that "all current theories have incorrect or grossly over-simplified underlying assumptions, and a good deal of further experimentation is needed to reduce the extent of our ignorance." (MFW/UMS)

171.
HENNESSY, T.R. and H.V. Hempleman.

An examination of the critical pressure-ratio concept in decompression sickness.

Alverstoke, UK, Roy. Nav. Physiol. Lab., Rep. 5-75, 24p. [1975].

If P_1 is the pressure breathed by men for a prolonged period, and P_2 is the pressure to which it is just safe to decompress rapidly, then assuming the volume of gas released upon decompression is critical, it is predictable from theoretical considerations that there is a relationship between P_1 and P_2 of the form $P_1 = aP_2 + b$, where a and b are constants. Examination of experimental evidence confirms this theoretical prediction, and thus the generally accepted concept of a critical decompression ratio (P_1/P_2) is seen to be misleading, especially at shallow pressures. The breathing gas composition controls the values of the constants a and b in a quantitatively predictable manner. This analysis also offers an explanation for the changes in signs and symptoms of decompression sickness which can follow changes in the nature of the exposure to pressure. (Authors' summary)

172.
HENNESSY, T.R.

Converting standard air decompression tables for no-stop diving from altitude or habitat.

Undersea Biomed. Res. 4:39-53; Mar. 1977.

Using the phase equilibration theory of Hills (1966), as modified by Hennessy and Hempleman (1977), it is possible to predict formulas for converting standard air decompression tables for no-stop diving at altitude or from a normoxic habitat, breathing air. For diving following equilibration at altitude, the Royal Navy, Royal Naval Physiological Laboratory, and Haldane-type rules appear to be too conservative, with the opposite result for diving after excursion to altitude. Predictions in the latter case are in fair agreement with the Swiss (Boni, Schibli, Nussberger, and Buhlmann 1976) no-stop altitude tables. In the case of flying directly after no-stop diving, the U.S. Navy rule of using repetitive group D appears to be conservative for dives less than 50 fsw, and possibly unsafe for dives over 50 fsw. It is concluded that for no-stop diving a single tissue and single safe ascent pressure formula are all that is necessary to generate equivalent air dives. This enforces the hypothesis that it is the volume of gas released on ascent that governs marginal type I bends, and that in a no-stop ascent, all excess dissolved gas is released in the worst case. (Author's abstract)

173.
HENNESSY, T.R. and H.V. Hempleman.

An examination of the critical released gas volume concept in decompression sickness.

Proc. R. Soc. Lond. B 197:299-313; 1977.

If P_1 is the pressure breathed by men for a prolonged period, and P_2 is the pressure to which it is just safe to decompress rapidly, then assuming the volume of tissue gas released upon decompression is critical, it is predictable from theoretical considerations that there is a relation between P_1 and P_2 of the form $P_1 = aP_2 + b$, where a and b are constants. The use of men as experimental subjects confirms this theoretical prediction for the case where mixtures of oxygen and helium are breathed. By assuming that the same critical volume of released gas provokes mild attacks of decompression sickness when air, or other respirable gases are breathed, the relevant values of a and b can be deduced, and the values accord well with the known facts for such gases. This analysis also offers an explanation for the changes in signs and symptoms of decompression sickness which can follow changes in the nature of the exposure to pressure. (Authors' abstract)

174.
HENNESSY, T.R.

Recent advances in decompression prediction.

In: Gamble, J.C. and R.A. Yorke, eds. Progress in underwater science. Volume 3 (New Series) of the Report of the Underwater Association, p.219-239. London, Pentech Press, 1978.

This paper discusses a fresh approach to the "critical supersaturation ratio" and describes a method for converting a standard no-stop decompression table for use in a variety of other no-stop diving situations, such as excursion diving from habitats, saturation diving, diving on different gas mixtures or diving at altitude. Some of the predicted tables are in very good agreement with published tables based on tested dives. It is shown that it is not necessary to use a multi-tissue multi-critical ratio model to generate no-stop decompression tables. Only one tissue and one safe ascent formula are needed. This enforces the hypothesis that ordinary limb bends are caused by a simple physical phenomenon–the volume of released gas in a particular critical tissue. (Author's abstract)

175.
HENRY, F.C.

Hyperbaric problems as they relate to divers.

Trans. Amer. Acad. Ophthalmol. Otolaryngol. 75:1322-1332; Nov./Dec. 1971.

The author reaches the following conclusions: Nitrogen bubbles always form during decompression with certain time and depth quotients; proper decompression eliminates most bubbles, but subclinical bubbles persist for as long as 24 hours. They start out small, and increase in size as they move with the flow of blood. The pulmonary vasculature is capable of absorbing a large number of bubbles, thus preventing them from reaching the heart. Recompression does not completely eliminate bubbles. The sheep is a satisfactory experimental animal. In recent experiments with sheep, the U.S. Navy decompression tables proved inadequate. Data and tables derived from sheep experiments should be more than safe for man. Bubbles do not occur in arterial circulation until extreme conditions are reached. Debubbling after saturation requires 24 hours. Exercise and massage may eliminate bubbles formed in tissue. Oxygen inhalation can cute decompression time in half, by preventing further intake of nitrogen during decompression; also, by some mechanism not yet understood, it aids in elimination of bubbles. (Author's conclusions abbreviated by MFW/BSCP)

176.
HESTER, R.

The Hills alternative to naval decompression concepts: A critical review.

U.S. Nav. Submar. Med. Cent., Rep. SMRL 620, vii + 46p. Mar. 24, 1970.

The problem here was to evaluate the thermodynamic and kinetic approach to decompression proposed by B.A. Hills [A thermodynamic and kinetic approach to decompression sickness. Adelaide, Australia, Libraries Board of South Australia, 1966]. This paper is limited to a critique of the theoretical system. The approach by Hills is based upon two hypotheses: a) inert gas transport is limited by diffusion in a single radial model of extra-vascular tissue and b) nucleation and phase equilibration between dissolved gas and gas in silent bubble effectively preclude supersaturation in excess of 74 mmHg. Actually, two different models, not always clearly distinguished, are presented. One, expounded in theoretical analysis is concerned with gas concentration in a certain average sense over the extra-vascular space. The other, used for his proposed optimum decompression method presumes a restraint on point tensions to 74 mmHg over the diffusion field is necessary to preclude nucleation. Numerical evaluation of transient tension gradients is prohibitively complicated, except by a computer; which effectively limits evaluation to experimental tests of computer generated ascent formats. Merits of the approach, however, do not necessarily depend upon the theoretical justification offered by the author. It is possible that decompression formats generated by the theory are safer and, under certain conditions, require less ascent time, when compared with conventional diving tables. A simple approximate model is presented by the author, based upon Hills' hypotheses, which retains the average extra-vascular tension concept, and which should yield near-optimum schedules. Application is simple. Two important features of Hills' approach become evident in this model: 1) saving in ascent time which Hills claims for his method is predicted only if the diver is resting at bottom and 2) the relation between ascent time and O_2 partial pressure is notably greater by this approach than by conventional diving theory. The latter property suggests an expedient approach to further experimental evaluation of the approach. The critique provides a perspective on and suggests guidelines for further empirical evaluation of the thermodynamic approach to decompression sickness. (Author's summary and abstract combined)

177.
HESTER, R.
Criteria for bubble growth.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the fourth symposium on underwater physiology, p.137-143. New York, Academic Press, 1971.

This paper examines "silent bubble" growth in decompression from helium saturation diving. The old theory is that gas in blood and tissues can be considered as remaining in solution and that supersaturation can exist at certain levels for short time intervals, and that when bubbles do form symptoms are associated. The most fundamental gap in our knowledge of decompression sickness is the exact nature of the relationship between effective desaturation rates and production of symptoms. It may be that phase equilibrium rather than tissue supersaturation with gas is the relevant condition in decompression sickness. The argument in favor of the silent bubble hypothesis is convincing although difficult to prove because the response of the whole organism to reduced pressure is a complex psychobiophysical process. (CWS/BSCP)

178.
HILL, L.
Caisson sickness and the physiology of work in compressed air.
London, Edward Arnold, 1912. 255p.

One of the classics in the field, covering all aspects of the diving field. He has two chapters on "The theory and practice of decompression," which are of interest for this review of the literature. In the first of the chapters he presents his animal work in which the uniform method was compared with the stage method of decompression. "The conclusion to be drawn, then from experiments on animals is that there is evidence in favour of stage decompression after short exposures, but no decisive evidence of its superiority after long exposures." In the second chapter the two methods are considered as applied to man. "The results show that a few slight cases of "bends" have occurred from the uniform method, which have been absent from the stage method. They do not by any means prove that great relative deficiency of the uniform method claimed by the theory of Haldane." He does admit that "while the efficiency of the superiority of the stage over uniform method is not so marked as the Admiralty Committee maintained, there can be no doubt that the stage method can be made fairly safe, and is the best one to use for caissons." (CWS/UMS)

179.
HILL, L.
Diving.
Proc. Roy. Inst. Great Britain 26:184-196; 1930.

A general discussion of submarine escape using the "escape dress" designed by Mr. R.H. Davis, and the value of breathing oxygen from the Davis device in washing out the nitrogen in the tissues of the body.

They did a study of nitrogen dissolved in urine and the effect of oxygen inhalation and found that "it is clear then that the breathing of oxygen quickly washes out nitrogen dissolved in the blood and tissues of the kidneys." The paper includes a set of tables by H.E. Soper, "Times of decompression using oxygen and air." (CWS/UMS)

180.
HILL, L. and M. Greenwood, Jr.
The influence of increased barometric pressure on man. I.
Proc. Roy. Soc. (Series B) 77:442-453; 1906.

The two authors subjected themselves to pressures up to 90 pounds and recorded their sensations in detail. Their decompression was by the continuous method but they did pause for a few minutes (not over 5) at each atmosphere to take measurements. In considering oxygen toxicity and diving limits on compressed air they predict that "the limit might be extended by diluting the air with nitrogen so as to lower the partial pressure of oxygen," thus predicting present practice. They state that: "It is proved that– 1) A man can be submitted to a total pressure of seven atmospheres without untoward effects, provided decompression be affected gradually, and the capillary circulation be aided by repeated contractions of muscles, joint movements, and changes of posture. 2) We have no sense of increased barometric pressure so long as the former is constant. It is probable– 1) That the subjective effects of increased pressure, apart from voice changes and lip anaesthesia, depend upon psychical conditions such as anxiety and excitement. 2) The changes in the percentage of carbon dioxide in the alveolar air are conditioned solely by physical variations, and not by any increase or diminution in the respiratory metabolism." (CWS/UMS)

181.
HILL, L. and M. Greenwood, Jr.
The influence of increased barometric pressure on man. II.
Proc. Roy. Soc. (Series B) 79:21-27; 1907.

The body fluids of man exposed to compressed air absorb nitrogen in accordance with Dalton's law. Saturation of the body fluids is attained after exposure to pressures of +30 – 45 lbs for from 10 to 15 minutes. Even with a decompression rate of 20 minutes an atmosphere, equilibrium between dissolved and atmospheric nitrogen is not completed 15 minutes after decompression. [These conclusions were arrived at through the analysis of urine samples taken at pressure, and during and after decompression.] (Authors' conclusions)

182.
HILLS, B.A.
A thermodynamic and kinetic approach to decompression sickness.
Adelaide; Libraries Board of S. Australia, 1966. 312p. plus append.

An hypothesis has been developed to explain the mechanism and kinetics of the occurrence of marginal symptoms of decompression sickness. The approach is essentially quantitative, all expressions being derived from fundamental physical and physiological parameters. The hypothesis attempts to offer a more comprehensive mechanism for processes leading to the onset of pain than do existing theories. It deviates widely from the latter on several major issues by including postulations of: 1) Random nucleation for gas phase separation in tissue. . . . 2) Tissue as a two-phase system of irregular internal boundaries. . . . 3) Diffusion as the rate-limiting process in this particular "worst possible" case. 4) The driving force for inert gas elimination following phase separation to be an "inherent" unsaturation arising in tissue by virtue of metabolism and the physico-chemical properties of blood. (From author's summary)

183.
HILLS, B.A.
A thermal analogue for the optimal decompression of divers: Theory.
Phys. Med. Biol. 12:437-444; Oct. 1967.

190.
HILLS, B.A.

Concepts of inert gas exchange in tissues during decompression.

In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the fourth symposium on underwater physiology, p.115-122. New York, Academic Press, 1971.

Tendon was the avascular tissue selected for study for gas formation during decompression. Gas has much higher electrical resistivity than tissue, and therefore the separation of any gas from solution should change the transtissue resistance. The tail of the rat was chosen as the tissue to be monitored conductometrically. First the rat was exposed to a particular breathing mixture (air, He-O_2 or N_2O-O_2) for six hours, killed within 30 seconds and its tail was cut off, mounted on a tray attached to the end plate of a small pressure chamber to which were attached electrode leads. The two thin platinum electrodes were slipped beneath the skin on opposite sides, and the preparation slid into the barrel of the chamber. The chamber was transferred to a constant temperature water bath (37.5°C) and the electrical resistance monitored during decompression from ambient pressure. "The results indicate that the gas phase forms during decompressions to pressures which differ from those predicted on the basis of phase equilibration by no more than 50-100 mmHg, while they differ by 230-290 mmHg from those predicted on a supersaturation basis." The evidence also "indicates that the gas phase is present following decompressions involving far smaller pressure changes than any known to give rise to symptoms, and hence, during those decompressions based on conventional supersaturation theories." (CWS/BSCP)

191.
HILLS, B.A.

Vital issues in computing decompression schedules from fundamentals: II. Diffusion versus blood perfusion in controlling blood: Tissue exchange.

Int. J. Biometeorol. 14(4):323-342; 1971.

A continued review of the vital issues which must be answered in deriving equations for predicting the imminence of decompression sickness [in mammals] from fundamental physical and physiological reasoning. The evidence is considered for deciding whether diffusion or blood perfusion limits the rate of uptake of inert gases by the tissue type(s) responsible for marginal symptoms. This is also discussed with regard to tissues of known anatomic identity relevant to estimations of the uptake of anaesthetic agents and the measurement of local circulation rates. While these data indicate that neither process can be ignored, the best correlation of decompression data which can be isolated from the effects of the other vital issues is offered by bulk diffusion models. The conventional method for computing decompression schedules can then be considered as a calculation technique by which hypothetical tissues of longer "half-time" must be invoked empirically in order to simulate deeper penetration of extravascular tissue by gas. (© BA)

192.
HILLS, B.A.

The driving force for inert gas elimination during decompression.

In: Abstracts of the Twenty-fifth Congress of Physiological Sciences Satellite Symposium. Recent progress in fundamental physiology of diving, Marseille, France, July 1971. p.60-62. (Proceedings unpublished).

Abstract only. Excerpt quoted: An overall review of the experimental evidence leaves little doubt that the gas phase is present during a conventional asymptomatic decompression, the relevant physical condition being one of phase equilibration in at least one fully-nucleated micro-region rather than supersaturation. This raises the question of what driving force there can be for the elimination of inert gas from such "equilibrated" zones. Analyses of subcutaneous gas pockets and total tension in rigid cavities suggest that O_2 and CO_2 remain at essentially normal venous values, PVO_2 and $PVCO_2$ respectively, in gas separated from solution in tissue. A simple pressure balance can then be applied to derive the driving force (ΔP) for inert gas elimination from that separated gas in a man breathing a mixture of inert fraction x at an absolute pressure P as: $\Delta p = (1-x)P - PVO_2 - PVCO_2 - PW + \delta$ where PW is body water vapour pressure and δ is a small "mechanical" term to allow for elastic deformation of tissue and any surface tension effects. The above expression implies a greater driving force at greater pressure (P) and hence an overall redistribution of decompression time towards deeper stops than employed in conventional Naval tables.

193.
HILLS, B.A.

Chemical engineering principles in medicine and biology.
Br. Chem. Eng. 16:700-703; Aug. 1971.

Engineering principles underlie the function of many organs—a realization which is just starting to be appreciated by the more progressive universities and research institutes. In this respect the chemical engineers are late starters yet, in the end, their contribution could be far greater than that of their colleagues. . . . Each tissue is effectively a fixed-bed reactor in which the gross distribution of reagents and the collection of products is effected by the circulation. The blood controls the supply of solutes necessary for the interstitial fluid to provide the environment ideal for the well-being of the cells to which metabolism is confined. This process can take a great many biochemical pathways with innumerable reagents, products and intermediates, but molecular oxygen is invariably necessary and carbon dioxide produced. Thus the gas transport aspect is termed 'tissue respiration' and can be studied in excised sections severed from their blood supply and exposed to gaseous oxygen. . . . It has proved most rewarding to regard these sections as heterogeneous reactors in which the biochemist's data refer only to the medium within the cells. A chemical engineering analysis of this type in which allowance is made for the purely physical processes such as diffusion in each phase, has provided a better correlation of experimental data and provided a simple physical explanation for an effect which biologists have termed 'active transport of oxygen.' . . . Reactor models can also be used to determine transient distribution of inert gases in tissue following change in the partial pressure of that gas in the breathing mixture. . . . The reactor model can thus be used to estimate both the steady-state assimilation of oxygen by tissue as well as the transient accumulation of inert gas upon compression of an individual. Thus the total gas tension distribution throughout the tissue can be calculated and hence the imminence of cavitation occurring during decompression. This has led the writer to propose a method of decompressing divers and caisson workers totally unlike that published in standard Naval tables based effectively upon the simple stirred-tank concept in which only inert gases are considered relevant. The 'reactor' model has produced tables which have enabled total decompression times to be reduced by as much as 35% when tested upon goats using the type of equipment shown. (Author)

194.
HILLS, B.A.

Some physiological aspects of dysbarism-induced osteonecrosis.
In: Beckman, E.L. and D.H. Elliott, eds. Dysbarism-related osteonecrosis. Proceedings of a symposium on dysbaric osteonecrosis, Marine Biomedical Institute, University of Texas Medical Branch, Galveston, Texas, February 1972, p.137-142. Washington, D.C., Department of Health, Education and Welfare, National Institute for Occupational Safety and Health, 1974.

The possible mechanisms of the initiation of osteonecrosis are discussed. Experiments were conducted to 1) compare osmosis induced by diving gases with that induced by nitrous oxide and alcohol, and 2) to obtain basic physiological data on bone in a hyperbaric environment. In the first series of experiments, bladder, peritoneum, and articular cartilage were examined in an osmometer. The findings indicated that gas-concentration gradients resulting from rapid compression and a rapid first phase of decompression can produce a significant displacement of fluid. It appears that slower compression and decompression will reduce the incidence of osteonecrosis. The second series of experiments were carried out with nine mongrel dogs. It was found that intramedullary pressure and bone blood flow varied in opposite directions with compression and decompression. These experiments indicate the advisability of avoiding rapid compression and decompression, but it cannot be assumed that osteonecrosis is attributable to inadequate time spent at various decompression stops. (MFW/UMS)

On the assumption that the diffusion of inert gases in tissues is several orders of magnitude slower than in water, the clearance of such a gas from tissues will be limited to diffusion. During the ascent from a dive, inert gases must be cleared from the tissues and too rapid decompression will lead to phase separation, and possibly to symptoms of decompression sickness. An analogue is described based on the similarity between gaseous diffusion and thermal conduction; this is used to predict optimal decompression. (Author's abstract)

184.
HILLS, B.A.
A thermal analogue for the optimal decompression of divers: Construction and use. Phys. Med. Biol. 12(4):445-454; 1967.

An analogue is described in which the condition of heat simulates the diffusion of inert gas in the cellular material of the tissue type responsible for marginal symptoms of decompression sickness. It forms the basis of an instrument designed to optimize the deployment of decompression time according to the principle of phase equilibrium. Allowance is made for the metabolizable gases. The decompression format produced by the analogue indicates appreciable reductions (20-40%) in the total ascent time of a diver for no loss of safety. This is supported by the results of practical trials in vivo. (Author's summary) (© Biol. Abstr.)

185.
HILLS, B.A.
Relevant phase conditions for predicting occurrence of decompression sickness.
J. Appl. Physiol. 25(3):310-315; 1968.

An experiment has been designed to determine whether phase equilibration or limited supersaturation is the relevant thermodynamic state of the critical tissue type to be considered in predicting the occurrence of decompression sickness. The total decompression times of 5 goats were titrated individually for direct surfacing from pressures equivalent to 10, 20, and 30 ft., apart from 2 of the animals which developed symptoms on reaching 10 ft. by the standard schedule employed. For the others time spent at the normal 10-ft. last stop of a conventional decompression format, based on the concept of limited supersaturation, can be employed more effectively if allotted to the 20-ft. stop. This would indicate that the gas phase is present during the popular Haldanian type of decompression so that the mathematical basis of such calculation methods would then be inconsistent with the physics of the system. (Author's summary) (© Biol. Abstr.)

186.
HILLS, B.A. and D.H. Lemessurier.
Unsaturation in living tissue relative to the presence and composition of inhaled gas and its significance in decompression theory.
Clin. Sci. 36:185-195; Apr. 1969.

1) An experimental investigation has been undertaken to test theoretical predictions of the variation in the total gas tension in tissue with respect to the pressure and composition of the inhaled atmosphere. 2) The total gas tension has been measured as the pressure allowed in constant volume cavities equilibrated with the adjacent tissue. This has been achieved in rabbits using fine-bore plastic tubing permeable to all physiological gases. 3) After reaching steady-state conditions, the total gas tension was invariably found to be lower than the pressure of the breathing mixture. This deficit or "inherent" unsaturation was found to: a) increase linearly with respect to the absolute pressure of a breathing mixture of constant composition, and b) decrease linearly with respect to the fraction of inert gas in an atmosphere inhaled at constant pressure. These findings are discussed in relation to their implications in the avoidance and treatment of decompression sickness. (Authors' summary)

187.
HILLS, B.A.
Thermodynamic decompression: an approach based upon the concept of phase equilibration in tissue.
In: Bennett, P.B. and D.H. Elliott, eds. The physiology and medicine of diving and compressed air work, p.319-356. Baltimore, Williams and Wilkins, 1969.

"According to the thermodynamic hypothesis, staging is advocated following any dive from which immediate decompression to atmospheric pressure could cause a volume of gas to separate from solution which is in excess of that required to produce the critical deformation pressure necessary to provoke marginal symptoms." "Thus, for the 'worst possible' case, the fastest elimination of the excess gas should be effected by adjusting the pressure of the diver continuously such that his critical tissue type is maintained just on the brink of a phase change." There are a number of questions which must be answered before the model is realistic: the number of tissue types involved; whether the separation of the gas phase from solution in tissue is determined by critical supersaturation, is rate-limited by the transfer of gas molecules across the gas-tissue interface, or very rapid, the relevant thermodynamic condition being one of phase equilibration; and whether the rate-limiting process in the uptake of inert gas by tissue is blood perfusion, bulk diffusion, membrane permeation or a combination thereof. All of these factors and many others are considered in detail by the author. "In conclusion it may be said that the 'thermodynamic approach,' and conventional theories of limited supersaturation, represent the two extreme cases for the separation of the gas phase from solution in tissue." (CWS/BSCP)

188.
HILLS, B.A.

Vital issues in computing decompression schedules from fundamentals. I. Critical supersaturation versus phase equilibration.
Int. J. Biometeor. 14(2):111-113; 1970.
(Also published as Roy. Nav. Physiol. Lab. Rep. 4-70).

A general review has been made of the vital issues which must be answered before any equation for predicting the occurrence of decompression sickness can be derived from fundamental physical and physiological experience. The evidence for the presence of a gas phase during a decompression which proves asymptomatic is discussed in detail. This queries the basic assumption inherent in calculation methods underlying the standard diving tables that there is a critical limit to the true supersaturation of a tissue by gas beyond which cavitation occurs. The evidence would seem more compatible with the formation of this gas phase for a much lower degree of supersaturation, if any, its presence not becoming manifest as symptoms during decompression provided its relative volume is not permitted to exceed a pain-provoking threshold. (Author's abstract)

189.
HILLS, B.A.

Limited supersaturation versus phase equilibration in predicting the occurrence of decompression sickness.
Clin. Sci. 38:251-267; Feb. 1970.

Three experiments have been designed to test the following assumptions underlying the conventional methods for calculating decompression schedules: a) that there is a critical limit to the supersaturation of a tissue by a gas, and b) that no gas is formed in the tissues of a subject who does not develop symptoms of decompression sickness. When decompression time was titrated by cutting back upon the time spent at various last stops, it was found that a last stop at a depth of 30 ft was more effective than one at 20 ft. which was, in turn, more effective than one at the conventional last stop at ten ft for each of five schedules. These trials involved fourteen goats and 486 exposures. In a second method, an exposure was selected for each animal from which the "titrated" stop was now the only one required; but the results were inconclusive since the interval of uncertain diagnosis was now of comparable order of magnitude to the total decompression time. In a third method, symptoms could not be induced in three goats, which had just completed marginally safe decompressions, by exposure to high-intensity ultrasound whose energy would be expected to cause the tissue to exceed any hypothetical metastable limit to supersaturation. It was concluded that it is far more likely that the quantity of gas separating from solution determines the imminence of decompression sickness rather than its mere presence as determined by a critical limit to supersaturation. This is discussed in relation to modifying the diving tables, and the serious implication that conventional schedules are really treating a gas phase in the tissues which does not give rise to symptoms due to the remaining compression afforded by the stopping pressures, rather than preventing the separation of gas from solution in tissue. (Author's abstract)

195.
HILLS, B.A.

Biophysical aspects of decompression.

In: Bennett, P.B. and D.H. Elliott. The physiology and medicine of diving and compressed air work. Second Edition, p.366-391. Baltimore, Williams and Wilkins Co., 1975.

It is stated that the biophysical aspects of decompression are "more likely to provide any fundamental basis generally adopted for designing safe diving tables." The following subject areas are explored: Site and mechanism of decompression sickness; Mechanism of "limb bends"; Phase conditions during decompression; Growth or coalescence; Transport; Thermodynamic (zero supersaturation) approach; Other biophysical aspects (including dysbaric osteonecrosis). (MFW/UMS)

196.
HILLS, B.A.

Decompression sickness. Volume 1. The biophysical basis of prevention and treatment. New York, John Wiley & Sons, 1977.

It is the purpose of this book to treat the subject on a physiological and physical basis rather than in terms of empirical procedures. Following the introduction, the chapters are as follows: The decompression syndrome; The mechanism; Gas separation; Prevention; Supersaturation versus phase equilibration; Other vital issues; Treatment and general hyperbaric limitations; Thermodynamic decompression. The text is followed by 26 pages of references, an appendix which contains U.S. Navy decompression tables and Royal Naval Physiological Laboratory decompression tables, and a subject index. (MFW/UMS)

197.
HILLS, B.A.

A fundamental approach to the prevention of decompression sickness.
SPUMS Newsletter, p.20-47; Apr.-June 1978.

This article is a distillation of the author's book, *Decompression sickness. Volume 1. The biophysical basis of prevention and treatment,* published by John Wiley and Sons in 1977. Decompression theory and practice are scrutinized. Methods of compiling decompression tables fall roughly into two groups: the mathematical calculation method and the method which monitors a body parameter—or the mathematical model versus the physiological model. The various types of decompression sickness—limb bends, vestibular dcs, cerebral dcs, and spinal dcs are discussed from the point of view of the mechanism of their occurrence and of their etiology. (MFW/UMS)

198.
HIRSCH, E.F.

Subaquean construction at the St. Louis Bridge initiates caisson disease.
Proc. Inst. Med. Chicago 27:297-298; Sept. 1969.

This is a brief historical account of caisson disease as experienced in the building of the St. Louis Bridge under the direction of the great engineer, J.B. Eads, around 1870. The occurrence of the bends resulted in the employment only of workers in good physical conditions, and the reduction of work periods to three daytime shifts of two hours each. Even so, there were 114 cases of caisson disease and 14 deaths. It was the first occurrence of this on record in the United States. The nature of the disease was recognized by Dr. Jammit, who advised the use of graduated decompression. (MFW/BSCP)

199.
HOFF, E.C., Chm.

Panel discussion.

In: Hyperbaric oxygenation. Symposium. Ann. N.Y. Acad. Sci. 117:860-864; Jan. 21, 1965.

This discussion follows the presentation of papers on "bends" read at a symposium on Hyperbaric Oxygenation. The problem of bone necrosis is discussed at some length. It is suggested that in chamber work, continuous decompression instead of the stage decompression employed in diving might aid in preventing bone necrosis. Decompression codes of New York and Washington states and the U.S. Navy Diving Manual are referred to. The need for slow recompression in cases of delayed treatment is emphasized. Maximal rate of ascent is discussed. The danger of flying after diving is noted. Repetitive dives and the possibly resultant danger of spinal cord injury are mentioned. The use of respiratory frequency and pulmonary artery pressure as evaluators of decompression sickness is discussed. Experiments on dogs involving breathing mixtures containing 50% nitrous oxide and 50% oxygen are described. (MFW/BSCP)

200.
HOOVER, A.W.
An analysis of hyperbaric diseases in tunnel workers.
In: Proceedings of the second joint meeting of the Panel on Diving Physiology and Technology, August 24-27, 1973, Seattle, Washington, p.17-21. United States-Japan Cooperative Program in Natural Resources, n.d.

It is noted that the investigations into decompression sickness and osteonecrosis in divers and those on the same subject with compressed air workers, tend to follow separate courses without much interchange of findings. In the case of tunnel work, there are no uniform reporting standards. It is noted that some sort of adaptation, at present not fully understood, occurs during a long tunneling operation. The history of decompression schedules in England and in the U.S. is briefly related. The shift from the New York tables of 1922 to the Washington State tables of 1963 has resulted in a tremendous reduction in the incidence of osteonecrosis. The Blackpool Tables in England are equally effective. The new theory of Dr. Brian Hill contends that schedules based on Haldanian principles are actually a treatment for a subsymptomatic gas phase, which occurs on the first long ascent. This theory would indicate different physics and different mathematics in computing tables, and should be further explored. (MFW/UMS)

201.
HOPPE, F.
Ueber den Einfluss, welchen der Wechsel des Luftdruckes auf das Blut ausubt.
[The influence of a change in air pressure on the blood].
Arch. Anat. Physiol. 24:63-73; 1857.

It has long been known that animals generally tolerate changes in air pressure well, and only die if certain limits are exceeded. Experiments were conducted on various animal species—amphibians, birds and mammals—to determine their tolerance to changing air pressures. It was determined that birds die long before their blood reaches the boiling point, mammals expire just after the boiling point has been reached, and amphibians do not die even when their blood boils. Warm-blooded animals showed gas bubbles in their blood vessels when the pressure was rapidly lowered, but amphibians did not. Additional experiments with guinea pigs showed that death was not caused by lack of oxygen but by gas bubbles in the major blood vessels. Raising the pressure again dissolved these bubbles. (MBK/UMS)

202.
HUGHES, D.M.
Many factors affect deepwater dives.
Offshore 33:57-64; Aug. 1973.

The author points out the advantage of bounce diving as opposed to saturation diving in industry, because of the much shorter decompression time required. Most working dives can be completed within half an hour, and almost all tasks could be accomplished in two half-hour dives. However, it is emphasized that due to a lack of firm data and adequate field research, a saturation decompression is required whenever a diver has been at 300-400 feet for more than one hour, or at 400-600 feet for more than half an hour, even though the diver has obviously not become saturated in this time. In diving deeper than 600 feet, hpns becomes a problem. Since the only way to avoid hpns at present is to compress slowly, a diver going to 1000 feet in order to do an hour's work would require 25 hours of compression time and ten days of decompression time. The central problem of deep diving in the near future is the development of a conventional, or bounce, diving system that has a saturation capability. Problems of human factors, atmosphere control, and support of the diver on the bottom are discussed. Much work needs to be done to meet these requirements. (MFW/UMS)

204.
HUGHES, D.M.
Diving industry – challenge and goals in '74.
Ocean Ind. 9:61-62; Mar. 1974.

The author states that the increasing demand for commercial oil field diving to depths of 600 feet and beyond necessitates intensive research into the perfecting of decompression tables for short working dives. Research is also underway to eliminate hpns so that bounce dives can be made to 1,000 feet. At present, saturation diving is the only safe way to work at depths of more than 650 feet. Compression schedules for saturation diving will be improved so as to make possible shorter decompression periods. All aspects of diving technology will receive a tremendous spur as a result of the energy crisis and the need to develop offshore oil fields as rapidly as possible. Training procedures must also be speeded up and intensified. (MFW/UMS)

205.
HUNTER, W.L., Jr., G.B. Pope and D.A. Arsu.
Decompression sickness and deep air diving.
Faceplate 9:7-9; Fall 1978.

The authors analyzed 6600 deep air dives (150 fsw or more) logged during a five-year period. Data was supplied by the Navy Safety Center. The dives were classified into three categories: those that were decompressed under schedule limits, those that were decompressed close to schedule limits, and those that exceeded the limit of the schedule used. Nearly 99 percent of the dives fell in the first two categories. Less than 20 percent followed the Naval School of Diving and Salvage recommendation to use deeper/longer schedule if near the limits. In the first two categories, the percentage of decompression sickness (dcs) cases was almost identical. There were no cases logged in the third category, but the number of these dives was too small to calculate a significant rate. In category three, no dives exceeded depth limits and the average excess of time was 5.08 minutes. This may have been an error in recording. The authors conclude that most dcs is related to factors other than the dive/decompression profile. Such factors as age, physical condition, anatomical patterns of small blood vessels, or sensitivity to stress contribute to the individual's susceptibility to dcs. (MFW/UMS)

206.
HYDROQUIP.
Air decompression chamber operation handbook.
Panama City Beach, Florida, Hydroquip Corporation, Inc., June 1978 (third printing).

Section one on air decompression contains the following: Introduction; General use of decompression tables; Air decompression tables; Repetitive dive flowchart; Section two on chamber operation contains the following: Introduction; Chamber operation; Recompression treatment; Chamber installation and maintenance; Other uses of recompression chamber; Medical; Formulas and conversion factors; Dangerous marine animals. Material presented here has been compiled from the latest U.S. Navy Diving Manual, including recent changes. (MFW/UMS)

207.
IDICULA, J., D.J. Graves, J.A. Quinn and C.J. Lambertsen.
Bubble formation resulting from the steady counterdiffusion of two inert gases.
In: Lambertsen, C.J., ed. Underwater physiology V. Proceedings of the fifth symposium on underwater physiology, p.335-340. Bethesda, Md., Federation of American Societies for Experimental Biology, 1976.

207a
JACOBSEN, E.
Decompression theory. A preliminary study of literature.
Norwegian Underwater Institute NUI-report N 5-79. June 26, 1979.

To achieve knowledge and perform research on decompression problems a review of a part of the enormous amount of literature on the subject has been performed.

The problems are stated and the trends of knowledge on causes, effects, relation cause/effect and counter measures are given.

The review then converges to what appears to be the core of the problems, -the separation of excess gas soluted in the body into bubbles. A suggestion of further research follows.

Came to our attention too late to be included in the regular fashion.

[The authors show] by use of mathematical and physical models of stable isobaric counterdiffusion that true gas supersaturation and bubble formation can be expected to occur, even without pressurization and subsequent decompression. These findings relate to the now well-demonstrated development of dermal gas lesions and vestibular derangement in circumstances where nitrogen or neon is breathed while the subjects are exposed to a helium-oxygen environment at increased ambient pressure. . . . These analyses of gas supersaturation under isobaric conditions, and demonstrations of actual bubble formation in skin and subcutaneous tissues clarify the inevitable hazard of the counterdiffusion process. This process must be considered capable of generating bubbles in dermal tissues, with transport of bubbles in the circulation to distant vital organs. It should in addition be considered capable of adding to or exaggerating the effects of gas bubbles formed during actual decompression. Prevention should include avoidance of exposure of skin, ear canal and eyes to counterdiffusion. Rational therapy could be considered equivalent to that employed for decompression sickness itself. (Authors)

208.
JONES, H.B.
Respiratory system: nitrogen elimination.
In Medical Physics. Vol. 2. Ed. O. Glasser. Chicago: Year Book Publishers, 1950.

The following subjects are discussed: The general method of gas-exchange calculations; nitrogen exchange of the body: nitrogen elimination from lung-gas mixing, gas exchange of the brain, of kidneys and thyroid, of the heart, of the small glands, of bone marrow, of liver, spleen and intestines, of skeleton muscle, of body fat, and of skin; the relation of gas exchange and circulation: nitrogen elimination as measure of cardiac output; application of gas-exchange studies: representation of intestinal-gas N_2 in gas-exchange measurements, and similarity of preoxygenation protection rates and N_2 e; o, omatopm rates. (MFW/UMS)

209.
JONES, H.B.
Molecular exchange and blood perfusion through tissue regions.
In Advances in Biology and Medical Physics, Ed. J. Lawrence. New York. Academic Press.

The contents of this paper are as follows: I. Gas exchange studies: 1) Gas exchange equation of the whole body, 2) Gas exchange measurement, regional gas exchange and blood perfusion; II. Other molecular exchange studies: 1) Iodide exchange and thyroid blood perfusion, 2) Sodium exchange, 3) Blood perfusion of liver and spleen; III. Decrease of regional perfusion with age.

210.
JONES, H.B.
Preoxygenation and nitrogen elimination. Part II. Gas exchange and blood-tissue perfusion factors in various body tissues.
In: Fulton, J.F. Decompression Sickness, p.278-321, Philadelphia & London, W.B. Saunders Company, 1951.

The exchange of the inert gases in the body has been shown to be a function of the blood perfusion of the tissues within the limits of experimental error. The gas exchange and blood-tissue perfusion factors have been matched directly or indirectly for most of the organs and tissues of the body and the results of the matching seem to be in complete harmony. New methods of measuring blood-tissue perfusion rates are indicated. Limitations are imposed upon the nitrogen method of cardiac output. The organs of great vascularity, the kidneys and the thyroid, are too rapidly cleared to be detected in whole body gas exchange measurements. The similarity of rate of exchange of all gases is pointed out. The only differences in exchange rates among the various gases is apparent in fatty tissues because of the differential solubility of the various gases in fat and water. Body fat is noted to be of about the same vascularity as resting muscle, but the nitrogen exchange of fat is approximately five times less than that of muscle. (Author)

211.
KAGIYAMA, S.
Studies on prevention of caisson disease.
J. Kumamoto Med. Soc. 10:262-564; 1934.

Employing 30 professional divers in dives of 25 to 55 m, the author determined safe resting times between dives, as well as safe bottom times. The size and extent of bubbles present in the blood after surfacing were determined by measuring bubbles in the urine. A mathematical equation was evolved from which the time required for the disappearance of gas could be determined for any depth of dive. An equation was also developed from which safe bottom time could be calculated. (MFW/UMS)

212.
KAHN, M.N. and J.K. Summit.
Report of experimental dives for ADS-4: Decompression schedules.
U.S. Navy Exp. Diving Unit, Rep. NEDU-RR-4-70, 115p. Aug. 26, 1970. (AD 711,842)

The report provides a detailed description of the developmental decompression schedules tested for use with the Advanced Diving System (ADS) IV. The evolution of the developmental schedules into the final decompression schedules is presented. A brief description of facilities and procedures used in performing these dives is also provided. The report is based on an analysis of the diving logs of 121 dives over the period March 1967 through May 1968, personnel interviews with divers, and Navy records. (Authors) (Aerosp. Biol. Med.)

212.a
KELLER, H. and A.A. Buhlmann.
Deep diving and short decompression by breathing mixed gases.
J. Applied Physiology 20:1267-1270; 1965.

A series of test dives carried out by 14 subjects in depths between 130 and 1,000 feet for periods varying between 5 minutes and 2 hours revealed that changes of the inert gas in the breathing mixture permit a considerable shortening of the decompression time. The physical and physiological basis of the method is discussed. (Authors' abstract)

213.
KELLER, H.
Use of multiple inert gas mixtures in deep diving.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the Third Symposium on Underwater Physiology, 23-25 March, 1966, Washington, D.C., p.267-274. Baltimore, Williams and Wilkins Co., 1967.

Working with men in a controlled pressure chamber gas uptake and elimination in the human body was studied; and in particular the theory was tested that the use of inert gases alternately during decompression would enable a shortening of the time of decompression as well as make it safer. Gas diffusion laws indicate that helium saturates 2.65 times faster than nitrogen and 3.16 times faster than argon. Use of these facts to speed gas elimination during decompression is illustrated by the following experiment in which 7 subjects made 120 foot dives with a bottom time of 2 hours. "During the bottom time after 70 minutes, the inert breathing gas was switched from helium to argon. Immediately the helium began to desaturate rapidly. At the same time argon began to dissolve very slowly, theoretically 3.16 times slower than the helium was being eliminated. After 50 minutes bottom time with argon, the helium had been eliminated while the argon had not yet reached a critical level. The final decompression first with argon and then with pure oxygen was done in 15 minutes. The normal decompression for an air dive would be about 90 minutes; for a helium dive it would be about 60 minutes." However, difficulties were experienced on a number of dives and there are many problems remaining. (CWS/BSCP)

214.
KELLER, H.
A method of deep diving with fast decompression by alternating different inert gases.
Rev. Physiol. Subaquatique Med. Hyperbare 1:127-129; Oct./Dec. 1968.

The author reports on the pilot experimental study of future diving methods without the necessity of employing decompression chambers and using various inert gases (N_2, He, Ar, etc.). [The author cites an experiment in which divers were exposed to 60-40 helium-oxygen for 70 minutes of a two hour dive, and were then switched, still at bottom pressure, to 60-40 argon-oxygen. The helium was driven out by the argon, which did not reach the saturation limit; in this manner, bottom time was extended.] Such methods prove to be faster than standard decompression methods. Electrically heated underwater and safe dry suits plus closed-circuit, mixed-gas apparatus will allow the divers to swim around for periods in the order of eight hours and to work during 45 minutes at 700 feet in depth. (Author's summary expanded by MFW/BSCP)

216.
KENYON, D.J., M. Freitag and M.R. Powell.
Efficient decompression procedure for 1000 foot diving.
In: Abstracts of papers presented at Undersea Medical Society Annual Scientific Meeting, May 10-11, Washington, D.C. Undersea Biomed. Res. 1:A7; Mar. 1974.

Abstract only. Entire item quoted: The majority of underwater work in support of the offshore petroleum industry requires but a few minutes of diver time at the work site. Likewise the need for a specific dive is rarely known very far in advance. For these reasons, it may be economically inefficient to employ saturation techniques for diving in the 500-1000 fsw range, and use of these procedures may constitute a significant risk, especially in the event of rig abandonment. Our approach is to reduce the length of time of exposure to high pressure by a rapid compression followed by immediate decompression. This decompression may be entirely to the surface or to an intermediate storage depth at which the diver becomes saturated. Employing a highly refined Haldane approach, we have computed and tested a laboratory decompression method for this depth range. For a dive from the surface to 800 fsw with a 30 minute working period, it requires 49 minutes to return to the storage level at 500 fsw. A 30 min (working) dive to 800 fsw when saturated at 500 fsw took 120 min to return to this storage depth. From surface to 1000 fsw for 30 min working time, a decompression time of 47 min was required to return to 600 fsw; the same dive from 600 fsw saturated took 271 min decompression to the holding level. Immediate decompression from 1000 fsw to surface required 4 days, but this included a treatment for decompression sickness at 450 fsw. This was successfully treated by slight recompression, a hold with periodic breathing of mixtures of higher oxygen, and a resumption of decompression on a saturation profile. Doppler ultrasound monitoring of the divers was conducted. At no time were bubbles detected during either the saturation excursions or during the ascent to the surface. This was found also in the case of decompression sickness.

217.
KENYON, D.J.
Computerized system of diving chamber data logging and control of decompression.
In: Ocean 75, San Diego, Calif. September 22-25, 1975. p.233. Publication IEEE 75 CHO 995-1 OEC, 1975.

The computerized data logging system is designed to interface with appropriate instruments to acquire and print relevant environmental data during the progress of a dive. This includes time of day, dive or decompression time, depth, oxygen and carbon dioxide partial pressure and operator's comments. The heart of the data logging system is a state-of-the-art microcomputer which incorporates solid-state memory for both storage and the program. The computer is programmed with a family of decompression tables; based on the pressure-gas-time profile it selects the appropriate decompression table and controls the chamber pressure accordingly. Long dives lasting many days stress the operating crew. Automatic control not only helps avoid errors in decompression but coupled with decompression computations it enables the selection of safer and more precise decompression profiles. (Author)

218.
KETELS, H. and J. McDowell.
Safe skin and scuba diving.
Boston, Little Brown and Co., 1975. 234p.

The contents of this well organized and well illustrated manual are as follows: 1) From out of the past; 2) The safe diver; 3) Snorkel, suit, and scuba; 4) Matter, motion, and you; 5) Skin diving skills; 6) Scuba diving skills; 7) The way the ocean behaves; 8) Life beneath the surface; 9) In case of an accident; 10) Now that you're a diver. Appendixes: A. Assessing physical fitness with the Harvard Step Test; B. Basic medical examination form for divers; C. Notes on decompression and repetitive diving; D. U.S. Navy dive tables; E. Repetitive dive worksheet; F. The "Nu-Way repetitive dive tables. (MFW/UMS)

219.
KETY, S.
The theory and applications of the exchange of inert gas at the lungs and tissues.
Pharmac. Rev. 3:1-41; 1951.

A detailed mathematical treatment of the processes involved in the operation of the respiratory and circulatory systems of the higher animals which constitute a "single homeostatic complex whose chief function is the maintenance of an optimal molecular concentration of oxygen and carbon dioxide about each cell." The in-depth treatment covers all aspects of the physiological processes, and considers the literature of the field in detail. (CWS/UMS)

220.
KIDD, D.J. and R.A. Stubbs.
The use of the pneumatic analogue computer for divers.
In: Bennett, P.B. and D.H. Elliott, eds. The physiology and medicine of diving and compressed air work, p.386-413. Baltimore, Williams and Wilkins, 1969.

Classical work on decompression makes the following assumptions: the partial pressure of inert gas in the body tissues will change with the ambient pressure of the breathing gas in accordance with the laws of diffusion; the inert gas partial pressure within the alveoli is in equilibrium with the inert gas partial pressure in the blood; the results of successive pressure changes will be an algebraic sum; and a degree of inert gas supersaturation is tolerated by the body without symptoms. A simple analogue computer was designed which carried out the tissue compartment partial pressure calculations continuously, regardless of descent pattern and time of depth. "The simplest physical analogue of the gas diffusion equation is a pneumatic resistor through which a gas can be introduced into a fixed volume. A resistor-volume combination can be adjusted to operate at a particular diffusion half-time constant. Four such resistor-volume combinations were assembled on a single manifold. If pressure is applied to the manifold to simulate a dive then the pressure measure in each of the fixed columns could represent the partial pressure of gas in a hypothetical tissue compartment." This pneumatic analogue computer has some advantages in safety, shortening decompression time and conserving air supply over the standard diving tables; but the greatest advantage is in the provision of efficient decompression from random profile dives and repetitive exposures. (CWS/BSCP)

221.
KIDD, D.J.
Decompression sickness–current trends in prophylaxis and treatment.
Med. Serv. J. Can. 22:79-86; Feb. 1966.

J.S. Haldane (J. Hyg. 8:342; 1908) described the principles upon which all subsequent decompression schedules have been based, a varying ascent rate of exponential shape. All tables are variants of these adjusted tables. There are reasons to believe that the optimum ascent path from any given dive follows a specific curve, departure from which may bring increased risk of "bends." However carefully a man is decompressed, statistical probability supports the view that the only way to avoid all cases of "bends" is to avoid diving. Decompression sickness is expected as an occupational hazard. Numbers of cases of decompression sickness (1963-1964) are given for the Canadian Navy, U.S. Navy, and the Royal Navy. The U.S. report shows importance of reducing delay between onset of symptoms and application of pressure therapy. Manifestations of decompression sickness are of 2 types: 1) cases of pain only, and the exhibiting of symptoms of cutaneous or lymphatic involvement and 2) cases of a more serious nature with C.N.S. and respiratory involvement. Generally speaking, medical officers supervising treatment of caisson workers have advocated minimal "relief" pressures for short periods, and relatively rapid continuous decompression crudely following an exponential release of pressure. The diving fraternity favor initial pressure in excess of "relief" pressure and step-wise decompression of a much longer time course. Ideally, what is required is recompression to the point that ischemia is relieved and normal circulation is restored and maintained for a sufficient period to assure recovery, while elimination of inert gas proceeds without further risk of bubble formation. All except serious cases involving C.N.S. are suitable for this treatment. The use of oxygen-helium mixtures when pressure in excess of 60 feet equivalent is necessary has been advocated, particularly in cases with respiratory distress. All well-equipped therapeutic chambers are 100% oxygen, and oxygen-helium to be used via demand valves and dispensers. (EH/BSCP)

222.
KIDD, D.J., R.A. Stubbs and R.S. Weaver.
Comparative approaches to prophylactic decompression.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the fourth symposium on underwater physiology, p.167-176. New York, Academic Press, 1971.

Some evidence exists to show that gas transfer in the tissues is nonlinear under hyperbaric conditions. The many linear models and systems discussed in this paper are special or simplified adaptations of a more complex general model. A pneumatic analog computer, which computes (in real time) directly from the breathing mixture, can be programmed for any of the decompression concepts described. Such a computer – programmed for nonlinear gas transfer with four equal time constant compartments in series and with a constant ratio ascent criterion – continues to offer a very acceptable real time solution to the problem of decompression sickness resulting from diving in an air atmosphere. The computer's efficacy has been verified for exposures ranging from 24 hr at 26.4 FSW to one hr at 250 FSW, and for single and repetitive exposures of any shape. Our experimental diving program using a 20% O_2-80% He mixture has to date been restricted by the limitations of our facilities to half-hour exposures at 300 FSW. Experience with the same computer parameters suggests equal reliability, however, at this depth for longer periods of exposure. The chief obstacle in the attempt to assess current decompression models and diving tables is the lack of published validated data. It is urged that a standard system for reporting the results of experimental diving and decompression table validation be devised for the mutual benefit of countries, organizations, and individuals concerned with diving. (Authors' conclusions)

223.
KINDWALL, E.P.
Aseptic necrosis due to occupational exposure to compressed air: experience with 62 cases.
In: Trapp, W.G., E.W. Bannister, A.J. Davison and P.A. Trapp, eds. O_2. Fifth international hyperbaric congress proceedings, p.863-866. Burnaby, Canada, Simon Fraser University, 1974.

It was found that of the compressed air workers digging a sewer system in Milwaukee, 35% had osteonecrosis, and of these, 71% had juxta-articular lesions. The author attributes this situation to inadequate decompression procedures of the New York Code of 1922, which called for a split shift of three hours in the morning, a one hour surface break, and three hours in the afternoon. The second decompression was identical to the first, with no allowance made for residual nitrogen. In August 1970, the Washington State Tables were adopted. These are now in use throughout the United States. They are similar to the Navy tables, and permit only one decompression a day. Asymptomatic and harmless shaft lesions are important in that they may assist in diagnosis of questionable lesions elsewhere in the individual. The U.S. Navy has found 76 cases of osteonecrosis among its diving personnel, only 15.8% of whom had reported decompression accidents. Most of these resulted from deep helium diving, saturation diving, or experimental diving of some sort. (MFW/UMS)

224.
KINDWALL, E.P.
Influence of the decompression profile on the elimination of inert gas during decompression.
In: Abstract of papers presented at Undersea Medical Society Annual Scientific Meeting, May 10-11, Washington, D.C. Undersea Biomed. Res. 1:A8; Mar. 1974.

Abstract only. Entire item quoted: Experiments were carried out to determine the influence of the depth of the decompression stop on inert gas elimination during decompression. Elimination of inert gas from the lungs was quantitatively measured using a mass spectrometer. Following a dry chamber dive to 100 feet (30 meters) for 40 minutes, subjects were decompressed breathing 80%-20% helium-oxygen in a closed circuit system. Nitrogen accumulation in the closed circuit were accurately quantified. According to Haldanian theory currently in use for computation of decompression schedules, nitrogen elimination should not be dependent on the depth of the decompression stop as regardless of depth, inspired nitrogen is dropped to virtually zero under the conditions described. However, preliminary data show that 17% more nitrogen is eliminated via the lungs during the first 90 minutes at

50 feet (15 meters) than during the first 90 minutes at 10 feet following identical dives by the same individual. This difference was found to be true for all six subjects tested. Nitrogen elimination curves for various depths between 10 feet (3 meters) and 100 feet (30 meters) will be presented. Initial experiments indicated that nitrogen elimination using this system was less at 100 feet than at either 50 feet or 10 feet. This anomaly, though not understood, will be discussed. Data comparing the efficacy of compressed air breathing versus oxygen breathing in helium elimination during decompression following a helium dive will also be presented.

225.
KINDWALL, E.P.

New treatment of air embolism avoiding the use of U.S. Navy Table IV.

In: Trapp, W.G., W.E. Bannister, A.J. Davison and P.A. Trapp. O_2. Fifth international hyperbaric congress proceedings, p.895-899. Burnaby, Canada, Simon Fraser University, 1974.

The author describes the treatment of six cases of air embolism, three of which were from scuba diving. The patients were compressed to 165 feet and kept there for periods of four minutes to one-half hour. Helium-oxygen was the breathing mixture at depth. They were decompressed to 60 feet in four to six minutes, and further treatment was in accordance with U.S. Navy oxygen treatment table VI-A. Steroids and dextran were given. Navy Table IV specifies that the patient be kept at 175 feet, on air, until definite improvement is shown or for a period of up to two hours. It has been found that short stays on helium are preferable for two reasons: the nitrogen in any residual bubbles is washed out, and hyperbaric oxygenation can be begun much sooner. Table IV was never intended for the treatment of air embolism. (MFW/UMS)

226.
KINDWALL, E.

Milwaukee sewerage tunnel project.

In: Beckman, E.L. and D.H. Elliott, eds. Dysbarism-related osteonecrosis. Proceedings of a symposium on dysbaric osteonecrosis, Marine Biomedical Institute, University of Texas Medical Branch, Galveston, Texas, Feb. 1972, p.41-46. Washington, D.C., U.S. Dept. of Health, Education and Welfare, National Institute for Occupational Safety and Health, 1974.

The x-ray survey of a caisson worker should include two views of the shoulders, two views of the hips, and A-P and lateral views of each knee—twelve films in all. Gonadal and pelvic shielding are necessary. While no cases of osteonecrosis have occurred where the Washington state tables are used, the incidence of decompression sickness is still unacceptably high. The author believes that these tables do not provide sufficient decompression time at intermediate pressures. Alteration of the tables to this end have resulted in a marked decrease in decompression sickness. Air contaminated with carbon dioxide appears to contribute to the incidence of bends. When joints become involved, surgery is performed as a last resort. Rehabilitation of compressed air workers disabled by osteonecrosis is rarely successful. (MFW/UMS)

227.
KINDWALL, E.P.

Medical aspects of commercial diving and compressed air work.

In: Zenz, C., ed. Occupational Medicine. Principles and practical applications, p.361-421. Chicago, Year Book Medical Publishers, Inc., 1975.

In this inclusive survey of the subject, the author deals with the following areas: The effects of compressed air on the body; Effects of increased partial pressures of gases; Decompression; Caisson and compressed air tunnel work; Flying after diving or exposure to compressed air; Commercial diving—general considerations; Emergency management of pressure-related accidents in diving and compressed air work; Treatment of air embolism; Underwater blast injury; Aseptic necrosis of bone in divers and compressed air workers; Physical examination standards for caisson and compressed air tunnel workers; Physical examination of men to be employed in compressed air tunnel work or caissons; Physical examination standards for divers. (MFW/UMS)

228.
KOCH, G.H. and R.Y. Nishi.
Decompression procedures for caisson work—a review of various techniques.
Downsview, Ontario, Def. Div. Inst. Environ. Med., Def. Res. Board, Rep. DCIEM 905, 24p. Nov. 1972.

Many different procedures are in effect for decompression after exposure to pressure in caisson work although they differ little in their basic concepts. The main principle is to prevent decompression sickness and aseptic bone necrosis in workers while affording rapid (and therefore economical) decompressions. In order to determine which of the new and highly favored procedures is the most safe and economical, an analysis was carried out comparing the Ontario, Washington State, and British "Blackpool" caisson decompression procedures, and the U.S. Navy and Royal Navy diving decompression procedures with the DCIEM Kidd-Stubbs decompression model. The conclusions reached are that the Ontario procedure is safe provided the second shift is eliminated for exposures to pressures greater than 14 psig, and that the Washington State and British "Blackpool" procedures become increasingly unsafe as the exposures become longer over all the pressure ranges up to 50 psig. It is noted that these "unsafe" exposures have not generally been used in practice. Recommendations for caisson decompression are suggested. (Authors' abstract)

229.
KUEHN, L.A. and D.M.C. Sweeney.
Canadian diving data: a computerized decompression data bank.
Comput. Biomed. Res. 6:266-280; 1973.

The study of decompression sickness is of major concern at various hyperbaric laboratories throughout the world. Although many data pertinent to decompression exist in various laboratories, few are circulated in any consistent format in the open literature. The development of an adequate decompression model that is suitable not only for shallow-depth short-time excursions but also for deep lengthy exposures requires the application of computer techniques and storage facilities. This computer methodology will make possible an efficient review of all pertinent data which in turn will lead to a better appreciation and elucidation of the important physiological parameters relevant to decompression sickness. Such an approach has proven successful in the collation and analysis of medical statistics. This report describes the development and use of such a computerized system to store, collate, and evaluate an extensive body of decompression information collected at the Defence and Civil Institute of Environmental Medicine (DCIEM). The system is known as Canadian Diving Data and is referred to by the acronym CANDID. . . . The merits of this computerized data bank on decompression appear to be: 1) Evaluation of the success of pneumatic analogue decompression computers in providing safe decompression profiles that are efficient in terms of time and life-support facilities. The quantitative measure of success is the "bends" incidence at various depths and times of hyperbaric exposure. 2) Evaluation of current theories of safe decompression models or techniques such as the USN and RN diving tables. 3) Correlation of various parameters of hyperbaric exposure (such as time of dive, date of dive, earlier incidences of decompression sickness, etc.) with the bends incidence at various depths and exposure times in an attempt to elucidate predisposing trends or factors in the etiology of decompression sickness. Extensions of the CANDID system have been prepared and are in the planning stage. These include: 1) Incorporation of all diving information in Canada into CANDID in an acceptable format for analysis by the CANDID system. It is hoped that diving information from European and American laboratories will also become part of the data bank. The deposition of such information into CANDID would entitle the donor to access to and analysis of all the data in the system. 2) Incorporation of the biomedical characteristics and medical histories of all divers in the data bank into the CANDID system. This information could then be searched for any predisposition of these personnel toward decompression sickness. (Authors)

230.
KULIG, J.W. and J.K. Summitt.
Saturation dives, with excursions, for the development of a decompression schedule for use during SEALAB III.
Cambridge, Mass., Astro Nautical Research Inc., Rep. NEDU-PR-9-70, 69p. Sept. 23, 1970. (AD 723,174)

Twenty-three saturation dives to depths of 200 to 850 feet were conducted at the U.S. Navy Experimental Diving Unit to verify a decompression schedule for use at SEALAB III. Seventy-one divers completed ninety-seven man-dives and tested decompression schedules based on two different fundamental rates of ascent during the dive series. Seventy-four man-excursion dives were conducted during the series, including a record-breaking excursion to a depth of 1025 feet. A decompression schedule for use from a depth of 600 feet was developed and found to be safe for use during SEALAB III. Eight cases of decompression illness occurred during the dive series. Details of these cases are covered in the report. (Authors' abstract) (GRA)

231.
KUNKLE, T.D.
Physics of surfactant stabilized gas nuclei.
In: Program and abstracts. Undersea Medical Society annual scientific meeting, May 13-16, 1977, Toronto, Canada, p.A33. Undersea Biomed. Res. 4, Mar. 1977. Appendix A.

Abstract only. Entire item quoted: The initiation of bubble formation in fluids is investigated by identifying and solving the set of coupled, first-order, nonlinear, partial differential equations relevant to this problem. Solutions are achieved through a calculational algorithm that traces the physical state of gas cavitation nuclei through any given pressure history. Theoretical predictions are compared with the data of Yount et al. on bubble formation in supersaturated gelatin. Using this computer model along with the assumptions that i) the bubble formation responsible for decompression sickness in mammals is initiated by stabilized nuclei similar to those observed in gelatin, and ii) that the onset of decompression sickness is indicated by growth into gross bubbles of all such nuclei larger than some critical size, decompression schedules for several saturation dives have been computed. These theoretical schedules are compared with the empirically determined profiles from the U.S. Navy and British Navy tables, and with the results of saturation excursion diving of rats by T.E. Berghage et al.

232.
LABA, L.
Zastosowanie standartowych norm rozprezania w profilaktyce choroby kesonowej u nurkow. Ocena polskich tabel nurkowan.
[Application of standard decompression tables in prevention of decompression sickness in divers. Estimation of Polish decompression tables].
Bull. Inst. Mar. Med. Gdansk 14:157-183; 1964.

The applications of standard norms determined in the Polish Decompression Tables was investigated. Twenty-one divers were subjected to 642 decompressions after dives to depths from 14 to 57 meters, with application of compressed air. The divers were observed for 12 hours after dives. No cases of decompression sickness were noted. Results were confirmed by an analysis of findings in 1,299 additional dives performed according to the same principles, at depths of 12 to 70 meters. In the conclusion the author compares the Polish norms with those of the U.S.A., Great Britain, France, Italy, and the Soviet Union, and pointed out the necessity of correction of the Polish standard decompression norms for short periods (10 to 30 minutes), particularly for dives below 40 meters. A physiologically justified correction will allow a prolongation of the effective work time on the bottom, particularly for skin divers. (MFW/BSCP from author's summary)

233.
LABA, L.
Wskazania do zmiany zasad rozprezania standardouego u kesoniarzy.
[Indications for changing standard decompression rules in caisson workers].
Rocz. Pomor. Akad. Med. Suppl. 10:239-240; 1974.

In the years 1970-1971 the author observed and treated two severe cases of acute decompression syndrome in caisson workers, and thereafter he collected data concerning further 14 cases of caisson disease. The above-mentioned malady occurred during intensive caisson works at the construction of a bridge over the Vistula River and a big water intake designed for one of the foundries. The analysis, covering the clinical data as well as hygienic norms upon taking into consideration the decompression tables used in other countries, points out the need of altering the existing rules of standard decompression in Polish caisson workers. Complete text of the paper will be published in the "Bulletin of Maritime Medicine Institute" in Gdansk 1974 nr 2/3. (English summary)

234.
LAGRUE, D., C. LePechon, G. Masurel, K. Kisman and R. Guillerm.
Etude comparative des methodes de decompression de surface de l'U.S. Navy et du Ministere Francais du Travail pour la plongee a l'air.
[Comparative study of the decompression method of the French Ministry of Labor and the method known as surface decompression of the U.S. Navy for air diving].
In: LePechon, J.C. and D. Lagrue. [Comparative study of the surface decompression methods of the U.S. Navy and the decompression methods of the French Ministry of Labor for air diving. Appendixes.] France, Contrat C.G. Doris–CNEXO No. 77-1780Y, n.d.

Eighteen dives were made using both methods and the same divers; bubble detection by the ultrasound Doppler effect was carried out during and after decompression. Evaluation of the magnitude of the bubbles, translated into indexes of severity, was made statistically. This analysis shows that the difference of severity between the two methods was not significant and that other factors related to the subjects were more important. The authors thus conclude that the decompression method known as "surface" presents no greater risk than the French method of decompression. (Authors' summary transl. by MFW/UMS)

235.
LAMBERTSEN, C.J.
Basic requirements for improving diving depth and decompression tolerance.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the Third Symposium on Underwater Physiology, 23-25 March, 1966, Washington, D.C., p.223-240. Baltimore, Williams and Wilkins Co., 1967.

Although the practical extension of manned undersea activity is now exploiting the basic physiological studies of the past there are several factors of such importance and about which more must be known that they may be considered to be primary limitations to further advances: deficient pulmonary ventilation; decompression problems; narcosis; and oxygen toxicity. Some secondary difficulties are: wetness; temperature; communication; vision, and propulsion. The presentation covered only: the limitation of decompression; acceleration of inert gas elimination; limitations of narcosis; and the limitation of pulmonary ventilation. The presentation ended with a plea for much hard work in developing "many kinds of information and laborious validation of concepts and procedures." (CWS/BSCP)

236.
LAMBERTSEN, C.J.
Concepts for advances in the therapy of bends in undersea and aerospace activity.
Aerosp. Med. 39:1086-1093; Oct. 1968.

In the prevention of bends, it is constantly necessary to look beyond the existing methods, towards what detailed investigative steps may lead to further understanding and improvement. Evolution of such improvement has been erratic, partly because of the general lack of appreciation for the commonality of factors in bends and in different circumstances. The fundamental premise which should guide investigation towards further improvement is that most of the factors and principles which will some day provide the ultimate in treatment of bends are the same factors and principles which will be involved in the ultimate methods for bends prevention and for the facilitation of normal decompression after diving. The aims of the therapy for treatment, the points of attack and the influence of body temperature change are discussed. Potential steps towards improvement of therapy and drugs used to improve circulation are outlined. Tables showing ratio of bubble volume during treatment to bubble volume at start of treatment are given. (EH/BSCP)

237.
LAMBERTSEN, C.J., ed.
Underwater physiology. Proceedings of the fourth symposium on underwater physiology. New York, Academic Press, 1971. 575p.

This volume is divided into twelve parts, as follows: 1) Oxygen: mechanisms of toxicity; 2) Oxygen effects on cells and systems; 3) Physical effects of pressure and gases; 4) Fundamentals of inert gas exchange and bubble formation; 5) Factors in decompression: the inert gases; 6) Factors in decompression: the circulation and the circulating blood; 7) Senses and communication; 8) Respiratory limitations of high ambient pressures; 9) Carbon dioxide, exercise and acclimitization to hypercarbia; 10) Temperature balance in shallow and deep exposures; 11) Influence of inert gases and pressure upon central nervous functions; 12) Undersea and manned chamber operations.

238.
LAMBERTSEN, C.J.
Predictive studies IV. Physiological effects and work capability in He-O_2 excursions staged to pressures of 400-800-1200 and 1600 FSW.
In: The working diver 1976. Symposium proceedings Mar. 2-3, 1976, Columbus, Ohio. p.156-173. Washington, D.C., Marine Technology Society, 1976.

In the fourth of the "Predictive Studies" series of the Institute for Environmental Medicine, trained professional diver-subjects were tracked by repeated measurement during exposure in laboratory chambers to progressive increases of pressure equivalent to 400-800-1200-1600 feet of seawater. It is an important purpose of this paper to describe not only findings of the study but also the reasons for the extensive investment and the method of attack. Goals included a) determination of physiological and performance decrements during intentionally rapid compression, b) determination of rates of adaptation to compression effects, c) development of markedly accelerated methods for decompression in deep saturation-excursion diving, and d) study of work diving in water at depths well beyond those in which practical work performance had been performed. Helium alone was used as the respirable inert gas for rapid compressions, since a solid baseline is required before any interpretation of effects of other gas mixtures can be made. Each of these goals was met, with demonstration of rapid physiological adaptation, in underwater work capability at 1200 and 1600 feet equivalent to that near the surface, and decompression time in deep excursion about one-tenth of equivalent depth-duration in excursion from the surface. (Author's abstract)

239.
LANPHIER, E.H. and J.V. Dwyer.
Decompression in air diving with self-contained apparatus.
In: Diving with self-contained apparatus. U.S. Navy Exp. Div. Unit, Washington, D.C. Special Report 7-54, 1954.

This is one of a series of ten reports bound together and all dealing with diving with self-contained apparatus. It consists of seven sections: Fundamentals; Practical difficulties; Air scuba decompression; Special decompression problems; Current status; Thumb rules and emergency limits; and Prospects, which also contains scuba decompression tables. In this section is discussed, not only scuba decompression tables and the inadequacy of the standard decompression tables, but also repetitive dives, and multilevel dives. (CWS/UMS)

240.
LANPHIER, E.H. and H. Rahn.
Alveolar gas exchange during breath-hold diving.
J. Appl. Physiol. 18:471-477; May 1963.

Use of a recompression chamber permitted simulation of breath-hold dives to 33 ft of seawater (2 atm abs). Four normal subjects made such dives during rest and mild exertion while delivering alveolar gas samples at frequent intervals by a partial-rebreathing procedure. The course of alveolar gas exchange differed greatly from that in ordinary breath-holding. Oxygen uptake remained at near normal levels until ascent owing to the maintenance of alveolar pO_2 by increased ambient pressure. Reversal of CO_2 transfer occurred during descent, and little CO_2 moved in the normal direction until ascent. One subject showed a final pO_2 of 24 mm Hg with evidence of reversed O_2 transfer. Acute hypoxia on ascent is a likely cause of drowning in breath-hold diving. (Authors' abstract)

241.
LANPHIER, E.H.
Interactions of factors limiting performance at high pressures.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the Third Symposium on Underwater Physiology, 23-25 March 1966, Washington, D.C., p.375-385. Baltimore, Williams and Wilkins, 1967.

Acknowledging the great uncertainty of such predictions, it seems likely that inert-gas narcosis and increased work of breathing will be the main factors limiting man's penetration of great depths with gaseous breathing media. The relative importance of these factors and the nature of their interactions may well be very similar to those found with heavier gases at lesser depths. If so, existing knowledge and studies conducted at relatively low pressures may be applicable to the problems of great depth. Intrapulmonary gas distribution and diffusion appear likely to be much less important than the work of breathing in determining respiratory limitations; but possible problems related to the diffusion dead space for oxygen deserve further attention. Any factor that requires significant elevation of oxygen pressures at depth will probably invite added complications. (Author's conclusion)

242.
LARSEN, R.T. and W.F. Mazzone.
Excursion diving from saturation exposures at depth.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the Third Symposium on Underwater Physiology, 23-25 March 1966, Washington, D.C., p.241-254. Baltimore, Williams and Wilkins Co., 1967.

The no-decompression curve for diving from the surface is shifted when excursion dives are made from saturation on air at 35 ft. gauge. The shift is in the direction of greater allowable depths and bottom times, and it is of very significant magnitude. The lack of specific diving tables and treatment tables for working from submerged habitats at hyperbaric pressure creates a dangerous situation for the divers involved. There is an urgent need for the preparation of such tables, including enough saturation depths to provide effective coverage for divers anywhere on the continental shelf. (Authors' conclusion)

243.
LE BOUCHER, F.
Status report on equipment developments in the French Navy.
In: Equipment for the working diver. Symposium proceedings. February 24-25, 1970. Columbus, Ohio, p.345-351. Washington, D.C. Marine Technology Society.

The author discusses briefly four areas of research: 1) Continuous decompression: The first part of this study concerned "a computer which would enable curves of continuous ascent to be prepared"; this led to the development of "a system incorporating a curve reader associated with a system of solenoid valves to control the pressure inside the caisson," for the purpose of "automatically decompressing a caisson following a predetermined law which can be modified easily." The system can obtain a decompression speed of 15 m/minute up to 15 m pressure, 2) Experimental saturation diving at 280 m using hydrogen oxygen: A series of dives made with rabbits resulted in a reduction of respiratory and motor activity; it was indicated that the mixture should not be used for saturation diving, but it is thought possible that it may be feasible for short duration dives. 3) Heat loss: Experiments with heated suits indicated that saturation of the tissues by helium has very little to do with heat loss. The water-heated suit appeared to have a slight advantage over the one with mercury heating resistance. 4) Gas recuperator: The PTC is being used as a closed-circuit apparatus, in order to augment its autonomy and to conserve gas. (MFW/BSCP)

244.
LEMESSURIER, D.H. and B.A. Hills.
Decompression sickness: a thermodynamic approach arising from a study of Torres Strait diving techniques.
Hvalradets Skr. 48:54-84; 1965.

The hypothesis presented postulates a much simpler mechanism than hitherto advanced quantitatively. It merely requires microequilibration of all tissue regions, i.e. equal tensions between adjacent layers of gas, lipid or aqueous phases, thus avoiding such nebulous terms as "active" or "inactive," "macro" and "micronuclei." The approach would appear consistent in so far as the inclusion of lipid substances in the critical tissue does not terminate with the thermodynamic convenience of providing the hydrophobic surfaces conducive to gas film formation, but that fat is also incorporated quantitatively in estimating net gas solubilities and diffusion coefficients. Qualitatively the hypothesis would appear to provide an interpretation of x-ray data, surface decompression, the diurnal bends effect, repetitive aerial data, the polymodality of total inert gas elimination, the variable onset time of symptoms, the additional working depth afforded by breathing an increased proportion of O_2, postflight bends, and the effects of exercise at all 4 stages. A study of electron micrographs indicates that the 3-dimensional transport system employed here would represent a rather more realistic picture than many described elsewhere. The apparent complexity of expressions for ψ (a, θ) should not detract from use of the equations derived, since dives can be analyzed more rapidly by this than conventional methods if a plot of the 2 dimensionless quantities $D' \psi (a, \theta) a^2$ vs. $D' \theta / a^2$ is obtained initially. The same plot can be used for different gases and work rates with only arithmetic adjustments. The most fundamental deviation from conventional approaches is the equating of absolute hydrostatic pressure with the total of tensions calculated independently for each gas after decompression. Apart from the known advantages of high-pressure treatment of symptoms, perhaps the most striking experimental evidence supporting this concept is the observed reduction in total gas elimination with hydrostatic pressure and not merely N_2 alveolar partial pressure change which occurs with O_2 washout (Behnke 1945). This reduction should correspond with that of total gas tension upon decompression. The driving force for tissue desaturation (Δp) coincides with the natural unsaturation. This increases with depth and permits reabsorption of gas—should separation have occurred. (Authors' summary) (© BA)

245.
LENIHAN, D. and K. Morgan.
High altitude diving.
Santa Fe, New Mexico, U.S. Department of the Interior, National Park Service, Southwest Region, Feb. 22, 1975. 23p.

This paper constitutes a compilation of data which represents the state-of-the-art in high altitude diving. It was intended for the use of divers in the National Park Service. A brief discussion of decompression sickness, its etiology, treatment, and prevention is given. The decompression problems of altitude diving are dealt with as they occur in the following situations: dive immediately after arriving at altitude from sea level; altitude dive, no extenuating circumstances; altitude dive followed by going to lowered ambient pressure; altitude dive without conversion tables; altitude dive to sea-level dive; sea-level dive to altitude dive; recompression after altitude dive. In concluding, two points are emphasized: First, altitude diving is in a primitive stage of development, and is only marginally safe. Second, tables must be followed strictly, and the use of oxygen in decompression is recommended. (MFW/UMS)

246.
Le PECHON, J.C. and D. Lagrue.
Etude comparative des methodes de decompression de surface de l'U.S. Navy et du Ministere Francais du Travail pour la plongee a l'air. Rapport.
[Comparative study of the surface decompression methods of the U.S. Navy and the decompression methods of the French Ministry of Labor for air diving. Report].
France, Contrat C.G. Doris–CNEXO No. 77-1780Y, 88p. n.d.

The U.S. Navy method of decompressing from an air dive and that of the French Ministry of Labor are described. The chief difference is that in France, surface decompression has not been allowed in the past. In this study, ultrasonic bubble detection was used as a means of evaluating the severity of a decompression. There appeared to be little difference in the severity of decompression under the two methods, and neither resulted in any symptoms of decompression sickness. However, minute and detailed investigation revealed a slight advantage in the French method. Before making use of the surface decompression method in France, it will be necessary to improve the schedule to the point where the results will be equivalent to those observed under the currently employed method. Factors to be considered are the depth and duration of the decompression stages in the water, the duration of the ascent, the depth of the recompression, and the duration of the sojourn in the chamber. The research instruments used in this study—bubble detection, indexes of severity, statistical analysis, and analysis of gas transport—will lend themselves well to animal experiments. Following such studies, it should be possible to propose a surface decompression schedule that would not be merely empirical. There are great advantages in surface decompression both from the human and from the operational point of view. (MFW/UMS)

247.
Le PECHON, J.C. and D. Lagrue.
Etude comparative des methodes de decompression de surface de l'U.S. Navy et du Ministere Francais du Travail pour la plongee a l'air. Annexes.
[Comparative study of the surface decompression methods of the U.S. Navy and the decompression methods of the French Ministry of Labor for air diving. Appendixes].
France, Contrat C.G. Doris-CNEXO No. 77-1780Y, n.d.

The appendixes to the report are published in a separate volume and consist of (A) Listings of the relative ordinates in the calculation of the indexes of severity for each dive; (B) Data sheets on each of the 22 divers; (C) The detailed protocol of the study, consisting of the handwritten report of Messieurs Boiteau and Bridier, describing and analyzing the study; (D) The seminary report from the applied mathematics department of the Central School of Arts and Industry, which consists of a comparative study (also handwritten) of the two tables, by Professor M.L. Clement; (E) Communication to the Society of Subaquatic and Hyperbaric Medicine, by D. Lagrue, J.C. Le Pechon, G. Masurel, K. Kisman, and R. Guillerm, which is handled separately in this bibliography (see Lagrue, D., et al. author entry): (F) Report of the preliminary results made by the Centre d'Etudes et de Recherches Techniques des Sous-Marins. (MFW/UMS)

248.
LESCURE, R.
Rappel des principes elementaires de protection en scaphandre autonome.
[Elementary principles of protection in scuba diving].
In: L'Huillier, J.-R., ed. Medecine de plongee. Gaz. Hop. 35:1043; Dec. 20, 1971.

This brief report states that the decompression tables now in effect are extremely safe. It is emphasized that this is only true if they are rigidly adhered to, and if the diver is in excellent physical condition, particularly as to pulmonary and cardio-circulatory functions. Control of speed in ascending is most important and must be regulated by the ascensional speed of the bubbles. One must always ascend slowly and at a speed below the ascensional speed of the bubbles. For dives of more than 12m, even when stage decompression is not required, it is recommended that a rest stop (palier de defatigation) be made for several minutes at 3m. As to decompression stages, it is important that they be observed at the exact depths specified. A device called a "pendeur" is recommended. It is a weighted rope, knotted at intervals of 3m. The use of ballast and inflatable vests of the exact equilibration of the stages is recommended. Recompression and resuscitation equipment should always be near at hand. Reserve air tanks should be available at the place of embarkation and should be lowered into the water with the "pendeur." (MFW/BSCP)

249.
LEVER, M.J., W.D.M. Paton and E.B. Smith.
Decompression characteristics of inert gases.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the fourth symposium on underwater physiology. p.123-136, New York, Academic Press, 1971.

By a critical assessment of the relative decompression characteristics of several inert gases (N_2, He, Ar, N_2O, O_2, CF_4 and SF_6) the following conclusions have been reached. 1) All the gases tested produced similar adverse decompression signs in mice, including respiratory abnormalities and convulsions, which could be mitigated by recompression. But the various gases exhibited qualitative and semiquantitative differences in a) the characteristics of the sickness, especially with respect to bubble profusion and distribution; b) sensitivity to hypoxia; and c) the time of onset of symptoms. The differences are most marked when SF_6 is breathed. 2) The most important single factor governing the appearance of decompression sickness seems to be the excess of gas in solution in fatty tissue. Consequently, the critical decompression ratio for a particular gas depends upon its fat solubility. 3) Experiments with mice indicate that the failure of a simple fat solubility model to predict quantitatively the potency of gases in causing decompression sickness may depend in part on the tolerance of the animals to the bubbles of the different gases, and in part to the relative rates of gas elimination from the tissues and rates of bubble development which are characteristic of the different gases. (Authors' conclusions)

250.

LIESE, W., R. Schikli, H. Gehring and A.A. Buhlmann.

Decompression after air dives in mountain lakes.

Abstract submitted to first annual scientific meeting of the European Undersea Biomedical Society, Stockholm, 13-15 June 1973. (Paper not published).

It is stated that the major factor in decompression sickness is the ratio of nitrogen pressure in the tissue to ambient pressure. Therefore, for the same depth and duration at a lower ambient pressure, i.e., at high altitude, longer decompression times are necessary. One hundred and six chamber dives, and 108 actual dives, were made under conditions of simulated altitude of 3000 meters and real altitude of 1250 meters respectively. Decompression was calculated by the usual method, but allowing for lower surface pressure, without altering the nitrogen half-time spectrum of 5-640 minutes nor the oversaturation factors. Both the real and simulated dives in these experiments can be classified as repetitive dives. These experiments, which were carried out without decompression sickness symptoms, form the basis for decompression tables for diving at altitude, including rules for repetitive dives. (MFW/UMS)

251.

LOMNES, R.K.

Microcomputers applied to underwater diving.

Can. Electron. Eng., Sept. 1975.

In order to safely extend dive times, deal properly with random dive profiles, and properly account for multiple dives, one needs a device which can monitor the actual dive and can properly compute the decompression schedule, taking into account the diver's complete time-depth history. The XDC-1 decompression calculator provides this capability in an easy to use package. Its dual function of calculator and real time monitor make it a very versatile tool for planning dives, for recovering from accidents, and for maintaining safe conditions during actual dives in a real time situation. Canadian Thin Films Ltd. (CTG) is continuing its development program in the field of decompression instrumentation. Advanced real time decompression monitors are presently being engineered which will eventually lead to low cost diver portable units for the sports diver. The microcomputer is a key element to such devices and will probably have a great influence on the development of all electronic diver support systems in the future. (Author's summary)

252.

LUNDELL, E.

Sukeltajantaudista ja uudella dekompressiomittarilla saavutetuista kokemuksista. [Decompression sickness and results obtained with a new decompression schedule]. Sotilaslaak. Aikak. 46:56-63; 1971.

A case report of a patient who died of decompression illness is described. Decompression disorders occurred when the diver had worked for 20 min at the depth of 58 meters. The diver ascended according to the orders and was immediately placed into the recompression chamber on board. The diver died, however of decompression illness. Safety orders and measures before and after diving, and the divers diet are discussed. Results obtained with a new decompression schedule are shown in Table 1. The schedule meets the requirements and corresponds with the newest tables as to the decompression times. The gauge makes the diver's work remarkably easier than before and gives better possibilities for the diver to work alone. (English summary)

253.
LUNDIN, G.

Nitrogen elimination during oxygen breathing.
Acta. Physiol. Scand. 30:Suppl. 111:130-143; 1953.

Cumulative measurements were taken of N_2 from subjects who breathed oxygen in a closed system. Nitrogen clearance was characterized as a three-stage exponential process: 1) A rapid phase with an elimination half-time of about 1-5 min. 2) A slower phase with a half-time of 12-13 min. 3) A slow phase with a half-time of about 100-200 min. (CWS/UMS)

254.
LUNDIN, G.

Nitrogen elimination from the tissues during oxygen breathing and its relationship to the fat:muscle ratio and the localization of bends.
J. Physiol. 152:167-175; 1960.

1) Nitrogen content of end-tidal air during oxygen breathing has been followed by means of a sensitive nitrogen meter. 2) The nitrogen desaturation rate of the body could be measured. 3) The desaturation curve could be separated into exponential fractions. 4) These fractions can be used to calculate the amount of fat and muscle tissue in the subjects. 5) The blood flow through these tissues can be calculated. 6) A relationship between nitrogen desaturation rate of fat tissue and decompression sickness seems to be probable. (Author's summary)

255.
LUNDGREN, C.E.G.

Relations between bends symptoms and tissue gas saturation.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the Third Symposium on Underwater Physiology, 23-25 March, 1966, Washington, D.C., p.183-190. Baltimore, Williams and Wilkins Co., 1967.

Goats trained to wear breathing masks were exposed to a number of different pressure and pre-pressure conditions and to varying decompression rates and techniques. Some conclusions may be made: compressed-air illness may originate from oversaturation in a wide spectrum of half-time tissue phases and also when fractions adjacent to the critical one are rather low in gas tensions; the amount of nitrogen available in the phase with oversaturation may not per se determine whether symptoms will appear or not; when the threshold of permissible oversaturation is exceeded in a tissue phase, its half-time and/or nitrogen content will probably determine the type of symptoms that appear; it is conceivable that the joint region is particularly likely to trap emboli which then grow to a size which produces symptoms; and oversaturation in slow tissue phases with high storage capacity for inert gases and for oxygen may be the source of more massive embolism. (CWS/BSCP)

256.
MAASS M., F.J. et al.

High altitude dive tables from Mexico.
In: National Association of Underwater Instructors. Proceedings of the tenth international conference on underwater education, p.251-258. Colton, Calif., Published by the Association, 1978.

The author gives the results of studies which were undertaken to develop a mathematical model and practical tables for use at altitudes up to 15,000 feet. The method consists of "a linear regression to find the relation between the pressure and the altitude." By this method, it is possible to compile decompression tables for any given altitude. An example is cited: a scuba diver at 4198 m. of altitude would dive to 23 ft using the calculations for 40 ft. Calculations are made by computer. U.S. Navy Decompression Table 1-5, and U.S. Navy no-decompression Table 1-6, are shown as adjusted for altitude diving. (MFW/UMS)

257.
MACKAY, R.S.

Ultrasonic imaging and decompression sickness.
Phys. Med. Biol. 15:175; Jan. 1970.

Abstract only. Entire item quoted: Pulsed ultrasonic equipment of the type pioneered by Howry and others allows imaging internal body structures without the potentially destructive effects that can accompany radiography. Gas-tissue and gas-fluid interfaces are excellent reflectors of sound and thus these methods readily display bubbles such as are produced when an animal or human too rapidly goes to a region of reduced pressure. Individual bubbles can be observed on the attenuation of an overall ultrasonic beam. Some theory of decompression sickness is given, along with applicability of these methods to the preparation of diving tables, the elucidation of the mechanism of pain, the verification of "silent bubbles," the verification of the postulates of the onset of "bends," and the possible manipulation of working divers or pilots with regard to decompression profiles. Recent experiments with George Rubissow are cited, as well as methods employing Doppler flowmeters, and possible techniques of imaging invoking laser-light ultrasonic-wave interactions. In connection with telemetry techniques for communicating signals through water, such objective indications of endpoint in supersaturation studies should allow observations on free-swimming animals, from dolphin to man.

258.
MANZ, A.

Probleme der Caissonkrankheit und kie neue Druckluftverordnung.
[Problems of caisson disease under compressed air conditions].
Zentralbl. Arbeitsmed. 25(6):161-167; June 1975.

A commentary on the main regulations of the new order governing work under compressed air conditions ("Druckluftverordnung"), based on theoretical thoughts on the pathogenesis of illnesses caused by falls in pressure, and the application of experience gained as a compressed air physician. The finding is made that the order does not satisfy in every respect its objective of improving precautionary medical conditions. The objections relate in detail to the regulations relating to decompression as well as to those relating to the duties of the compressed air physician. Corresponding suggestions for possible improvements are made in regard to the various points. (English summary)

259.
MASUREL, G., B. Gardette, M. Comet, K. Kisman and R. Guillerm.

Ultrasonic detection of circulating bubbles during JANUS IV excursion dives at sea to 460 and 501 MSW.
In: Program and Abstracts, Undersea Medical Society, Inc., Annual Scientific Meeting. Undersea Biomed. Res. 5 (Suppl.):29; Mar. 1978.

Abstract only. Excerpt quoted: During the JANUS IV dives in the Mediterranean Sea, 4 COMEX divers and 2 GISMER divers in 2 teams of 3 divers each were compressed in 30 h to 430 msw where they spent 6 days and each team performed 1 excursion per day. Five excursions were made to 460 msw and 1 to 501 msw for durations at depth between 2.5 and 5 h and work was performed on a simulated pipeline worksite. The final decompression, 24 h after the last excursion, lasted 185 h and included 5 depth ranges of constant percentage oxygen for each range. A DUG Doppler apparatus was used and the dives were monitored after each excursion and 3 times per day during the final decompression. The bubble grades were evaluated . . . One diver had grade 2 bubbles 1.5 h after the excursion to 501 msw with no clinical symptoms. . . . Pains having characteristics of arthralgia rather than articular bends occurred in 2 divers. In our experience, the bubble grades observed do not indicate an immediate danger for the divers. However such decompression should be improved to minimize the flow of bubbles.

260.
McCALLUM, R.I.

Decompression sickness: A review.
Brit. J. Ind. Med. 25:4-21; Jan. 1968.

This review is concerned with industrial decompression sickness. Records of tunnel projects from 1914 to 1966, giving such data as maximum pressure, length of workshifts, number of decompressions and incidence of decompression sickness are tabulated and discussed. The author traces the development of the understanding of high pressure from Bert (1874) through Haldane, who provided the scientific basis for the 1958 British decompression tables, to the present. The development of health regulations, culminating in those issued in 1958 is also traced; these tables and regulations are considered to be inadequate in some ways, chiefly the insufficiency of the required decompression times. The need for research in industrial decompressions comparable to that carried on with regard to divers is emphasized. The different and complex problems involved in the industrial aspect, largely due to the nature and habits of the personnel involved, are noted. Certain specific aspects of the subject are discussed: the relation of acclimitization to the incidence of bends; the use of oxygen in decompression; respirators in compressed air; gas-detecting instruments; the possible causes and the nature of bone necrosis, lung cysts, neurological complications, deterioration of cerebral function, ECG changes, blood changes; problems of supervision. (MFW/BSCP)

261.
MEESTER, J.N.
Decompression procedures used in Holland.
In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October 1965. Newcastle upon Tyne, Oriel Press, 1967.

The sinking of the Melanie shaft in 1957 resulted in an unacceptable number of cases of bends, and thus to a restudy of the problem and a review of what other countries were doing. This in turn led to a revision of the decompression procedures used in Holland. The working hours were shortened, and the decompression times were calculated by Haldane's method, and the tables were adjusted to agree with the British decompression tables and the U.S. Navy Experimental Diving Unit. (CWS/BSCP)

262.
MENSH, I.N.
Decompression studies.
Eur. Sci. Notes 24(3):81-82; Mar. 31, 1970.

The Third Workshop on Decompression Diseases held in April 1968 in Germany reviews in detail all the problems related to the area of divers employed in caisson construction of underwater tunnels, bridge pilings, etc., as well as free and scuba divers. In the proceedings of the conference, practical experience as well as research is stressed and applications of the knowledge gained from the decompression studies has been seen to result in improved treatment. The document is Proceedings of the Third Working Session on Decompression Diseases, 18/19 April, 1968. Institute of Flight Medicine, DVL/DLR FB 69-58; September, 1969. (CWS/BSCP)

263.
MERER, P.
The efficiency of the decompression schedule used in French civil engineering work since 1959.
In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October 1965, p.84-90. Newcastle upon Tyne, Oriel Press, 1967.

Careful records were kept of all civil engineering work since the new decompression tables were developed in 1959 and the evidence is overwhelming that the tables are not safe. The workers on the Great Vauban Dock in Toulon in 1963, and on the dam of the Rance Tidal Power Station at Saint Malo both experienced a much too high incidence of bends. Animal work carried out using the same tables also showed a serious evidence of danger. One of the defects in the table is the uniform rate of decompression rather than the stage method. The safety coefficient of 2.0 is not reliable in all cases. Further testing is imperative. Length of shift must be seriously considered and a suggestion is made to use "undersea houses" so as not to have to undergo decompression after every shift. (CWS/BSCP)

264.
MERER, P.

Decompression schedules used in French civil engineering work.

In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October 1965, p.31-33. Newcastle upon Tyne, Oriel Press, 1967.

The first decompression tables used in France in Civil Engineering Work were prescribed in 1913. These were found over the years to cause a high occupational morbidity, but it was not until 1959 that any official revision was made and then there was no legal regulation requiring any particular decompression for civil engineering workers. The new tables suggested for use were based on tissue saturation of different tissues and a safety coefficient of 2:1 supersaturation. The decompression times are only fixed for maximum periods of employment and no consideration is given to shorter work periods. (CWS/BSCP)

265.
MERER, P.

Bilan des accidents et manifestations pathologiques survenus sur le chantier de Tramarance (usine Maremotrice de la Rance) et imputables au travail dans l'air comprime.

[Summary of accidents and pathological manifestations occurring in the Tramarance shipyard (tide-driven power plant of the Rance) and ascribed to work in compressed air].

Arch. Mal. Prof. 29:155-156; 1968.

This summary is based on the medical records of 56 serious decompression accidents treated by medical recompression in the period October 1961-November 1962. Fifty cases (89%) of bends with osteomyoarticular symptoms occurred; 21 (42%) had symptoms in one lower leg, 20 (40%) in both lower legs, 8 (16%) in upper members, and 1 (.56%) in the thorax. The number of accidents per worker was 19 with 1 severe accident, 8 with 2 severe accidents, and 7 with 3 severe accidents. Six cases (11%) were treated for vertigo originating in a middle ear condition, paralysis, lipothymia, loss of consciousness, dyspnea and other conditions affecting the general state. Signs of osteonecrosis appeared in only a few cases, but such signs commonly appear after a greater lapse of time. Three cases, 2 in one patient, showed probable osteonecrosis; 4 possible additional cases were noted. The statute of limitation for declaring osteonecrosis to be due to work in compressed air is fixed in France at 10 years after termination of employment. The findings appear to raise doubts of the validity and efficaciousness of the official decompression tables for underwater work in compression chambers, as established by decree of 31 August, 1959; new tables should be developed based on further studies of the present type. (MP/BSCP)

266.
MERER, P.

Plongee professionnelle et prevention, en France, du risque sous-marin.

[Professional diving and prevention, in France, of underwater risk].

Evol. Med. 16(4):325-329; 1972.

The author notes the inadequacy of the French decompression Tables of 1913 and of 1959, both of which ignore the fundamental principal of tissue decompression, stated by Haldane in 1922 and universally accepted since that time. The 1959 Tables are undergoing review. There are no regulations or tables for divers who must work at great depths. A complete revision of underwater regulations adequate to meet current needs is urgently needed. (MFW/UMS)

267.
MILES, S.

Underwater medicine.

J.B. Lippincott Co., Philadelphia, 328p., 1962.

A well written but semi-popular book dealing with all aspects of the problem of working under water. His chapter on 'Decompression' is quite good and should be added to this bibliography, not only for historical reasons, but for the completeness of its coverage. (CWS/UMS)

268.
MILWEE, W.I., Jr.

Operational U.S. Navy diving systems.

In: Progress into the sea. Transactions of the Symposium 20-22 October 1969, Washington, D.C., p.289-296. Washington, D.C., Marine Technology Society, 1970.

The ADS IV, a diving system developed by Ocean Systems, Inc. was the first to be used by the Navy. Having become acquainted with the problems and requirements involved, the Navy then went on to develop more adequate systems, the first of which was the Mark 1 Deep Dive System, which was designed to meet the following requirements: a depth capacity of 850 feet; suitability for use in observation, bounce, or long-term saturation dives; transportability by air; adaptability for use with older ships as well as with the new ATS. Diagrams and photographs show the system and how it operates; the life support system and the life support package are illustrated. The system consists principally of two Deck Decompression Chambers (DDC's) and a Personnel Transfer Capsule (PTC). An entrance lock connects the two DDC's and a furnished transition area between the PTC and the DDC's, also permitting different pressures to be maintained simultaneously in the two chambers. The PTC is a 79-inch HY80 steel sphere. It normally carries an operator and two divers, and has a completely independent life support system, with lines to the surface for use if needed. Voice communications are made by hardware; there is a hydrophone as standby equipment. Divers are monitored by TV from the main control console. At time of writing (fall, 1969) the system had been satisfactorily tested to a depth of 450 feet. In the last of the 450 foot dives, the divers saturated at 300 feet and decompressed on a saturation schedule. Decompression schedules have been validated for 60-minute dives at 450 feet, and are being validated for greater depths. (MFW/BSCP)

269.
MOELLER, G.

STANDIVE, FORTRAN solution of decompression equations.

U.S. Nav. Submar. Med. Cent. Rep. 465, 10p. Jan. 20, 1966.

STANDIVE is a digital computer program devised for the solution of decompression problems in stop-type dives. Its intended uses are to generate diving tables to meet practical needs and to explore the implications of various theoretical assumptions about decompression. The program computes partial pressure for two components and total inert gas in each of nine tissues for each stop. The calculations may be completely specified by input to the computer, or the dive plan, as well as the calculations, may be generated by the computer. The report describes the program through flow charts, sample outputs, a catalog of inputs, and description of program applications to date. A FORTRAN listing and program glossary are provided. (Author's abstract)

270.
MOLUMPHY, G.G.

Computation of helium-oxygen decompression tables.

U.S. Navy Exp. Diving Unit, Rep. 7-50, 25p. Sept. 25, 1950.

A complete, detailed description and illustration of the computation of decompression tables, assuming a 300-foot dive on helium 77%-oxygen 23% mix, using the stage method. (CWS/UMS)

271.
MOLUMPHY, G.G.

Evaluation of newly computed helium-oxygen decompression tables at depths greater than provided for in the published tables. The effectiveness of the improved recirculation system and the feasibility of accomplishing useful work by highly trained and conditioned divers at these depths.

U.S. Navy Exp. Diving Unit, Rep. 9-50, 7p. Oct. 19, 1950.

[It was concluded] that the present recirculating system of the helium-oxygen helmet adequately provides for the removal of CO_2 and moisture; that the enclosed decompression tables are safe for 10 minute exposures to 561 feet; that shifting the first oxygen stop from 60 to 50 feet has reduced the incidence of oxygen poisoning; that equipment now on hand permits diving to depths in excess of 500 feet; that the accepted physics of decompression is not valid for working dives to depths in excess of 430 feet for exposures greater than ten minutes, but can be used as a guide for the development of safe tables; that longer and possibly deeper early stops are necessary to prevent bubble formation and subsequent bends; that whether or not tissues slower than the 70 minute must be considered, must await further experimental work; that the incidence of surface interval and post dive bends and mild bends may be reduced by taking a greater part of the 40 foot stop in the water when surface decompression is followed. Present procedure calls for a 40-foot water stop equal in time to the 50-minute stop. There is some evidence that the decompression period after surfacing should be limited to about 80 minutes; that better helium elimination may be obtained by shifting to a helium-oxygen mixture containing a higher percentage of oxygen than used during the dive when reaching the first stop. (Author's conclusions)

272.
MOMSEN, C.B.
Report on use of helium oxygen mixtures for diving.
U.S. Navy Exp. Diving Unit, Rep. 2-42, 67p. plus append. Apr. 1939, revised Oct. 1942.

The results of using a helium-oxygen breathing mixture were studied from 1 September 1937 to 1 April 1939, during which time almost 700 dives were made. It was found that the diver was much more comfortable because of the increased ventilatory efficiency of the mixture as compared with air. The reduced sense of depth made for an improved mental attitude. Decompression time was shorter because of the lower water fat solubility ratio of helium. Helium-oxygen decompression tables differ from nitrogen tables because a larger volume of gas is concentrated in the faster desaturating part of the body and the rapid diffusion of gas from one part of the body to another requires the keeping of the body at higher pressures for a longer period during the primary period of the decompression. Appended to the report are the following: "The treatment of compressed air illness utilizing oxygen," by O.D. Yarbrough and A.R. Behnke, and "Physiologic studies of helium," by A.R. Behnke and O.D. Yarbrough. (MFW/UMS)

273.
MORETTI, G.
The theory of decompression and the calculation of decompression tables for diving with air, according to the procedure of American authors.
Ann. Med. Nav. (Roma) 69:235-266; Mar./Apr. 1964.

In this report, the author has illustrated the procedure for step-by-step calculation of air decompression schedules adopted by U.S. Navy A.A.; he has premised in summarizing form the basic theory of experimental saturation and tissue ratios. Tabulation of the time function and worksheet for the calculation and tabulation of decompression schedules are reported in appendix. (EH/BSCP)

274.
MORETTI, G. and S. Fontanesi.
Esperienze di immersioni profonde con miscele elio–ossigino.
[Experiments in deep diving with helium-oxygen mixtures].
Ann. Med. Nav. 79:511-538; Oct./Dec. 1974.

At the hyperbaric facility of the Italian Navy (COMSUBIN) in La Spezia trials were carried out of dives up to the depth of 492 ft (150 m) with heliox mixtures as media; the most significant results, both physiological and operative, are reported. The research has proved the validity of the decompression schedules worked out at COMSUBIN, so that a standardization of these procedures for the most advanced underwater activity of the Italian Navy can be recommended. (English summary)

275.
MORETTI, G., S. Fontanesi and L. Ghittoni.
La mallattia da decompressione: analisi di una serie di 96 casi trattati nello ambito della marina militare nel triennio 1969-71.
[Decompression sickness: Analysis of a series of 96 cases treated under the auspices of the Italian Navy, 1969-1971].
Ann. Med. Nav. 78:499-522; Oct./Dec. 1973.

The authors summarize a series of 96 cases of decompression sickness with emphasis on evaluating the recompression-decompression therapeutic protocol. Most patients underwent recompression-decompression in accordance with Van der Aue's table; in a few cases, Workman's Table was used. Osteo-myoarthralgic symptoms regressed completely under Van der Aue type repressurization therapy, but neurosensory symptoms were resolved only about 60% of the time. It is suggested that in cases with cardiorespiratory involvement, as well as in cases with neurosensory symptoms, the Workman-Goodman method, using pure oxygen, may be preferable. The authors note also that in "Neurosensory" cases in which treatment is instituted within 5-6 hours of the decompression accident, the prognosis for complete cure is greatly improved. (MEMH/UMS)

276.
MORITA, A., Y. Gotoh and I. Nashimoto.
Incidence of decompression sickness in relation to decompression schedules in a caisson work.
In: Program and abstracts. Undersea Medical Society annual scientific meeting, May 13-16, 1977, Toronto, Canada, p.A25. Undersea Biomed. Res. 4, Mar. 1977. Appendix A.

Abstract only. Entire item quoted: Since 1961, two decompression tables have been established in Japan. In most of caisson works, however, these tables have not been employed because of the restriction of working time, but empirical decompressions have been carried out with the foremen's skill. Recently we investigated the incidence of decompression sickness in relation to decompression schedules in a caisson work. The working pressure was 1.1 - 3.2 kg/cm^2C and the working period was 235 - 740 min. Total numbers of decompression and of the sickness were 824 and 37 respectively. The overall incidence was 4.5%. There was found difference in bends rate among three working groups (1.9 - 13.2%), which seemed to depend on foremen's skill in decompression. Furthermore, modified Blackpool tables were used on trial for the decompression of prolonged work at relatively high pressures exceeding 2.0 kg/cm^2C. Precordial bubble signals (ultrasonic doppler method) were monitored during and after decompression, or only after decompression. The signals were heard in 18.2% of men under decompression according to the modified Blackpool tables, while in 55.6% in the case of empirical decompression. Incidence of decompression sickness were 4.5% in the former and 11.1% in the latter. From these results, the modified Blackpool tables seem to be rather effective in preventing decompression sickness for prolonged compressed air works.

277.
MORITA, A., Y. Gotoh and I. Nashimoto.
[Comparison of decompression method between diving worker and compressed air worker in their empirical way].
J. Saitama Med. Sch. 5:233-237; 1978.

Information about the knowledge of decompression sickness was obtained through questionnaires sent to 199 diving fishermen and 70 compressed air workers. Ninety-one percent of divers and 97% of compressed air workers knew about decompression sickness. Only 15% of divers and 16% of compressed air workers decompressed according to the established tables. Fifty-three percent of divers and 57% of compressed air workers thought that it was natural or unavoidable for them to suffer from decompression sickness. The results showed that most of them did not take decompression sickness seriously. Their empirical decompression schedules were analyzed with an analogue computer. The decompression stops in diving were generally deeper than those in compressed air work. It was suggested that the empirical decompression schedule in diving was effective for preventing decompression sickness compared with those in compressed air work. (English abstract)

278.
MORRISON, J.B.

Pneumatically controlled mixed gas underwater breathing apparatus.
Mar. Technol. Soc. J. 12:8-12; Aug.-Sept. 1978.

A pneumatically controlled gas mixing system was developed to supply semi-closed circuit underwater breathing apparatus with O_2-N_2 or O_2-He gas mixture of constant oxygen partial pressure irrespective of ambient pressure. Variations in counterlung P_{O_2} are dependent only on diver activity and can be present to desired limits by adjusting the flow of oxygen and inert gas. A prototype of the control system was constructed and installed in a rebreathing apparatus for experimental testing. A series of O_2-N_2 chamber dives was undertaken involving wet working dives to 20, 30 and 50 meters to test the response of the control system. Self-contained decompression was accelerated by closing off the inert gas supply and utilizing oxygen breathing compression tables. Experiments were successful and indicated that this type of apparatus is suitable for self-contained diving to 75 meters and to greater depth with an umbilical supply of helium. (Author's abstract)

279.
MOUNT, T. and A.H. Ikehara.

Practical diving.
Coral Gables, Fla., of Miami Press, 1975. 191p.

This is a well written and illustrated handbook for serious divers from students to instructors, written by two experienced professionals. It includes tabular dive and decompression data, discussions of diver qualifications and safety precautions. The diving and training programs at the Rosenstiel School of Marine and Atmospheric Science (University of Miami) are used to illustrate qualification requirements at various levels of proficiency. This text has already been adopted by advanced scuba training programs. A most useful and practical adjunct for any such program, but also for any diver. (Sea Frontiers)

280.
NASHIMOTO, I.

Decompression schedules in civil engineering work in Japan.
In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October 1965, p.46-55. Newcastle upon Tyne, Oriel Press, 1967.

Tables for decompression were developed in 1960 based on the assumption that there are half-time saturation tissues of five, ten, twenty, forty, seventy-five and one hundred and twenty minutes and that they are saturated and desaturated symmetrically with nitrogen by an exponential law. The value of 1.76 was adopted as a safe threshold ratio of tissue pN_2 to ambient pressure. Complete tables are presented for all levels of saturation and pressure. An interesting nomogram is presented which enables one to handle the problem of successive shifts which increase the hazard of decompression sickness. (CWS/BSCP)

281.
NASHIMOTO, I.

A method of adjusting decompression schedule for repetitive high pressure exposures.
In: Wada, J. and I. Takashi, eds. Proceedings of the fourth international congress of hyperbaric medicine, Sapporo, Japan, Sept. 1969, p.105-108. Baltimore, Williams and Wilkins, 1970.

The author discusses the problem of accumulated nitrogen in the tissues, when two compressions are undergone within a period (6 to 12 hours) insufficient for the elimination of nitrogen. A nomogram is developed which takes this factor in account. By giving the values of the residual gas pressure coefficient in the decompression table, the time between two successive compressions, and the subsequent working pressure in the nomogram, the adjustment time is obtained. This adjustment time is added to the actual exposure time, thus giving a schedule adequate for successive compressions. (MFW/BSCP)

282.
NASHIMOTO, I. and Y. Baba.

Regulation and decompression schedule for diving work in Japan.

In: United States-Japan conference on natural resources development. Proceedings of the first joint meeting of the U.S.-Japan panel on diving and technology, Tokyo, 1972, p.95-99. Japan, Ministry of Agriculture and Forestry, 1972.

The Japanese regulations governing industrial diving and compressed air work are described. There are now in Japan 20,000 licensed divers who have completed the required training, which covers diving operations, apparatus and equipment, air supply, descent and ascent, and pressure-related disorders. Most of the professional divers are fishermen; the remainder are salvage or underwater construction workers. There are two accepted decompression tables: one for compressed air workers who work at 1.0 kg/cm^2 with two shifts a day, and the other for both divers and compressed air workers who work at 1.0 to 9.0 kg/cm^2 or at depths from 10 to 90 m, without limitation on number of exposures. The tables include diving depths, bottom time, decompression stops, residual gas pressure coefficient, required time between exposures, required time after final exposure that a diver or worker must remain at or near the work site so as to be near recompression equipment, and the upper limit of total working time diving one day. A special nomogram has been devised to provide for the dangers of repetitive diving. (MFW/UMS)

283.
NASHIMOTO, I. and Y. Mano.

Oxygen decompression–its effectiveness in preventing decompression sickness and shortening decompression time.

In: United States-Japan conference on natural resources development. Proceedings of the first joint meeting of the U.S.-Japan panel on diving and technology, Tokyo, 1972, p.122-129. Japan, Ministry of Agriculture and Forestry, 1972.

The disadvantages of oxygen decompression are: 1) the danger of oxygen toxicity and 2) the increased fire hazard. The latter has been considerably lessened by the development of breathing equipment which discharges expired oxygen directly out of the chamber. In a recent total of 1,417 trials in Japan, 1,381 used oxygen decompression. In the oxygen breathing group, the incidence of decompression sickness was 1.32%, while in the remainder it was 8.93%. For deep and prolonged diving, oxygen decompression should be very useful. (MFW/UMS)

285.
NASHIMOTO, I.

Effectiveness of decompression tables used in compressed-air works in Japan.

In: Proceedings of the second joint meeting of the Panel on Diving Physiology and Technology, August 24-27, 1973, Seattle, Washington, p.76-79. United States-Japan Cooperative Program in Natural Resources, n.d.

In Japan, since 1961, two decompression tables have been used for compressed air workers. Table 1 is for exposures between 1.0 kg/cm^2 and 4.0 kg/cm^2 for two work periods per day. Table 2 is applied to compressed air workers exposed to as much as 9.0 kg/cm^2, and also to diving to depths of 10 - 90 meters. The effectiveness of Table 1 was tested during the sinking of the piers in Tagonoura Harbor which took 3½ months. Out of 4,042 total man-shifts, there were 32 mild cases of decompression sickness, all occurring after the second exposure. The U.S. Navy treatment tables were successful in the treatment of all cases. (MFW/UMS)

286.
NASHIMOTO, I. and Y. Mano.

Experimental studies on oxygen decompression.

In: Trapp, W.G., W.E. Bannister, A.J. Davison and P.A. Trapp. O_2. Fifth international hyperbaric congress proceedings, p.900-904. Burnaby, Canada, Simon Fraser University, 1974.

The purpose of this study was to devise oxygen decompression tables for compressed air work and to study the effectiveness of oxygen decompression as compared with air. Oxygen was breathed at the first decompression stop. A specially designed oxygen breathing apparatus was used to prevent fire hazards. Oxygen was released automatically out of the air lock. During the experiment, the oxygen decompression group had 1.32% incidence of bends, while the air decompression group had 8.93% incidence. Oxygen decompression tables for 2.0 kg/cm^2 pressure and for 4.0 kg/cm^2 pressure are given for working times of from 30 to 480 minutes. Total decompression times ranged from 13 to 98 minutes at the lower pressure, and from 35 to 190 minutes at the higher. (MFW/UMS)

287.
NASHIMOTO, I. and Y. Gotoh.
[Automation of decompression method in the prevention of decompression sickness].
Jap. J. Hyg. 30:265; Apr. 1975.

Abstract only. Entire item translated: By combining a manometer and compartments of orifices and capacities of various sizes, a biological model with an inert gas exchange rate of 10-120 min. was prepared. The apparatus was further fitted with a maximum safety pressure indicator. By applying various pressure for different lengths of time, inert gas exchange in vivo was simulated at the same time decompression was conducted according to the maximum pressure indicated in the apparatus. The procedure was compared with the decompression schedule shown on a conventional decompression chart. The authors found this apparatus to be a more accurate indicator of the proper decompression schedule and expect to improve the technique for a wider and more practical application. (OLC/UMS)

288.
NASHIMOTO, I., Y. Gotoh and A. Morita.
[The present state of decompression sickness in compressed air works—Survey of decompression sickness in a caisson work].
J. Saitama Med. Sch. 4:171-174; 1977.

Decompression sickness was investigated in a caisson work. The working pressure, the working time and the decompression profiles were recorded in a barograph. The working pressure was 0.9-3.3 kg/cm^2G. The total number of workers and the cases of decompression sickness were 2,037 and 130, respectively. The incidence of the sickness was 6.4% on an average and reached to a peak of 29% at 2.5 kg/cm^2G. The decompression time in the majority of cases was shorter compared with those based upon the established decompression tables. It is clear from these data that the high incidence of decompression sickness is caused by unsuitable decompression. (Authors' abstract)

289.
NIKOLAEV, V.P.
Formation of gas bubbles in supersaturated solutions and in the living organism during decompression.
Space Biol. Med. 3(5):78-87; 1970. (JPRS 49533).

Basic characteristics of gas solutions within fluids are discussed and the mechanisms of bubble formation in supersaturated solutions and in body fluids during decompression are described. The new data obtained with respect to the structure of fluids suggest a hypothesis of the origin and nature of gas nuclei in fluid. The theory of the bubble nucleation mechanism in a living organism is discussed. (Author's abstract)

290.
NIMS, L.F.
Environmental factors affecting decompression sickness. Part I. A physical theory of decompression sickness.
In: Fulton, J.F., Decompression Sickness, p.192-222. Philadelphia and London, W.B. Saunders Company, 1951.

He presents "an hypothesis which accords a quantitative mathematical description of the physical facts of the syndrome" of decompression sickness and its cause by formation of bubbles in the blood stream and the tissues. He speaks of deformation pressure in the tissues as causing pain by stretching and eventual rupture of tissues, and explains pain by the "postulate that when the deformation pressure (D) exceeds a threshold value (D*) nerve fibers or endings are stimulated by the mechanical deformation of the tissues." (CWS/UMS)

291.
NINOW, E.H.
Undersea medicine.
Aerosp. Med. 42:691-692; June 1971.

In this report of the Undersea Medical Society the president, Dr. Ninow, notes that the 42nd Annual Scientific Meeting of the Aerospace Medical Association was the occasion of the fifth anniversary of the founding of the Undersea Medical Society. The subject of the scientific session of this meeting was "An international open decompression data bank." The discussion stressed the potential application of electronic data processing and information management systems to the development of effective decompression procedures. Dr. C.J. Lambertsen, who opened the discussion, stressed the need for the development of an international decompression data bank. (MFW/BSCP)

292.
NISHI, R.Y. and L.A. Kuehn.
Digital computation of decompression profiles.
Downsview, Ont., Can., Def. Civ. Inst. Environ. Med., Rep. DCIEM-884, 28p. Jan. 1973. (AD 765 704/2).

The Kidd-Stubbs pneumatic analogue decompression computer is used for the real-time prediction of the safe ascent depth following an excursion to depth. The theoretical model which is derived from the decompression computer can be solved using numerical techniques on a digital computer, or can be solved on an analogue computer. This report describes a series of Fortran IV programs which have been written to solve this theoretical model under a variety of conditions. The basic program can be used to calculate the safe ascent depth for a standard dive or for repetitive dives, and if desired, the safe ascent height for flying after diving. Modifications to the basic program are described which permit the use of the model for applications such as the design of pneumatic computers and the analysis of decompression tables. (Author) (GRA)

293.
OHRESSER, P., J. Tassy, J.F. Amoros and J. Dor.
Les accidents de plongee: A propos de 75 observations recueillies en 3 ans.
[Diving accidents: 75 cases collected in three years].
Maroc Med. 52:445-447; 1972.

The author discusses the frequency and general characteristics of various types of diving accidents, including cerebral accidents, pneumothorax, bends, and neurological accidents, and recommends treatment procedures. Since most diving accidents can be traced to disregarding or misuse of the decompression tables, the author recommends a strict adherence to the appropriate decompression procedures, and applauds the educational work undertaken by the diving clubs in this regard. (MEMH/SCD)

294.
PACE, N.
Environmental physiology syllabus. A lecture supplement.
Berkeley, Cal., Univ. Cal., 1970. 79p.

This is a data book for use in connection with a course in physiology. Some of the diagrams and tables of interest to the underwater physiologist describe the light intensity at various depths, oxygen toxicity at various PO_2 and at various exposure durations, effects of age and obesity on bends susceptibility, U.S. Navy decompression tables, Bateman threshold decompression curves, and conversion factors of pressure terms (such as atm and bar). (MFW/BSCP)

295.
PARC, J., L. Barthelemy, A. Michaud and J. Le Chuiton.
Problems poses par la plongee profond d'intervention.
[Interventional deep diving problems].
Rev. Physiol. Subaquatique Med. Hyperbare 1:103-105; Oct./Dec. 1968.

The authors bring forward some solutions to the intricate problems raised by dives of medium duration (from 30 to 90 minutes) at medium depths (from 100 to 150 meters). The cold problem is in part solved by a new heated neoprene suit with a compensated pressure. The respiratory system contains 40% of nitrogen and 50% of helium and decompression tables calculated according to Haldane method have been completely satisfying. It has been possible to apply with success to actual dives these as yet experimental solutions. (English summary)

296.
PARTRIDGE, C.H.
The decompression procedure at Auckland Harbour Bridge, New Zealand, and its effectiveness.
In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an International Working Party held at the Ciba foundation, London, October 1965, p.162-169. Newcastle upon Tyne, Oriel Press, 1967.

A review of the decompression procedures in New Zealand reveals that in general their decompression follows the United Kingdom code and table. They had a 3.3% incidence of compressed air illness. They found that they were much better off to reject all fat men, and individuals susceptible to the disease should also be eliminated. The oxygen in treatment is recommended. (CWS/BSCP)

297.
PATON, W.D.M.
The physiological basis of the British decompression table of 1958.
In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an International Working Party held at the Ciba Foundation, London, October 1965, p.2-13. Newcastle upon Tyne, Oriel Press, 1967.

A review was conducted of the areas of interest considered in the 1947 determination of the appropriate decompression for industrial use in Britain. The original study had considered the following: decompression—the safe exit saturation, i.e., 22 p.s.i.g. or 18, 15, or 12; saturation and shift length was considered to be 5 hours for complete saturation; varying working pressures; phase decompression or working at lower pressure areas during the locking out process; decanting or being decompressed entirely apart from the working area; and medical precautions such as age limits, selection and examination. In the intervening 20 years new knowledge had accumulated indicating the need to revise the decompression tables: acclimatization has been demonstrated; five hours does not provide complete saturation; bends may occur at pressures below 18 p.s.i.g.; the 2:1 ratio may not be safe; there is evidence of bone disease associated with compressed air work; and the importance of lung pathology is shown. (CWS/BSCP)

298.
PELLEGRINI, L.
Working at depth without decompression.
In: Eaton, B., ed. The undersea challenge. Proceedings of the Second World Congress of Undersea Activities, p.133-138. London, The British Sub-Aqua Club, 1963.

Divers receiving air from a surface unit are working for 7 hours at a depth of 25 meters and surface immediately without decompression. This has been going on for several months without any even minor case of embolism occurring. The Moss 55 Mark I or "Micoperi" unit that provides air to the divers is described. It delivers to the diver a mixture of pure oxygen and air. The unit can deliver either oxygen or air alone as well as a special mixture of oxygen and nitrogen. Work is in progress to develop a new unit which will permit safe work at a depth of 70 meters and immediate surfacing without stops for decompression. The questions following the talk reported here brought out the information that the partial pressure of oxygen in the mixture supplied to the divers was between 1.6 and 1.8 kilograms per square centimeter and that the mixture could not be used with a standard diving helmet. (ART/BSCP)

299.
PELLEGRINI, L.
Immersioni nel gelo: motivi e problemi.
[Diving in the cold: motives and problems].
In: [Proceedings of the first national symposium of the Italian Committee on Underwater Research, Rome, 11-12 Oct. 1974]. p.58-60. Published by Il Subacqueo.

Difficulties and rewards of sport diving in very cold water and under ice are discussed. The rewards of unusual underwater sights, including seals and penguins, giant algae, and the kaleidoscopic colors of sunlight shining through the ice, are great. The problems include transportation of equipment (especially to Alpine lakes), protection from cold in the water and while dressing and undressing, and the necessity for changing breathing mixtures and decompression schedules for high altitudes. Industrial applications of cold-water diving are foreseen, especially in petroleum exploration. (MEMH/UMS)

300.
PETERSON, R.E., K.M. Greene and C.J. Lambertsen.
Decompression from excursion exposures.
In: Lambertsen, C.J., R. Gelfand and J.M. Clark. Predictive Studies IV. Work capability and physiological effects in He-O_2 excursions to pressures of 400-800-1200 and 1600 feet of seawater, p.G1-1 - G1-20. Philadelphia, Pa., Univ. Pennsylvania Med. Cent., Inst. Environ. Med., 1978.

If excursions greater in degree than those allowed by the U.S. Navy Unlimited Excursion Table must be made, then the decompression system developed for these studies can be the basis for developing decompression procedures for many different exposures. Without further practical trial this approach is not without risk, and two precautions are recommended: a) The exposure used as the basis of schedule calculation should be a conservative one, by reducing either the exposure time or depth used in this study. b) Although therapeutic recompressions in both Phases I and II did not exceed the saturation depth by more than 250 fsw, availability of surface-based saturation capability to the maximum depth of excursion is recommended for the treatment of decompression sickness. The time-weighted calculation technique devised for these simulated saturation-excursion dives should be applicable to solution of decompression requirements for many other exposure situations, including less extreme circumstances. Specific investigation is necessary, however, to describe accurately the relationships of duration and excess gas pressures in precipitating decompression sickness in order to exploit this technique over the full range of its applicability. (Author)

301.
POWELL, M.R., W. Thoma, H.D. Fust and P. Cabarrou.
Gas phase formation during decompression with elevated oxygen partial pressures (1.5 - 2.5 bar).
In: Program and Abstracts, Undersea Medical Society, Inc., Annual Scientific Meeting. Undersea Biomed. Res. 5(Suppl.):20-21; Mar. 1978.

Abstract only. Entire item quoted: Decompressions attendant with partial pressures of oxygen in the range of 1.5 to 2.5 bar afford a large savings of total decompression time. Computer calculations of mixed gas tensions in tissues with half-times of 5 to 120 minutes give the maximum inert tension ratio as 1.20. The inert gas tension ratios average 1.14 during decompression in the depth range of 12 to 20 meters. Oxygen partial pressures average 1.9 bar, and decompressions from a depth of 200 meters typically can be accomplished in less than 8 hours. Of interest is the role of oxygen in this methodology; specifically is it aiding in inert gas elimination (via the "oxygen window") or is it treating bubbles formed during the decompression phase? We have monitored 34 human divers in the depth range of 150 to 200 meters with a doppler ultrasound flowmeter in the precordial mode. Detectable bubbles could be found in only 20% of the divers, most of which were asymptomatic. Bubbles were found mostly in the depth ranges of 20 meters to the surface. None were found deeper than 25 meters even on the 200 meter dives. We conclude from these studies that oxygen tensions in the range of 1.5 to 2.4 bar are of value in aiding inert gas elimination, and tables based on this methodology should not simply be considered as treatment tables for deep-generated gas phases.

302.
REED, C. and M. Hawes.
Dive planning: take time for the tables.
Diver Underwater Adventure 4:18-20; June 1978.

U.S. Navy tables 1-11, No-decompression limits and repetitive group designation table for no-decompression air dives, 1-12, Surface interval credit table for air decompression dives, and 1-13, Repetitive dive time table for air dives, are reproduced here. Table 1-11 is the safest table in existence for use by a sport diver. The way to use tables 1-12 and 1-13 is explained. A problem is presented in which the purpose is to determine the maximum safe bottom time during a repetitive dive at a given depth that will make it possible to avoid decompression, and also to determine the minimum safe surface interval between dives at given depths that will make it possible to dive to a given depth for a given period without decompression. (MFW/UMS)

303.
REESE, K.M.
GE divers come up with antibends device.
Chem. Eng. News, p.32; Nov. 12, 1973.

Two scuba diving scientists from General Electric have invented a wrist computer that replaces tables currently used to avoid bubble formation while ascending. The computer device calculates decompression schedules continuously over variations in depth and time, while the U.S. Navy decompression tables are limited to specific depths and durations. The computer device, it is claimed, permits longer dives and faster decompressions. The computer simulates the different absorption rates of muscle, fat, and cartilage in the body, and indicates when a decompression stop is required, and when the ascent can continue to the next level. At present the device weighs nine ounces, is 2.75 inches in diameter, and 2 inches thick. With design refinement, it is believed possible to reduce the size by half. (MFW/SCD)

304.
REEVES, E. and E.L. Beckman.
The incidence of decompression sickness in dogs following 7, 12, 18, and 24 hour saturation dives with 'no-stop' decompression.
Report No. 4, Nav. Med. Res. Inst., Bethesda, Md., 1966.

The bends threshold for "no-stop" decompression dives to various pressures and for durations of 7, 12, 18, and 24 hours was determined on a group of male dogs of various weights from 48-82 lbs. The bends threshold under these experimental conditions was found: 1) to be consistent and reproducible for each individual animal; 2) to vary between animals from 57-86 feet of water pressure; and 3) to be smaller at durations of pressure exposure of 18 and 24 hours than at 7 hour exposures. (Authors' abstract)

305.
RICCI, G.C., P. Baldi and M. Lettieri.
La ricompressione terapeutica di emergenza in acqua: Presentazione di principi ed orientamenti medici e tecnologici (1).
[Emergency therapeutic recompression under water: Presentation of medical and technological principles and methods].
Ann. Med. Nav. 83:15-24; Jan.-Mar. 1978.

Emergency underwater recompression therapy with compressed air should be carried out in accordance with Table 1A. There seems to be no contraindication of the use of oxygen in underwater recompression. In using oxygen tables under water, it is not necessary to apply the complete table starting from 2.8 ATA. A shorter recompression starting from 2.2 ATA or less is sufficient. The authors emphasize the benefit of a 50/50 nitrogen-oxygen recompression table in accordance with the GERS-COMEX short table. This table should be administered by a diving doctor or by a very well trained individual, capable of evaluating the environmental conditions, the breathing apparatus, the pathogenesis and the pathophysiology. Pharmacological therapy should consist of liquids, corticoids, and acetylsalicylic acid or its derivatives. These can be administered orally, intramuscularly, or intravenously, whether or not a doctor is present. (MFW from English summary)

306.
ROBERTSON, J.S. and G. Moeller.
Computation of continuous decompression schedules for deep sea dives.
Brookhaven Nat. Lab. Rep. 501404 (T0490); U.S. Nav. Submar. Med. Cent. Rep. 517, 37p. 1968.

A digital computer program for calculating either continuous ascent or stop-type decompression schedules is described, and examples of applications are given. The formulas used for continuous ascent were obtained analytically as solutions of differential equations relating the inert gas tension in the current critical tissue to the safe depth and with the actual depth kept equal to the safe depth at all times after an initial fast rise from the bottom to the safe depth. Thus the rate of decompression of the critical tissue controls the rate of ascent. Gas tensions in nine tissues having the same range of gas exchange half-times as have been used in EDU reports are calculated on a continuous basis, with the one having the deepest safe depth being the current critical tissue. The stop-type ascent portion of the program may be used to generate a staged ascent using the same parameters for comparison with the continuous ascent schedule. The starting conditions for ascent may either be computed by the program from the dive history or be communicated to it as a subroutine in connection with another program. The program may be used either to prescribe ascent schedules or to analyze dives for which the history is known. (Authors' summary)

307.
ROBINSON, E.S.
Decompression procedure at the Highbury Tunnel, Vancouver.
In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October 1965, p.28-30. Newcastle upon Tyne, Oriel Press, 1967.

The first major compressed air project in 30 years was the construction of the tunnel at Highbury, Vancouver, British Columbia in 1961. The schedule for decompression dating from 1933 was based on the N.Y. state split shift system. This was modified for continuous shift and based on saturation in five hours. Shorter acclimatization shifts were used for new workers or for those absent from work more than five days. Everyone had to stay around one hour for observation and all cases were treated by recompression. Careful medical examination and frequent inspection were employed. (CWS/BSCP)

308.
ROSE, R.J., ed.
Survey of work in compressed air, Auckland Harbor Bridge.
Wellington, New Zealand, Medical Statistics Branch of the Department of Health, 1962. 108p.

Decompression sickness resulting from caisson work is described and analyzed. The conclusions drawn in the report agree with those in an earlier report on the construction of the Tyne tunnel, as to the wide variation in individual susceptibility, the phenomenon of acclimatization, and the direct relationship of the increased incidence of "bends" with increased work pressure. A new system of decompression called "decanting" was used, in which men were rapidly decompressed, transferred to a larger chamber, rapidly recompressed, then decompressed at a normal rate. Findings indicate that bubbles formed during the decanting (or rapid decompression); caution in using this method is advised. Two cases of bone necrosis are described, one of which occurred after a single exposure at only 20 p.s.i.; further study of this aspect of decompression sickness is apparently required. Inadequacies of the decompression tables that were in general use at the time are generally indicated, although the use of "decanting" makes evaluation difficult. (MFW/BSCP) (From a review by Paton, W.D.M., Brit. J. Ind. Med. 20:253-254; 1963)

309.
ROYAL NAVAL PHYSIOLOGICAL LABORATORY.
Experimental observations on men at pressures between 4 bars (100 ft) and 47 bars (1500 ft). Report 1-71.
Alverstoke, UK, published by the Laboratory, 1971. 133p. plus illustrations.

This is a detailed and extensive report of four dives which took place in late 1969 and early 1970 at the Royal Naval Physiological Laboratory at Alverstoke. It is divided into the following sections: Planning and organization, the control and maintenance of the pressure vessel, respiratory function, neurophysiological, psychological, biochemical and other physiological studies; medical aspects and decompression. Each section is fully illustrated with photographs, tables, charts and diagrams. Parts of the report have been handled separately and will be found under the following author entries: Barnard, E.E.P.; Bennett, P.B.; Eaton, W.J.; Morrison, J.M. (MFW/BSCP)

310.
ROZSAHEGYI, I.
Decompression tables in civil engineering in Hungary.
In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October 1965, p.41-45. Newcastle upon Tyne, Oriel Press, 1967.

The first obligatory regulation of decompression was established in 1929. This was completely overhauled in 1950 and again revised in 1953 and in 1960. A decompression table for maximum work period is presented which shows 5 min. decompression from an exposure to 12.8 p.s.i.g. to 60 min. for exposure to 48.7 p.s.i.g. In the first part of the decompression the pressure is reduced at a speed of 2.1 p.s.i.g./min. until half the gauge pressure is reached, and then decompression must be continued slowly in such a way that the whole decompression time is not less than that given in the schedules. However, since this was found to require modification the author constructed a much more conservative table based on the experience of several other nations which may be officially adopted. (CWS/BSCP)

311.
RUFF, S. and K.G. Muller.
Theorie der Druckfallbes Chwerden und ihre Andwendung auf Tauchtabellen.
[Theory of decompression sickness and its application to diving tables].
Int. Z. Angew. Physiol. 23:251-292; Dec. 3, 1966.

The decompression sickness is caused by localized gas bubbles in the body tissues resulting from dissolved gas. The basis for a calculation of these bubbles is derived. Only the inactive permanent gases which are not involved in respiration as e.g. N_2 He, are of interest. The bubble grows due to the deriving tension of these gases between tissue and bubble where approximately the gas tensions of the surrounding atmosphere exist. The ratio of this tension in the bubble appears as the governing quantity; its time integral is proportional to the size of the bubble. In a special tissue the size of the bubble, multiplied by the relative sensitivity of the tissue, can be chosen as a measure for the intensity of the bends. From the limit for the appearance of bends a critical size of the bubble can be calculated for each tissue. These considerations are specialized for a simple decompression in 3 stages and applied to the tables of the U.S. Navy diving manual. It can be demonstrated that the first pressure stage of the tables under high pressure must be far below the critical limit for the appearance of bends. The relative sensitivity of the tissue must decrease with increasing half life period for the gas exchange tissue-surrounding atmosphere. (Authors' summary)

312.
RUFF, S.
Experimental and theoretical investigation of the decompression problem.
Bad Godesberg, West Germany, Deutsche Forschungs- und Versuchsanstalt fur Luft- und Raumfahrt, Rep. DLR-FB-71-48, 101p. Oct. 7, 1971. (N72-20075).

The bubble in the organism is recognized as the governing quantity for the construction of safe decompressions. On this basis and using the empirical material, a set of allowed gas tensions in the tissue is proposed. From this, decompression schedules for arbitrary dives in helium-nitrogen mixtures can be calculated. An expression for the bubble growth in the organism during a decompression is developed and applied to the discussion of the allowed gas tensions proposed here. In the appendix dives of the institute and the decompression schedules of the U.S. Diving Manual are analyzed. (Author) (STAR)

313.
SAYERS, R.R., W.P. Yant and J.H. Hildebrand.
Possibilities in the use of helium-oxygen mixtures as a mitigation of caisson disease.
Rep. Invest. U.S. Bur. Mines, No. 2670, 15p. 1925.

Helium is without odor or taste and has physical properties which promise to be of interest physiologically and which have been found to have possibilities of great practical use, especially in making a synthetic atmosphere that will reduce the hazard of caisson disease. The substitution of helium for the nitrogen ordinarily present in the air we breathe has been found to result in an atmosphere which is as respirable as that provided by nature. The results obtained indicate that helium not only has the advantage of being less soluble than nitrogen, but also has the advantage of diffusing more rapidly in the body fluids and tissues which results in rapid elimination of the gas from the tissues during decompression. Along with mitigating the hazard of caisson illness, helium should markedly increase the scope of other kinds of engineering work in compressed air. The tests conducted by the writers indicated that through the use of helium and oxygen mixtures as a substitute for air in diving work, the time of decompression can be materially reduced. In a series of experiments on animals, after similar exposures decompression could be made from the helium-oxygen mixtures in as low as one-sixth the time necessary for air or nitrogen-oxygen mixtures. In a few preliminary experiments on men, decompression was made in one-fourth to one-eighth the time ordinarily recommended for air. (Modified authors' summary)

314.
SAYERS, R.R. and W.P. Yant.
Value of helium-oxygen atmosphere in diving and caisson operations.
Anesth. Analg. 5:127-138; 1926.

1) Oxygen poisoning, produced by breathing high partial pressures of oxygen, can be prevented by controlling the amount of oxygen present in the atmosphere supplied to animals exposed to high barometric pressures. 2) Helium-oxygen mixtures can be breathed by men without apparent discomfort and by animals without demonstrable ill effects. 3) Helium-oxygen atmosphere theoretically has an advantage over nitrogen-oxygen atmosphere for persons exposed to high barometric pressure, as divers and caisson workers, due to the fact that helium has a lower coefficient of solubility and a greater diffusivity than nitrogen. 4) Animals exposed to 10 atmospheres of helium-oxygen mixture from 1 to 5 hours can be decompressed in from 1/3 to 1/4 the time necessary for animals exposed to nitrogen-oxygen mixtures at the same pressure and time to obtain similar physiological effects. 5) The possibilities of the use of the helium-oxygen atmosphere may be for extended depth and time of submarine operations; also for the prevention of caisson disease in tunnel and caisson workers, and by using the mixture as a wash gas during decompression among tunnel workers.

315.
SCHIBLI, R.A. and A.A. Buhlmann.
The influence of physical work upon decompression time after simulated oxy-helium dives.
Helv. Med. Acta. 36:327-342; 1972.

The effect of physical work on decompression was examined by determining the minimal decompression time of simulated He/O_2 diving procedures in 82 different subjects. At a bottom time of 60 min at 10 ATA He/O_2, the minimal decompression time without work was 250 min; if work was performed by bicycling during bottom time the minimal decompression time was 360 min. Similarly, the minimal decompression after a bottom time of 120 min without work was 475 min; however, with work 565 min at least were required. In a bottom time of 180 min at 4.5 ATA with He/O_2 the minimal decompression time without work was 150 min; with work 180 min. The results demonstrate that minimal decompression after a 60 or 120 min dive with work must be longer than the minimal decompression time after a similar dive without work. It is suggested that primarily "slow tissues" become more saturated. We now compute decompression time after work using virtual bottom times. For the He half times of 2-105 min the virtual bottom times are set 100% of the real bottom time, for 120 min half time it is 120%, for 150 it is 125%, for 180 it is 133%, for 210 it is 140%, and for 240 it is 145%. (Authors' summary)

316.
SCHREINER, H.R.
Safe ascent after deep dives.
Rev. Physiol. Subaquatique Med. Hyperbare 1:28-37; Mar./May 1968.

After recalling the main rules of deep diving, the author reports on the experimental use of various inert gases, illustrated by a great number of very revealing curves. He describes the specific time constants of transport of inert gases at the main tissues of the organism, and deducts from them the period and levels of decompression. (Author's summary)

317.
SCHREINER, H.R.
Advances in decompression research.
J. Occup. Med. 11(5):229-237; May 1969.

The three broad aspects of current decompression research include the transport of inert gases in the body, gas phase separation and the growth of bubbles, and the pathophysiology of decompression sickness. This paper deals largely with the first mentioned aspect and reviews some of the more current attempts to obtain indications of a significant decompression advantage to the worker in hyperbaric atmospheres by the preferential, sequential or simultaneous use of different inert gases. Decompression from a two-hour dive to 1,000 feet takes two to three days now and radical improvements in decompression procedures must be sought if dives to greater depths are to become feasible in the future. Factors are discussed that govern the uptake and elimination of inert gases by the body. Perfusion-limited inert gas transport between the lungs and peripheral tissues is discussed and appropriate gas transport equations are worked out to account for ambient gas pressure and tissue gas pressure differences utilizing helium, neon, nitrogen, and argon. A mathematical model of inert gas transport is described. Neon appears to exhibit a decompression advantage over helium and both gases have an advantage over nitrogen. (ART/BSCP)

318.
SCHREINER, H.R.
Ein kritischer Ueberblick ueber den gegenwaertigen Stand der angewandten Tieftauchphysiologie.
[The current status of applied deep diving physiology: A critical overview].
Int. Z. Angew. Physiol. 27(1):76-98; 1969.
(Also published in: Uber Leben auf See. II. Marine medizinisch-wissenschaftliches Symposium in Kiel, May 4-5, 1968 [Survival at sea. II. Symposium on the science of marine medicine in Kiel, May 4-5, 1968], p.81-101. n.p., n.d.).

In this review article, the author discusses the related problems of hydrostatic pressure, and the need to compensate for this by increasing the pressure of the breathing mixture, which results in oxygen toxicity unless inert gases are employed. This in turn brings on problems of the effects of compressed gas mixtures and the uptake of these gases by body tissues. Increased gas density leads to CO_2 retention which enhances the narcotic effect of inert gases. It is noted that since 1962, nearly 100 saturation exposures have been carried out both in pressure chambers and in underwater habitats at pressures up to 27 ata without serious physiological aftereffects; however, it is emphasized that environmental parameters such as temperature breathing mixtures, etc. must be strictly controlled. Shorter working dives present more of a problem; decompression tables are constantly being revised and refined, but it is felt that the mechanism of inert gas transport is as yet not fully enough understood to enable the deep diver to carry out with maximum efficiency and safety the tasks required of him. (© BA) (Condensed by MFW/BSCP)

319.
SCHREINER, H.R.
The design of decompression schedules.
In: Progress into the sea. Transactions of the Symposium, 20-22 October 1969, Washington, D.C., p.145-153. Washington, D.C. Marine Technology Society, 1970.

Returning divers successfully to the surface requires decompression schedules which permit the most rapid reduction in ambient pressure consistent with the avoidance of decompression sickness. The design of such schedules is based on straightforward physical principles but requires empirical observations of the maximum level of inert gas tension that can be maintained in solution in the various tissues of the body. This paper attempts to convey an understanding of the basic rationale of decompression schedules. [In conclusion, it is stated that in the laboratory at Ocean Systems, Inc.] ascent-limiting tissue gas tensions obtained in manned chamber experiments are augmented by similar data obtained through the computer analysis of all Ocean Systems operational dives at sea. This massive body of decompression information is being stored in a digital data bank from which it can be retrieved at will, subjected to statistical analysis and the results applied to the development of ascent-limiting inert gas tensions. This approach to the design of decompression schedules has reduced the rate of incidence of decompression sickness in operational helium diving to depths between 70 and 150 meters to a current average of less than 2.3%. (Author's abstract)

320.
SCHREINER, H.R. and P.L. Kelley.
Computation of decompression schedules for repetitive saturation-excursion dives.
Aerosp. Med. 41:491-494; May 1970.

A general method is described for the computation of decompression schedules for repetitive dives to depth D_2 from an initial depth D_1 at which the human body is in equilibrium with the inert gas present in the ambient atmosphere. Variables considered by this method are: depths D_1 and D_2, partial pressure of inert gas prevailing at these depths, time required for compression and decompression, time spent at D_2 during each excursion, and the frequency of these excursions. (Authors' abstract)

321.
SCHREINER, H.R.
Physical limits of manned underwater activity.
In: Laughlin, J.S. and E.W. Webster, eds. Advances in medical physics. Symposium papers of the Second International Conference on Medical Physics, Boston, Aug. 1969, p.232-254. Published by the Conference, 1971.

This paper outlines the problems "created by the impact of the physical facts of submergence on the biological pecularities of man." It is stated that "it is the inability of the human lung to function properly in the face of an uncompensated increase in external pressure which produces the most significant limitation of manned underwater activity." The principles governing the selection of breathing gases – oxygen toxicity, inert gas narcosis, are discussed, and the mechanisms of these phenomena are explained and illustrated by diagrams. Inert gas narcosis is defined as "apparently the result of a molecular-level physical interaction of nitrogen with structures within the central nervous system." Other effects of inert gases, such as heat loss and deterioration of speech intelligibility with helium are mentioned. Increased gas density, submersion, respiratory hindrances caused by equipment and exertion all tend to increase carbon dioxide levels; this leads to peripheral vasodilation, which in turn increases tissue perfusion. This is desirable during decompression, but during maximum pressure it increases the required decompression time by increasing inert gas uptake. Also, increased perfusion enhances the susceptibility to oxygen toxicity. The efficacy of increasing the oxygen at bottom pressure in order to reduce inert gas uptake and speed up decompression is questioned, because of the vasoconstriction effect which partially nullifies the enhancement of inert gas elimination. Also, the risk of oxygen toxicity becomes greater. An analysis of the mechanisms of inert gas transport and bubble formation, and the prevalent theories regarding decompression is given. It is stated that current procedures represent merely the "empirical avoidance of clinically significant gas bubbles in body tissue" while the processes of inert gas transport, nucleation, bubble formation and growth in body tissues are still poorly understood." Saturation diving and saturation-excursion diving, and the decompression schedules employed are discussed and diagrammed. An appendix tabulates all chamber and open sea saturation dives from 1962 through 1969, giving year, saturation depth, bottom time, bottom gas mixture, number of divers, and project information. A useful bibliography of 79 references is given. (MFW/BSCP)

322.
SCHREINER, H.R. and P.L. Kelley.
A pragmatic view of decompression.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the fourth symposium on underwater physiology, p.205-219. New York, Academic Press, 1971.

A decompression model was postulated on the assumption that "the transport of inert gas to and from the body tissues is limited by the rate at which these tissues are perfused with blood, and not by the rate at which inert gas is being transported between the capillaries and the surrounding tissue." It is thoroughly tested and the authors conclude: "We have prescribed a pragmatic model of decompression that lives up to all expectations that one can reasonably have of such a concept. It yields decompression regimes that permit the most rapid rate of reduction of ambient pressure consistent with an acceptable level of risk of decompression sickness; it can be tested and refined experimentally; it reflects fundamental physiological realities such as the importance of tissue perfusion and individual differences in susceptibility to decompression sickness; it accounts adequately for past decompression experience; it predicts with statistical accuracy the probable outcome of future decompression experience and can cope with a multiplicity of inert gases that may be breathed simultaneously or sequentially." (Authors' conclusions augmented by CWS/BSCP)

324.
SCHREINER, H.R. and P.L. Kelley.
Computation methods for decompression from deep dives.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the Third Symposium on Underwater Physiology, 23-25 March 1966, Washington, D.C., p.275-299. Baltimore, Williams and Wilkins Co., 1967.

Twenty-five pages of mathematical formulae and computations relating to the problem of computing ascent profiles that are both physiologically sound and operationally feasible for deep, extended dives. Half-time saturation times for various tissues is developed in detail with calculations for tissues with half-times as great as 720 minutes (calculations were for 160, 180, 200, 240, 360, 480 and 720). Calculations were for nitrogen and for helium. Most calculations indicate that probably a 240-minute tissue could not sustain safely more than 12 feet of excess inert gas pressure for short periods of time or more than approximately 10 feet over a period of days. An excellent theoretical paper. (CWS/BSCP)

325.
SCHREINER, H.R.
Mathematical approaches to decompression.
Int. J. Biometeor. 11(3):301-310; 1967.

A flexible mathematical treatment of diver decompression has been developed by modifying the classical Haldanian model of inert gas transport. It is based on the assumption that inert gases will remain in solution in the tissues of a diver as long as a particular metastable limit is not exceeded, and that this limit varies with depth, nature of the inert gas, and the specific time constant of its transport in the body. Proposed metastable limits (M-values) of helium partial pressure have been developed empirically by the Experimental Diving Unit of the United States Navy. These limits permit the design by digital computer of decompression procedures expected to be safer than contemporary decompression tables for extended deep dives. (Author's abstract)

326.
SEALEY, J.L.

Decompression procedures in civil engineering projects in the United States.

In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an International Working Party held at the Ciba Foundation, London, October 1965, p.14-21. Newcastle upon Tyne, Oriel Press, 1967.

In the USA each state has its own safety regulations which include decompression procedures for caisson and tunnel workers. Most of the work prior to 1961 was done around NYC and the New York code has been adopted or in some cases adapted by most of the other states. Most of the tables provide for a divided or split working shift with a period in the open air between working shifts. A hypothetical three tissue compartment concept is used, having half saturation times of 30, 60 and 120 minutes. Decompression is in stages with the first or rapid stage at 1/5 min/lb. for the initial 15 lb reduction, and the final 4 lb. stage is at a rate of 1.0 to 32.5 min/lb as indicated. There may be one or more intermediary stages. Other requirements are imposed by some states and for special situations. (CWS/BSCP)

327.
SEALEY, J.L.

Seattle tunnel follow-up report.

In: Beckman, E.L. and D.H. Elliott, eds. Dysbarism-related osteonecrosis. Proceedings of a symposium on dysbaric osteonecrosis, Marine Biomedical Institute, University of Texas Medical Branch, Galveston, Texas, Feb. 1972. p.23. Washington, D.C., U.S. Dept. of Health, Education and Welfare, National Institute for Occupational Safety and Health, 1974.

This is a report of daily workshifts, pressure exposure, and number of days worked during the construction of the Lake City Sewer Tunnel in Seattle. A few men voluntarily spent 8-hour shifts at pressures of from 24 to 32 psig but 90% of the shifts at these pressures lasted about four hours. Shifts at 13 to 23 psig were of six to eight hours. The entire project lasted 150 weeks. During the course of the construction, recompression therapy for simple bends was performed 212 times. There were no CNS decompression sickness cases, and no disability claims. The tables used were the Washington State Standards for Work in Compressed Air, developed in 1962-1963 with the help of the U.S. Navy. In one-third of the cases, air tables were used, and in two-thirds low-pressure oxygen tables were used. (MFW/UMS)

328.
SEEMAN, K.

Decompression tables in civil engineering in Germany.

In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October 1965, p.56-64. Newcastle upon Tyne, Oriel Press, 1967.

In Germany the most recent regulations are those of 1935 which state that when the working pressure is 1.3 kg/sq. cm. or above the pressure is halved rapidly, and the minimum time for the remaining decompression is according to a table which allows 13 minutes decompression for exposure to 1.3 kg/sq. cm. These times should be extended and it is reported that the regulations are being revised. (CWS/BSCP)

329.
SEM-JACOBSEN, C.W.

Investigation on the saturation and clearance of hydrogen gas in the brain and extremities of man.

Oslo, Norway, EEG Research Institute, Rep. on Contract N00014-72-C-1345, 18p. Nov. 14, 1976.

A unique clinical situation at the EEG Research Institute has made it possible to collect gas clearance data in man. Hydrogen gas clearance and saturation in the brain have been monitored in 22 subjects—twice in 4 of them with 6-12 months interval. Each subject has been studied with from 18 to 36 chronically implanted electrodes. The T/2 for H_2 gas clearance/saturation has been measured from 1 to 76 times around each of the 460 electrodes. The half time for hydrogen gas clearance/saturation in the human brain may fluctuate between ½ minute and 30 minutes in grey matter and between 6 and 14 minutes in white matter. In the ear-lobes it may vary from 1 to 5 minutes, and from 2 to 20 minutes in the skeletal muscles. 8% CO_2 added to the breathing air caused a drastic reduction of the half time only in some areas in the brain. There must be a focal mechanism regulating the blood flow to various areas in the brain. The information obtained in these studies should be taken into account in the development of diving tables for diving on oxygen/hydrogen. The data may help to improve the understanding and treatment of decompression sickness and increase the safety of deep sea diving important to the U.S. Navy. (From author's abstract)

330.
SETTLE, S.J., T.K. Akers and W.A. Bares.
Applied simulated decompression profiles.
Biomed. Sci. Instrum. 13:107-110; Apr. 25-27; 1977.

The authors distinguish between "CNS hits" and "cord hits" in guinea pigs. The former is characterized by convulsions, the latter by hind limb paralysis. Both are preceded by "skin hits," and both present with abdominal bloating, dyspnea, and finally Cheyne-Stokes breathing just before death. Blood pooling occurs in the cord hits, but not in the CNS hits. Decompression profiles were applied to guinea pigs and rats of different sizes. A compartmental-resistance-capacitance scaling model was applied in the hope of lowering the incidence of decompression sickness at higher pressures in heavier animals. Only the heaviest (600 g), which were taken from 300 psig to 150 psig in 15 minutes had d.s. (MFW/UMS)

331.
SHAW, L.A., A.R. Behnke, A.C. Messer, R.M. Thomson and E.P. Motley.
The equilibrium time of the gaseous nitrogen in the dog's body following changes of nitrogen tension in the lungs.
Am. J. Physiol. 112:545-553; 1935.

A method for measuring the nitrogen content of the body and its rate of elimination is described. The experiments were done upon dogs. Under conditions of equilibrium at pressures up to 4 atmospheres absolute, the nitrogen content of the body is proportional to the partial pressure of nitrogen in the lungs, and the rate of nitrogen elimination is the same at all pressures. The rate of nitrogen elimination from the completely saturated body, i.e., under conditions of equilibrium, is the same as the rate of elimination from the partially saturated body. The saturation time is the same as the desaturation time. Evidence is given showing that nitrogen is held by the blood and tissue fluids in a state of supersaturation to a high degree. (Authors' summary)

332.
SHIKANOV, Ye. P., ed.
Handbook for divers.
Arlington, Va., Joint Publications Research Service, Dec. 4, 1973. 317p. JPRS 60691. (Translation of Spravochnik Vodolaza, Moscow, Voyenizdat, 1973).

Brief information is presented on the structure, operation, maintenance and repair of the basic forms and types of diving gear, mechanisms and devices providing for the diving, ascent, decompression, air and gas supply for the divers, telephone communications, underwater lighting and television. The fundamentals of the organization of dives and safety engineering as applied to diving are discussed. Some instructive example situations with divers are presented. Practical advice to divers in underwater emergency situations, the standard dive calculations, diving medicine, specific diseases of divers and measures taken to prevent them, an explanation of the basic diving terms, and the decompression and recompression tables are given. The book is designed for divers and diving specialists. It will be useful to engineering-technical and medical personnel connected with diving operations. It will be of interest to all who are engaged in underwater research and underwater sports. (Author's abstract)

333.
SHILLING, C.W. and J.A. Hawkins.
The hazard of caisson disease in individual submarine escape.
Naval Med. Bull. 34:47-52; 1936.

Two thousand one hundred and forty-three simulated escapes with the "lung" were made at depths of 100, 150, 167, 185, and 200 feet. It was found safe under these experimental conditions to remain 37 minutes at a simulated depth of 100 feet, 18 minutes at 150 feet, 17 minutes at 167 feet, 14 minutes at 185 feet, and 13 minutes at 200 feet, the subjects coming to the surface at the rate of 50 feet per minute. It was also found that air could be safely used in place of oxygen to charge the "lung" in making escapes to the surface from depths of 100 and 150 feet by continuous ascent at the rate of 50 feet per minute. Should stops be required on the ascending line from any cause whatsoever the length of time which such stops could be made before developing an oxygen deficiency in the "lung," when charged with air, is still problematical. Actual ascents were made from 100 feet after an exposure of 32 minutes and from 150 feet after an exposure of 20 minutes, but it is recommended that actual ascents with the "lung" be conducted in seawater with a larger number of subjects in order to confirm the above data. (Authors' summary)

334.
SHILLING, C.W.
Helium.
U.S. Nav. Med. Bull. 39(1):64-71; 1941.

A complete review of the properties and known uses of helium at that time. Of particular interest is the report of its use in diving. (CWS/UMS)

335.
SHILLING, C.W.
Compressed air illness.
U.S. Nav. Med. Bull. 39(3):367-376; 1941.

A general review of the literature dealing with compressed air illness, with a section on prophylaxis which brings up to date the advances in decompression—"the continuous method of decompression retains some advocates although the stage method is most generally accepted." Oxygen was being extensively recommended "as the gas to be breathed in order to shorten the decompression time," and helium was being used in order to shorten the decompression time. (Author)

336.
SMITH, C.L.
Navy tables and the sport diver.
NAUI News, p.13-16; Oct. 1975.

The U.S. Navy diving tables are often not applicable to the sports diver because of the different nature of the sports dive profile. The Navy dive profile usually spends the bottom time at the greatest depth of the dive, thus requiring decompression time, while the sports diver frequently dives deep for a short time, and then spends most of his time at a shallower depth. This in itself constitutes a decompression. The author gives tables for two dive profiles which he calls the initial bounce dive and the shallow finish dive. However, it is considered unlikely that satisfactory sport dive tables will ever be compiled. The author believes that the ultimate solution is an accurate decompression meter that monitors several body tissues. A depth gauge could be combined with a miniature electronic calculator. (MFW/UMS)

337.
SMITH, C.L.
A summary of practical altitude diving procedures.
In: Proceedings of the Eighth International Conference on Underwater Education, Nov. 1976, San Diego, Calif. p.281-295. Colton, Calif., National Association of Underwater Instructors, 1976.

The altitude diving environment differs from that of the ocean due to the lesser density of fresh water and the reduced atmospheric pressure. Exposure to decompression sickness is greatly increased, being introduced to its special problems. Significant changes in diving practice are needed to compensate for the differences. These include adjustments to buoyancy, bottom time limits, ascent rate, and depth gauge readings. Practical rules are given here, both for altitude diving and for flying, and tables are presented which permit decompression depth corrections directly from depth gauge readings. (Author's abstract)

338.
SMITH, C.L.
The sport dive table: A need.
In: Proceedings of the Eighth International Conference on Underwater Education, Nov. 1976, San Diego, Calif., p.296-301. Colton, Calif., National Association of Underwater Instructors, 1976.

The standard decompression tables, based on a very simple depth profile, are not well suited to scuba diving. Although the Navy tables themselves contain no margin, they can be extremely conservative when applied to a sport dive, giving answers which alienate the experienced diver. Special rules are needed which allow the scuba diver to benefit from his usual depth variations, and prevent his abandonment of safety procedures altogether. An example sport dive table is presented which illustrates the potential advantages, and shows that even deep dives can be safely finished by lengthy stays in 30 or 40 feet of water. (Author's abstract)

339.
SMITH, C.L.
Altitude procedures for the ocean diver.
Colton, California, NAUI Headquarters, 1976. 46p.

The contents of this handbook are as follows: 1) Altitude diving procedures: Adjusting for the buoyancy change; Adjusting for the new decompression requirements; Correcting the depth gauges. 2) Buoyancy change: The fresh water effect; The additional altitude effect. 3) Technical changes in decompression: Pressure ratios and the Navy dive tables; Equivalent ocean depth; Ascent rate; Decompression stops. 4) Flying after a sea level dive: An alternate procedure. 5) Arrival at altitude. 6) Depth gauge corrections: Bourdon and other non-capillary gauges; Capillary gauges. 7) Altitude dive tables: The E.R. Cross tables; Individual altitude dive tables.

340.
SMITH, E.B.
Decompression experiments with various inert gases.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the third symposium on underwater physiology, 23-25 March, 1966, Washington, D.C., p.425-429. Baltimore, Williams and Wilkins Co., 1967.

The use of a variety of gases has proved of some interest when applied to the problem of decompression sickness in mice. In particular the anomalous properties of fluorine compounds are providing a novel means of investigating: 1) the mechanism of uptake of gases into the tissues; 2) the relation between solubilities in various media and decompression sickness; 3) the different roles of intravascular and extravascular bubbles in causing decompression sickness; and 4) factors which influence the rate of onset of the symptoms of decompression sickness. (Author's conclusions)

341.
SMITH, K.H. and P. Stegall.
Experimentally induced osteonecrosis in miniature swine.
In: Beckman, E.L. and D.H. Elliott, eds. Dysbarism-related osteonecrosis. Proceedings of a symposium on dysbaric osteonecrosis, Marine Biomedical Institute, University of Texas Medical Branch, Galveston, Texas, February 1972. p.105-111. Washington, D.C., U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, 1974.

As illustrated in this study, the most profound consequence of exposure to inadequate decompression profiles is aseptic bone necrosis. The study also produced initial evidence of severe hematologic changes, which occur simultaneously with bubble formation or as a result of it. All links in the chain stretching from initial hyperbaric insult to osteonecrosis have, of course, not been identified. Nevertheless, the connection between bubble formation—with alterations in the clotting mechanism—and the resulting infarcts in the small vasculature supplying nutrition to bone cells is generally recognized. Ongoing studies are being designed to investigate and isolate more specifically the observed hemostatic and cellular alterations that occur when decompression rates are inadequate. Only then can the gap be filled between bends and bubbles on the one hand and bone necrosis on the other. (Authors)

342.
SOLODKOV, A.S.
Dekompressionnye rasstroistva u vodolazov.
[Decompression disorders in deep-sea divers].
Gig. Tr. Prof. Zabol. 11(1):29-32; 1967.

Deep-sea divers were made to descend into water at periods of training and to execute practical tasks at various seasons of the year. From among the total number of 1040 decompressions affected in conformity with the existing schedules 23 cases of caisson disease were recorded. In 730 cases the divers were lowered to a depth of 45-60 meters (6 instances of this affection). The greatest incidence of caisson disease is recorded in the autumn and winter months (16 cases out of 23). In 7 out of 23 cases caisson disease was of medium and highly severe forms, occurring during divers' work in winter months directly after their emergency from under the water, or 1-2 hr. thereafter. These 7 patients underwent therapeutic recompression by following schedules II-V and after a lapse of a certain period of time were allowed to continue their work without any restrictions as to the depth. Henceforth, to prevent the occurrence of caisson disease in winter months, pauses at "stops" have been lengthened. A substantial reduction in the incidence of caisson disease by using decompression schedules 1 line below, or by increasing the depth of the 1st "stop" give grounds to presume it expedient that the depth interval to the first "stops" should be increased in the now existing decompression tables. (Author's summary) (© BA)

343.
SOMERS, L.H. and M.J. Nemiroff.
Hyperbaric chamber attendant's handbook.
Ann Arbor, Mich., Univ. Mich. Sea Grant Program, Rep. MICHU-SG-74-601, 75p. July 1974.

This handbook is intended to serve as a guide to the operation of the University of Michigan hyperbaric chamber, and to the treatment of diving casualties. It is patterned after the "U.S. Navy recompression chamber operator's handbook," with modifications dictated by the nature of the Michigan facilities, and by civilian operational procedures. Portions of the handbook are quoted directly from the aforesaid publication and from the U.S. Navy Diving Manual. The section on chamber operation includes: predive checklist, tending the patient, patient examination, tending the chamber, postdive maintenance checklist, safety precautions for chamber operation; the section on recompression treatment includes: decompression sickness (types I and II), gas embolism, complications, general notes on treatment of gas embolism and decompression sickness, carbon monoxide poisoning, smoke inhalation, cyanide poisoning, gas gangrene, emergency medical kit; the section on chamber system installation and maintenance includes: air supply requirements, oxygen breathing mask, oxygen monitoring equipment, corrosion protection, fire extinguishing equipment and agents, fire retardant clothing, pressure test; the section on additional use includes: surface decompression, omitted decompression, U.S. Navy diver candidate pressure and oxygen tolerance test, and pressurizing personnel for training and demonstration. Seven appendixes contain such material as U.S. Navy air decompression tables, specifications for and maintenance of various types of equipment, questionnaires and other forms, and course outline. (MFW/UMS)

344.
SPENCER, M.P. and D.C. Johanson.

New principles for modeling the human response to excess inert gas and the development of decompression tables.

In: Proceedings of the first annual meeting of the North Pacific Branch of the Undersea Medical Society, 5-7 Sept. 1974. p.23. Avalon, Calif. Univ. So. Calif., Santa Catalina Mar. Sci. Cent., 1974.

Abstract only. Excerpt quoted: The direct decompression limits have been established for human subjects using exposures ranging from 233 feet for 7 minutes to 30 feet for 720 minutes. The model assumes no half-time M values, supersaturation ratios or any other theoretical description of tissue compartments, but was initially projected from human nitrogen elimination data of Behnke. The contour of the model, when plotted on log-log paper, is curvilinear, as is the prediction from nitrogen elimination data. The model differs from present U.S. Navy No-D air diving limits in that those limits describe a linear plot on log-log paper, and are not sufficiently conservative for the long, shallow dives. The model allows greater exposures possible for the short, shallow dives than allowed by the Navy recommendations. Experience with working divers in the open ocean indicates that the model accurately and safely describes the body's performance in the presence of excess inert gas.

345.
SPENCER, M.P.

A method for development of safe decompression schedules using Doppler ultrasonic bubble detection.

In: Program and Abstracts, Undersea Medical Society, Inc., Annual Scientific Meeting. Undersea Biomed. Res. 5(Suppl.):28; Mar. 1978.

Abstract only. Entire item quoted: Graded Doppler ultrasonic detection of venous gas emboli (VGE) provides an objective method for detection of supersaturation bubbles before the occurrence of bends. The recommended steps are 1) select three bottom times within the range of exposure requirements, 2) select trial decompression schedules believed to be optimum. 3) Test a group of divers under reproducible conditions. 4) Monitor, at frequent intervals, the pulmonary artery and peripheral veins during and after the decompression procedure. 5) Modify the schedule to find one that produces less than 20% incidence of VGE among the divers or an average grade (1-4) of precordial VGE of less than 0.4. Accept no procedure which produces grades 3 or 4 VGE in any diver. For direct decompression (DD) excursions from surface air dives (Journal of Applied Physiology 40:229, 1976) a 20% incidence of VGE was associated with less than 5% incidence of mild bends pain. Habitat saturations at 30 feet carried out on ten divers using 3 excursions; 70/360, 90/120, and 115/40 (ft/min), produced 10%, 60%, and 20% VGE respectively without bends. Calculations indicate that saturation at 30 feet allows excursion depths 40 feet greater than allowed by surface DD excursions. 100% O_2 breathing before surfacing demonstrated that increasing O_2 time from 2 to 3 hours reduced surface VGE from 50% to 40% and reduced bends from 40% to 10%. Use of this method allows optimization of decompression schedules without necessitating the production of bends.

346.
STEGALL, P.J., K.H. Smith and J. Hildebrandt.

Aseptic bone necrosis and hematologic changes in miniature pigs as the result of compression/decompression exposures.

Fed. Proc. 31:653; Mar./Apr. 1972.

Abstract only. Entire item quoted: Aseptic bone necrosis was produced in one of five miniature pigs exposed to a combination of decompression profiles varying in rate from fast (65.5 fpm) to slow (5-1.3 fpm). A suspicious area in one of the femoral metaphyses found three months after the pig's initial dive became more radiolucent in the following three months, and additional radiolucencies were noted in the other femur and bilaterally in the humeri. A diagnosis of aseptic bone necrosis was confirmed by biopsy. "Bends" thresholds fell in each pig with successive stress; one possible explanation for this induced sensitivity may be the presence of gas nuclei persisting from one exposure to the next, initiating bubble formation at lower degrees of supersaturation. After each exposure, significant decreases in fibrinogen concentration and thrombin times were noted. Platelet adhesiveness was elevated 25% immediately postdive, but platelet counts were maximally decreased (> 50%) 24-48 hours later. Reticulocyte counts fell significantly as well. CPK levels increased markedly in samples drawn after both fast and slow decompression rates, while LDH values fell by > 30% in the same samples. Serum lipid levels rose > 30%, with the greatest changes being in triglycerides and phospholipids. Hematologic and chemical changes were not always accompanied by observable symptoms, suggesting that disseminated intravascular coagulation (consistent with this picture) may occur without clinical evidence of decompression sickness.

347.
STEVENS, F.D., H.W. Ryder, E.B. Ferris, Jr. and M. Iantome.
The rate of nitrogen elimination from the body through the lungs.
J. Aviat. Med. 18:111-133; 1947.

Data are presented here to demonstrate the quantitative relations between nitrogen elimination and time of day, sex, and other variables. . . . Individuals differ in the rates at which they eliminate nitrogen from their lungs while at rest breathing oxygen at ground level. In young men these differences are related to differences in body weight. Even though the nitrogen elimination be calculated as per unit of body weight, marked individual differences are evident. (Authors)

348.
STRAUSS, R.H.
Bubble formation in gelatin: a potential model for prevention of decompression sickness.
Fed. Proc. 33(3, Pt. 1):350; Mar. 1974.

Abstract only. Entire item quoted: Gelatin was exposed to N_2 at high pressures and decompressed to form bubbles. Results suggest that bubble formation can be decreased and decompression time shortened if supersaturation is less at the beginning of decompression than at the end. This is the converse of the Haldane ratio principle which is currently employed to prevent decompression sickness in divers. Results are consistent with the existence in gelatin of a spectrum of stable gas nuclei which can be compressed or transformed into bubbles.

349.
STRAUSS, R.H.
Bubble formation in gelatin: implications for prevention of decompression sickness.
Undersea Biomed. Res. 1:169-174; June 1974.

Gelatin exposed to N_2 at differing pressures was decompressed to form bubbles. Findings are consistent with the existence in gelatin of a spectrum of stable gas nuclei which can be compressed or transformed into bubbles. Results suggest that the number of bubbles and their total volume can be decreased, and decompression time shortened, if the gas supersaturation pressure (i.e. the difference in pressure between dissolved gas and environment) remains constant for decompression of a given tissue.

350.
STRAUSS, R.H. and D.E. Yount.
Decompression sickness.
Amer. Sci. 65:598-604; Sept.-Oct. 1977.

Decompression sickness (d.s.) is caused by the formation of gas bubbles in the blood and body tissues when ambient pressure is reduced. By reducing pressure gradually, nitrogen is allowed to diffuse from the tissue to the lungs without forming bubbles. Among sport divers, the U.S. Navy air decompression tables as put forth in the 1973 Navy Diving Manual are most generally observed. Symptoms may appear during or immediately following decompression, or several hours later. In fatal cases, bubbles have been seen throughout the body—in the vascular system, in tissue, and possibly in cells. In some cases venous bubbles can be ultrasonically detected when there are no symptoms of d.s. Erythrocytes become more concentrated, and the blood more viscous. Platelets aggregate at the blood-bubble interface and release biologically active substances. In central nervous system d.s. the white matter of the spinal cord is generally affected. Immediate recompression is essential. The first symptom may be transient back pain with radiation to the abdomen, followed by "pins and needles" in the legs. The walk becomes unsteady and finally paralysis may occur. Brain damage is less frequent, and may be indicated by visual disturbances, vertigo, or weakness on one side of the body. Simple limb or joint pain will often subside, even if untreated. Well-perfused tissues, such as the brain, absorb gas quickly; fatty tissues, which are poorly perfused, absorb it slowly. The mechanism of bubble formation in animals is not clearly understood. Some sort of nuclei apparently exist; another theory is that bubbles form at aqueous-lipid interfaces due to decreased surface tension. Standard treatment for d.s. consists of recompression to 60 fsw and intermittent oxygen breathing. In cases of central nervous system d.s., the patient should be given oxygen continuously while he is transported as rapidly as possible to a chamber. (MFW/UMS)

351.
STUBBS, R.A. and D.J. Kidd.
Pneumatic analogue computer control of decompression.
In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October 1965, p.255-268. Newcastle-upon-Tyne, Oriel Press, 1967.

Decompression tables are not readily adaptable to the unusual case or to the repetitive exposures. It is difficult in actual working conditions to get really good estimates of the number of cases of caisson disease. Thus for testing tables it is wise to go to simulated dives in a chamber. A mathematical model was constructed to describe the uptake and elimination of inert gas by the body based on two assumptions: The partial pressure of inert gas in the body tissues will change with the ambient pressure of the respiratory gas in accordance with the laws of diffusion; and a degree of inert gas supersaturation is tolerated by the body, without symptoms. Also considered was the tissue half-time saturation and the critical supersaturation. Using these considerations and making many experimental dives the analogue computer was calibrated and has been used to control decompression for a large number of dives. (CWS/BSCP)

352.
SUGAWARA, K.
Decompression procedures on board fishing ships.
In: Proceedings of the second joint meeting of the Panel on Diving Physiology and Technology, August 24-27, 1973, Seattle, Washington, p.59. United States-Japan Cooperative Program in Natural Resources, n.d.

There are approximately 2,500 divers in the Japanese fishing industry. There are about 250 one-man decompression chambers aboard fishing vessels. Although the regulations state that normal decompression should take place in the water, and the chambers should be used only for emergencies, they are, in fact, used for decompression while the boat is returning to port. One must assume there is only one diver per fishing vessel. A typical dive consists of two hours at 50 meters, direct ascent to the surface with no stops, a ten-minute interval on the surface before entering the chamber. The pressure in the chamber is regulated by the diver. The author raises the question of standard international decompression tables, and compares the tables of the UK, the U.S., the Netherlands and Japan. (MFW/UMS)

353.
SUMMITT, J.K. and R.W. Crowley.
Report of experimental dives for SeaLab III surface support decompression schedules. U.S. Navy Exp. Diving Unit, Rep. NEDU-RR015-70, 111p. Dec. 1, 1970.

This report describes the decompression schedules that were developed and tested by the U.S. Navy Experimental Diving Unit in preparation for SeaLab III. The need was foreseen for a surface supported diving capability for underwater tasks of relatively short duration which would not necessitate the use of saturation diving with its resulting long decompression times. The decompression schedules described in this report were designed to provide that capability. Decompression schedules were developed for dives of 300, 350, 400 and 450 feet with bottom times of 15, 30, and 60 minutes at each depth. A schedule for a 500-foot dive with a bottom time of 30 minutes was also developed. These developmental schedules were tested in a series of 54 experimental dives in the NAVXDIVINGU facility during the period April 1965 through July 1967. Certain schedules were modified and retested as a result of experience gained in the initial testing effort. This report presents each developmental decompression schedule and summarizes the experimental dives that were made to evaluate them. Problems encountered, particularly problems of decompression sickness are also summarized. The final decompression schedules which emerged from the experimental dives and evaluation of their results are presented in detail. The final schedules are published for information of all interested activities and individuals. At the time of publication of this report, these schedules had not been evaluated in the open sea and have not been promulgated by the Navy for routine diving operations. (Authors' abstract)

354.
SUMMITT, J.K., J.M. Herron and E.T. Flynn.
Repetitive excursion dives from saturated depths on helium-oxygen mixtures. Phase I: Saturation depth 350 feet.
U.S. Navy Exp. Diving Unit, Rep. NEDU-RR-2-7070, 45p. Mar. 15, 1970.

Five 350 foot saturation dives were conducted at the Navy Experimental Diving Unit to verify a no-decompression, repetitive excursion format developed by DSSP (PM-11). Twenty divers completed a total of 344 man-excursion dives from the saturation depth. No symptoms of decompression sickness were reported during the excursion dives, during the bottom time at 350 feet or during the first 200 feet of decompression back to the surface. This criteria is considered to be satisfactory evidence of the safety of the Repetitive Excursion Format. Five cases of decompression sickness did occur during the latter stages of decompression and they are discussed briefly. The occurrence of compression arthralgia and external otitis on deep saturation-excursion dives is also discussed. (Authors' abstract)

355.
SUMMITT, J.K. and J.W. Kulig.
Saturation dives, with excursions, for the development of a decompression schedule for use during SeaLab III.
U.S. Navy Exp. Diving Unit, Rep. NEDU-RR-9-70, 59p. Sept. 23, 1970.

Twenty-three saturation dives to depths of 200 to 850 feet were conducted at the U.S. Navy Experimental Diving Unit to verify a decompression schedule for use at SeaLab II. Seventy-one divers completed ninety-seven man-dives and tested decompression schedules based on two different fundamental rates of ascent during the dives series. Seventy-four man-excursion dives were conducted during the series, including a record-breaking excursion to a depth of 1025 feet. A decompression schedule for use from a depth of 600 feet was developed and found to be safe for use during SeaLab III. Eight cases of decompression illness occurred during the dive series. Details of these cases are covered in this report. (Authors' abstract)

356.
TAILLEUR, J.
Justification du palier de defatigation.
[Justification of the rest stop].
In: L'Huillier, J.-R., ed. Medecine de plongee. Gaz. Hop. 35:1058; Dec. 20, 1971.

Even when the conditions of a dive permit ascending without stops, a stop of five minutes at three meters is considered helpful. If the diver maintains the discipline of slow breathing throughout the dive, there follows an inadequate elimination of gas. During the five minute stop, the diver can breathe at a more rapid rate, and then expire as forcefully as possible several times. This practice ensures the satisfactory elimination of nitrogen, and prevents the occurrence of headaches and other minor discomforts that otherwise frequently accompany a dive made under even the most favorable conditions. (MFW/BSCP)

357.
TAYLOR, D.M.
COMEX thinks deep.
Ocean Ind. 6:16-19; May 1971.

The author briefly summarizes the accomplishments of COMEX. Janus II - 840 ft in the open sea - was carried out in 1970. The equipment used is described. It was demonstrated that divers living at 660 ft could safely work two hours a day at 840 ft without decompression. Also new, faster decompression schedules were developed. The Baluga I experiment had the purpose of studying the effects of cold water and on developing methods to combat heat loss. Electrically heated undergarments were worn under constant volume suits. Respiration heat loss still remained a problem. An electronically regulated gas heater was developed, to be worn on the diver's back; it supplied him with a breathing mixture at 100°F; Physalie V was devoted to the investigation of the high pressure nervous syndrome (hpns). The compression and decompression profile, a group premedicated with ganglioplegics and the hypothermic group survived in spite of a certain number of deaths in the control groups. At the normothermic state, arterial hematocrit ration of the dogs increased significantly with exposure to OHP when anesthetized with pentobarbitol alone. A simultaneous decrease in base excess was also observed. These changes were less remarkable following the administration of ganglioplegics. Bradycardia and an increase in arterial blood pressure and certain kinds of arrhythmias were seen by the exposure to OHP under normothermia, but these changes were minimized when exposed to OHP combined with hypothermia. A decrease in arterial pH, an increase of arterial PCO_2 and a decrease in base excess, which were seen by the exposure to OHP under normothermia, were also alleviated under hypothermia. The value of excess lactate showed a great variance, but the lactate-pyruvate ratio showed a tendency to increase at normothermia-OHP and to decrease at hypothermia-OHP. At the normothermic state, respiratory and metabolic acidosis as well as hemodynamic disturbances developed by the exposure to OHP. Under hypothermia hemodynamic and acid-base balance remained relatively steady even with the exposure to OHP. (© BA)

358.
TAYLOR, D.M.
Bounce diving in 450-600 ft. water depths and deeper.
Ocean Ind. 9:35-37; Mar. 1974.

In the recent 1,000-foot chamber dive at Duke University, the breathing mixture consisted of helium, oxygen and nitrogen. (Exact proportions are not given.) Compression time was 33 minutes, and decompression time 96 hours, as compared with the U.S. Navy rate of 24 hours compression and 11 days of decompression. (The latter figures are apparently for a saturation dive.) The bottom time of this dive was one hour. Since most tasks required of commercial divers are of short duration, the time and money saving aspects of the bounce dive as opposed to the saturation dive is obvious. The use of the three-gas mixture prevents the occurrence of hpns, at depths of 1,000 feet, so that no performance deterioration occurs. The graph of the dive shows rapid decompression to 850 feet, a slower rate to 301 feet, slower again from 301 to 99 feet, and still slower from there to the surface. The exact rates of feet per minute are not given here. (MFW/UMS)

359.
THOMAS, J.R., K.J. Conda, F.W. Armstrong, Jr., J.M. Woolley and J.M. Walsh.
Decompression schedules for use in behavioral studies with laboratory rats.
U.S. Nav. Med. Res. Inst., Rep. 5 on MF12.524.004.7007D, Oct. 1973.

Air and helium decompression schedules for use with laboratory research animals are presented. Animals repeatedly exposed to these schedules have been relatively free from barotrauma and decompression problems. (Authors' abstract)

360.
TOBIAS, C.A., H.B. Jones, J.H. Lawrence and J.G. Hamilton.
The uptake and elimination of Krypton and other inert gases by the human body.
J. Clin. Invest. 28:1371-1385; 1949.

The rate of change of radioactive krypton concentration in the extremities of young male subjects has been studied. If the subjects breathed a constant concentration of radiokrypton, mixed with oxygen, the uptake and desaturation curves could be satisfactorily expressed as the sum of not more than three superimposed components, changing as the simple exponential function of time. Exercise or heating of the hand prior to the gas exchange resulted in a generally faster exchange. Vasoconstriction or adrenaline caused slower exchange. A fatty meal eaten two hours before the krypton exchange had no effect on the rapidity of the test. The gas exchange of some subjects slowed down while at 35,000 feet simulated altitude, breathing oxygen. Radioactive krypton, administered via stomach tube appeared rapidly in the circulation of the extremities and in the exhaled air of the lungs. The techniques and results reported suggest that these radioactive gases have applications in the study of the circulation to the extremities in the living patient and in numerous problems of gas exchange in normal and pathologic states. (Authors' summary)

361.
TODD, G.P.
Decompression patterns developed by an interdependent electric analog.
U.S. Nav. Submar. Med. Cent., Rep. SMRL 580, 10p. May 16, 1969.

A simple, inexpensive electronic analog has been developed and constructed which is based on a modification to the classical Haldane mathematical model. Unlike the Haldane model this analog uses a series alignment of theoretical half-time tissues rather than the usual parallel arrangement. Schedules produced by this analog closely follow the experimental inert gas elimination curves developed by Behnke and the mathematical model theorized by B.A. Hills. The results raise an interesting question as to the adequacy of the present Haldane model modification employed by the U.S. Navy for decompression schedule calculation. Further studies must be made before this latter question can be answered. (Author's abstract)

362.
TODD, M.
Protection from the bends–new easy-to-learn RNPL/BS-AC decompression tables.
Triton 21:28-29; Jan. 1976.

The British Sub-Aqua Club has adapted the recent (1972) decompression tables compiled by the Royal Naval Physiological Laboratory to depths of 50 meters at increments of two meters, so that they will be suitable for use by the average sport diver. The method of calculating decompression tables for repeat dives is also given. The descent rate is 30 meters per minute and the ascent rate is 15 meters per minute. No more than 8 hours in any 24 hour period should be spent under pressure. Adjustments for diving at altitude are given, also limitations on flying after diving. (MFW/UMS)

363.
TROTTER, C.
Evolution of therapeutic recompression for exceptional cases of decompression sickness in guinea pigs.
Alverstoke, U.K., Roy. Nav. Physiol. Lab., Rep. 2-71, 11p. 1971.

The author is interested in developing decompression and recompression schedules for use on small animals, whose higher metabolisms and faster circulation cause them to respond differently than man to pressure changes. In recent experiments rats were taken to 92 ATA and decompressed successfully in five and one-half hours. Methods used with rats were extrapolated to guinea pigs. The author discusses the graphical plot of the tables, the stage decompression method, the use of oxygen inhalation, and deeper recompression therapy. The effectiveness of these methods will be tested on experimentally produced forms of severe decompression sickness such as pulmonary barotrauma, in guinea pigs. (MFW/BSCP)

364.
UNDERSEA MEDICAL SOCIETY, INC.
U.S. Navy Supervisor of Diving, Dive – 1600 feet.
Pressure Med. Physiol. 2(Spec. Insert 2):1-4; July/Aug. 1973.

The April-May 1973 dive was designed to document the diver's ability to perform useful work at depth, using U.S. Navy apparatus and procedures. Six U.S. Navy divers, including two medical officers, participated. The compression rate was 0-14 fsw at 14 fpm, 14-400 fsw at 5 fpm, 400-1000 at 400 fph, 1000-1300 fsw at 30 fph, and 1300-1600 fsw 20 fph with stops at 400, 100, and 1300 feet for studies. At 1600 feet, the MK10 MOD4 closed circuit breathing apparatus was tested, and it was found that light work could be accomplished, but increased work loads brought on respiratory distress which differed from that observed at shallower depths in that no significant carbon dioxide retention was detected. No EEG abnormalities were observed. Otitis externa was prevented by prophylactic use of 2% acetic acid in aluminum acetate in the ear and twice daily and immediately following each immersion. Subjective mood checklists revealed an increase in anxiety and hostility during compression, which remained slightly above normal until the eighth day of decompression. Mood fluctuated and appeared to be related to success or failure in performance tests. The ARL Helium Speech Converter from the U.K. was successfully used. Thermal comfort was achieved apparently at the expense of increased oxygen consumption. A higher than normal caloric intake was recorded though all divers lost weight. The decompression schedule was 10 fph for the first 30 f, then 1600-200 fsw at 6 fph, 200-100 fsw at 5 fph, 100-50 fsw at 4 fph, and 50 fsw-surface at 3 fph. For additional findings, see Spaur, W.H., Rough draft, May 20, 1973. (MFW/SCD)

365.
UNDERSEA MEDICAL SOCIETY, INC.
National plan for the safety and health of divers in their quest for subsea energy.
Bethesda, Md., Published by the Society, January 1976.

This report is the product of a contract with the National Institute for Occupational Safety and Health, the Energy Research and Development Administration, the National Oceanic and Atmospheric Administration, and the National Heart and Lung Institute. It consists of reports on separate workshops on the following subjects: Audio-vestibular derangements; Osteonecrosis; Subtle physiological changes; Respiratory/pulmonary function in hyperbaric exposures; Selection and training of professional divers; Cognitive and psychomotor performance; Exchange of inert gases, oxygen and carbon dioxide; Assessment of gases suitable for diving; Physiological and toxic effects of respiratory and contaminant gases (acute and chronic); Oxygen; Use of drugs and other medical treatment under hyperbaric conditions; High pressure nervous syndrome; Microbiological aspects; Thermal problems; Compression and decompression protocols; Systems design criteria; Monitoring techniques; Selection and training of physicians and paramedics for offshore diving; Legal and compensatory aspects. The chairmen of the individual committees agreed on two main overall priorities: first, more careful selection and training of professional divers; and second, the problem of medical and paramedical care for the divers in the oil industry (selection, training, and deployment of physicians and paramedics, development of appropriate rescue vehicles, and the establishment of shore-based hospital treatment facilities. (MFW/UMS)

366.
UNITED STATES NAVY.
U.S. Navy diving manual.
Washington, D.C., U.S. Government Printing Office, 1970. (Navships 0994-001-9010).

This edition of the U.S. Navy Diving Manual represents an extensive revision of and addition to all past editions of the manual. The changes reflected in this manual are the result of a careful appraisal, made from past experience and the expectation of future developments, of all areas in the field of diving. . . In many instances the equipment description given in the appendixes is taken from the technical manuals for that equipment, and therefore the diving manual is a technical manual on diving equipment as well as a repository of information on diving procedures. . . . One of the most obvious changes in this edition of the manual is in the diving tables. These tables have been enlarged for easier reading and have been given a new and uniform format. . . . New oxygen depth-time limits have been used to provide for greater safety in the prevention of oxygen poisoning, and the tables reflect these limits. . . . Several new tables (such as the helium-oxygen decompression for mixed-gas scuba, and the minimal recompression oxygen treatment tables) have been added to this edition along with instructions for their use. The oxygen treatment tables are further referenced in many areas of the text for treatment of specific casualties. . . . The use of oxygen in recompression chambers has long caused concern to many people because of the hazards of fire in an oxygen-rich environment. Therefore, the allowable limits of oxygen concentration in recompression chambers have had to be lowered. This lower concentration in turn has made it necessary to revise the ventilation rules for recompression chambers, and has imposed ventilation rates that are quite high and can cause hearing loss. The means to avert this hearing loss are given in the text and are easily achieved. . . . In addition to the appendixes on technical information, there are several appendixes that deal with matters relating to diving; these have been separated from the main text so that they may be kept current or so that new appendices may be added as the horizons of diving expand. One such appendix is a short and concise guide to first aid and covers most of the situations which might confront divers at some time when no medical care is immediately available. Another appendix deals with marine life and its hazards. A further appendix deals with the selection, qualification, and training of personnel and is taken from the latest instructions of the Bureau of Medicine and Surgery and the Bureau of Personnel. (From Preface)

367.
UNITED STATES NAVY.
U.S. Navy diving manual.
Washington, D.C., Government Printing Office, 1973. (NAVSHIPS 0994-001-9010).

The manual has been rewritten, and its format changed. Volume 1 deals with air diving, and its contents are: 1) History of diving; 2) Underwater physics; 3) Underwater physiology; 4) Operations planning; 5) Air diving operations (scuba); 6) Surface-supplied air diving operations; 7) Air decompression; 8) Diving emergencies; (App. A) Formulas and conversion factors; (App. B) Record keeping and reporting; (App. C) Sea state chart; (App. D) U.S. Navy-approved diving equipment; (App. E) Selection, qualification and training of personnel; (App. F) Ship repair safety checklist; (App. G) Navship Publications; (App. H) Gauge calibration procedures; (App. I) Dangerous marine animals; (App. J) General safety checklist; (App. K) Surface-supplied diving operations predive checklist; (App. L) Pressure test for USN recompression chambers. Volume 2 concerns mixed gas diving, and its contents are: 9) Mixed-gas diving theory; 10) Mixed-gas underwater breathing apparatus; 11) Surface-supplied mixed gas diving operations; 12) Deep diving systems; 13) Oxygen diving operations; 14) Mixed-gas decompression (App. II-A) Diving gases; (App. II-B) Cleaning oxygen systems; (App. II-C) Safe handling of gases; (App. II-D) U.S. Navy-approved mixed-gas diving equipment; (App. II-E) Mk 6 Mod O mixed-gas scuba; (App. II-F) Mk 10 Mod 4 mixed-gas UBA; (App. II-G) Mk II Mod O mixed-gas UBA; (App. II-H) Surface-supplied mixed-gas diving operations - predive checklist. (MFW/UMS)

368.
UNITED STATES NAVY SUPERVISOR OF DIVING.
U.S. Navy recompression chamber operator's handbook.
Washington, D.C., Department of the Navy, Naval Ships Systems Command, June 1973. (NAVSHIPS 0994-014-5010).

This concise publication is intended as a quick reference on-station guide, and not as a substitute for the U.S. Navy Diving Manual section on this subject, which is more complete. This well-organized, pocket-size handbook discusses chamber operation, recompression treatment, installation and maintenance, and other uses (such as surface decompression, omitted decompression, and diver candidate tests for selection). (MFW/UMS)

369.
UNITED STATES NAVY SUPERVISOR OF DIVING.
Handbook: U.S. Navy diving operations.
Washington, D.C., Navy Department, Naval Ships Systems Command, 1971. 197p. (NAVSHIPS 0994-009-6010).

As part of a continuing effort to maximize the availability of useful information for the fleet diver, the Office of The Supervisor of Diving has prepared this concise guide for the conduct of diving operations. Its content is based upon the most frequently used information from the Diving Manual and also introduces several new types of equipment and previously unpublished information on diving. The handbook has been designed for quick reference by the diver "on station" and features many new visual forms of information display. Throughout the handbook illustrations, charts, and diagrams have been used in place of text matter. Rotary selector charts and calculators have been employed to condense information into compact forms and minimize the need for computations and cross-referencing to other sources of information. Color printing has been used to highlight and separate various sections. Areas, such as recompression treatment, have been reorganized to simplify instructions. (From Preface)

370.
VAN DER AUE, O.E., E.S. Brinton and R.J. Keller.
Surface decompression, derivation and testing of decompression tables with safety limits for certain depths and exposures.
U.S. Navy Exp. Diving Unit, Rep. 1-45, 32p. 1945.

A total of 282 dives were made in this project. Four of the depth and time limits for surface decompression quoted in the diving manual were tested. The tables tested were – 100 feet for 85 min.; 130 feet for 55 min.; 150 feet for 38 min.; and 170 feet for 30 min. Work, rest, wet tank and dry chamber dives were made in these tests. Work dives in the wet tank using standard decompression were also made as controls for each of the above depths. Resulting from all dives made were 27 cases of caisson disease which required recompression and 25 cases of mild caisson disease which did not require recompression. The incidence of "bends" was higher for the control dives that were decompressed on the standard U.S. Navy Decompression Table than it was for those that were given surface decompression. Of 81 standard decompression work dives 24.69% terminated with "bends" requiring treatment or "mild bends" not requiring treatment. Using the same tables and identical work but with surface decompression the incidence of "bends" or "mild bends" was 21.43% for 98 dives. Surface decompression work dives were followed by more "bends" and "mild bends" than surface decompression rest dives, an incidence of 21.43% for 98 work dives and 10.68% for 103 rest dives. There was no appreciable difference in the incidence of "bends" or "mild bends" resulting from the dry chamber and wet tank runs for the 100 foot table. Evidence is presented to show the relationship between the site of bends symptoms and the part of the body exercised. Localized symptoms of bends occur most frequently in that part of the body which is subjected to the most vigorous exercise while under pressure. (Authors' summary)

371.
VAN DER AUE, O.E., R.J. Keller, E.S. Brinton, G. Barron, H.D. Gilliam and R.J. Jones.
Calculation and testing of decompression tables for air dives employing the procedure of surface decompression and the use of oxygen.
U.S. Navy Exp. Diving Unit, Rep. 1-51, 56p. 1951.

A series of decompression schedules which employ the procedure of surface decompression and which utilize the administration of oxygen during the recompression period have been formulated and tested for service use at depths of 70 to 170 feet inclusive. These tables represent the culmination of 1165 experimental dives performed at the Experimental Diving Unit plus interim testing by 40 additional dives at the Naval Torpedo Testing Range at Newport, Rhode Island. Final evaluation of the accepted tables was conducted by the performance of 212 dives in the open sea at Key West, Florida, followed by 6 additional repeat dives, and by 151 dives in cold water at the Diving Unit, followed by 2 additional repeat dives. (Authors' summary)

372.
VAN LIEW, H.D.
Dissolved gas washout and bubble absorption in routine decompression.
In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the fourth symposium on underwater physiology, p.145-150. New York, Academic Press, 1971.

It is hypothesized that following decompression the breathing of nitrous oxide (N_2O) should act as a bubble amplifier to reveal silent bubbles since it will diffuse into a N_2 bubble 11 times faster than N_2 will diffuse out. Rats were exposed to pressure of 6 atm. abs. for 110 min., then were decompressed at a rate of 50 ft/min. On completion of decompression one group were left in the cage breathing air while the others were supplied a breathing mixture of 80% N_2O-20% O_2. The increased incidence of severe signs of decompression sickness and of death was two- or three-fold for those exposed to the nitrous oxide. (CWS/BSCP)

373.
VINCENT, C.E.
The magnitude of pressure fluctuations encountered by divers.
J. Soc. Underwater Technol. 2:16-18; Jan. 1977.

The author writes in answer to a letter by Dr. O.F. Conran (J. Soc. Underwater Technol. 2:25; Sept. 1976) regarding the possibility of barotrauma and decompression sickness being caused by waves, in which it is pointed out that decompression tables do not take waves into account, although a 5 m wave gives a variation of ½ atm over a diver until he reaches the point where he goes up and down with the surface waves. The present author feels that this is an exaggeration. Pressure fluctuations are to be found mostly in shallow water. In deep water, problems occur only when the diver is not free-swimming. He should allow himself to move as freely as possible and not cling rigidly to a fixed structure. Another reply to the same letter, by Dr. H.V. Hempleman of the Royal Naval Physiological Laboratory, Alverstoke, states that there is a small group of professional divers who do not use bells and who are subjected to unacceptable pressure variations at the 3-meter stop due to surface conditions. Therefore, the Construction Industry Research and Information (1968) Air Diving Tables have the final stop at 20 feet (6 meters), and the metric version (1972) has it at 5 meters, thus ensuring better depth keeping. (MFW/UMS)

374.
VOROSMARTI, J., Jr., R. de G. Hanson and E.E.P. Barnard.
Further studies in decompression from steady-state exposure to 250 meters.
In: Shilling, C.W. and M.W. Beckett, eds. Underwater physiology VI. Proceedings of the sixth symposium on underwater physiology, p.435-442. Bethesda, Md., Federation of American Societies for Experimental Biology, 1978.

This report describes a series of 78 man-exposures which were done to extend the investigations reported previously by Barnard. The purpose was to produce a single schedule for decompression from steady-state exposures at all depths down to 250 metres for the atmospheric conditions of 0.22 bar oxygen in helium with nitrogen content less than 1% of 1 atmosphere. It was found that the equation which described the decompression from depths down to 180 metres as derived from the early dives in the series did not provide adequate decompression schedules for deeper depths. Empirical changes to the slope and/or total time of the decompression curve did not make any significant difference in the outcome. Using Barnard's original equation with a partial pressure of 0.4 bar of oxygen was successful. Thirty-six man-exposures to 250 metres for bottom times of between 1 and 7 days have been conducted using this schedule. Using the lower oxygen tension at depth appears to have no effect on the outcome of decompression as long as the higher partial pressure is used throughout decompression. (From Sixth symposium program and abstracts)

375.
WALDER, D.N.
The effectiveness of the British decompression table.
In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, 1965. p.65-70. Newcastle-upon-Tyne, Oriel Press, 1967.

With tables based on Haldane's concepts and designed as a compromise between the theoretical ideal decompression and a practical procedure acceptable to the industry a bends rate of two percent was accepted as a working basis. On this basis the British decompression tables are successful for neither type I or type II bends exceeded this rate on any of the contracts. Several factors may influence the bends rates: accuracy of data depends on both whether the men report or the medical attendant accepts the complaint as valid; there is a process of natural selection by which the bends-susceptible individuals tend to quit; and workers tend to be acclimatized; length of shift is related to the number of cases with the longer working hours producing more bends; and with the present table the higher the working pressure the more cases of bends. (CWS/BSCP)

376.
WALDER, D.N., A. Evans and H.V. Hempleman.
Ultrasonic monitoring of decompression.
Lancet 1:897-898; Apr. 27, 1968.

Decompression sickness is still disturbingly prevalent among divers and caisson workers. Acute decompression sickness has been divided into two types. Type 1, "the bends" is defined as pain usually in the limbs from which there is no danger of loss of life. Type 2, "other manifestations" can affect the cardiovascular, the respiratory and the central nervous systems. These are dangerous unless treated. This kind of decompression sickness can develop in man after a very short exposure to pressures as low as 25 p.s.i.g. There is also caisson disease of the bone. If these decompression sickness diseases are results of bubbles in the body, and if caisson disease of the bone is due to "silent" bubbles, then the logical way to avoid decompression sickness is to prevent bubble formation or to ensure that the bubbles are kept to a minimum size. A method has been devised for detecting bubbles in animals using ultrasonic techniques. Other workers have explored the possibility of exploring and detecting them by the attenuation of an ultrasonic beam, and by use of an implanted Doppler ultrasonic flow meter. Our method makes use of a pulsed ultrasonic transducer, which is held by a clip onto a fold of back skin of the animal. This is connected to an ultrasonic transmitter-viewer, which displays on an oscilloscope screen echo pulses representing the proximal and distal surfaces of the fold of the skin. Illustrations and a further explanation of the methods are given. (EH/BSCP)

377.
WALDER, D.N.
Bone lesions in divers.
J. Bone Joint Surg. 56B:1-2; Feb. 1974.

In this brief editorial, the author makes some general observations on the incidence of osteonecrosis in compressed air workers and in divers, as discovered in surveys made during the past few years. Although the disease has occurred in divers and workers who have observed the currently accepted decompression tables, it is still generally believed that it is decompression-connected. Japanese divers, who observe no decompression control at all, have an overwhelming incidence of osteonecrosis (more than 70% in all with more than ten years of diving experience). This would appear to refute the theory that compression rate is involved, since the Japanese divers were not subjected to rapid compression. New decompression tables have been computed by the Construction Industry Research and Information Service, and it is hoped that their observance will reduce the incidence of osteonecrosis. (MFW/UMS)

378.
WALDER, D.N. and R.I. McCallum.
An objective appraisal of the Blackpool (U.K.) and Washington state (U.S.A.) decompression tables.
In: Trapp, W.G., E.W. Bannister, A.J. Davison and P.A. Trapp. O_2. Fifth international hyperbaric congress proceedings, p.905-911. Burnaby, Canada, Simon Fraser University, 1974.

The incidence of bends during the Dungeness B contract in the U.K. is compared with that in three major U.S. contracts. Seattle, San Francisco, and Milwaukee. The U.K. tables were more effective in the first two, but less effective in the third. A different approach to the data resulted in a graph which indicates that the U.K. tables are considerably more effective. As to bone lesions, it is indicated that had the U.K. tables been used at Seattle, San Francisco, and Milwaukee, one bone lesion would have occurred, since all but one of the bone lesions that occurred at Dungeness B were at pressures or exposure times in excess of the U.S. limits. No bone lesions have been reported from the U.S. contracts. Thus, when bone lesion incidence is used as the criterion, the two tables appear about equal. The authors strongly recommend a centralized system of data collection, such as the Medical Research Council Decompression Sickness Panel has set up in the U.K. There is no such uniform system of data collection in the U.S. (MFW/UMS)

379.
WALDVOGEL, W. and A.A. Buhlmann.
Man's reaction to long-lasting overpressure exposure. Examination of the saturated organism at a helium pressure of 21-22 atmospheres.
Helv. Med. Acta p.130-150; Mar. 1968.

Four subjects breathing a mixture of 2.0-3.5% O_2, 93-94% He and 3.0-3.5% N_2 were exposed in a pressure chamber for 66 hours with a pressure of 23.0 atm, and there was a practically complete saturation of the organism with a He pressure of 21-22 atm. The experiment was well tolerated. Decompression followed without complication and lasted 64 hours. No important changes as to body temperature, blood pressure, pulse rate, hemoglobin concentration, serum electrolytes and serum proteins, ferment activity, blood corticosteroids and catecholamine excretion were observed either during or immediately after exposure. We noticed, however, an increase of the urea-concentration without hemoconcentration, a negative fluid balance and an increased leucocyte count in all 4 of the subjects. (Authors' summary)

380.
WATT, D.G. and Y.C. Lin.
Doppler determination of thresholds for decompression-induced venous gas emboli in the awake rat.
Physiologist 21:126; Aug. 1978.

Abstract only. Entire item quoted: Attempts to formulate safe decompression schedules for man have relied heavily on extrapolation from animal models. The convenience, however, of using small laboratory animals such as rats has been offset by the difficulties in assessing less than severe decompression sickness (DS). Male Wistar rats (470 ± 25g) were prepared with chronic implants of 2mm, 9MHz perivascular doppler probes on the posterior vena cava with the leads exteriorized. Awake, unrestrained animals were allowed to saturate on compressed air in a 1 L. plexiglass chamber at a max. pressure (P_1), were rapidly decompressed by a predetermined pressure (P_2) and then monitored for the presence of intravascular bubbles. The predictable relationship $P_1 = a P_2 + b$, where a and b are constants defining the threshold for bubble formation, was experimentally verified at pressures from 3 to 10 ATA by determining the max. P_2 not producing detectable bubbles. The linear relationship $P_1 = 2.29 P_2 - 1.37$ ($r = 0.99$, $p < .001$) was found for first exposures and $P_1 = 1.64 P_2 - 0.14$ ($r = 0.99$, $p < .001$) for repeat exposures. This method is based on a well-defined end point for DS thresholds, can be used on awake, unrestrained small laboratory animals and does not result in debilitation or death, thereby allowing construction of more efficient decompression schedules.

381.
WHYTE, H.E.
A modification of the British decompression table used at the Clyde Tunnels.
In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, October 1965. p.170-176. Newcastle upon Tyne, Oriel Press, 1967.

The decompression tables used for the workers on the Clyde Tunnels in England were entirely satisfactory for pressures up to 20 p.s.i.g., but the incidence of bends became 4.8% in the first week when pressure was increased to 27 p.s.i.g. An adjustment was made to use the decompression time for a two pound increase and the incidence was cut to 0.29%. This amounts to 469 recompressions necessary following 161,005 decompressions. For some of the other tunnel work the percentage became as high as 1.05%. The experiences in Britain indicate that the 1958 tables need revision. (CWS/BSCP)

382.
WILSON, H.D.
Commercial saturation diving operations.
In: The working diver – 1974. Symposium proceedings, March 1974, Columbus, Ohio. p.29-39. Washington, D.C., Marine Technology Society, 1974.

The growth rate of scientific development often surpasses man's ability to balance the benefits of new technology against the proven effectivensss of old techniques and equipment. The diving industry is faced with such a quandary today with the rapid advance of deeper diving and more complex systems. This paper identifies the need for closer observation of diving techniques as applied to underwater problems, addressing the question of when to use what system for accomplishing the job. The needs for saturation diving, bell diving, surface diving, and observation diving all exist in today's offshore operations, and the determination of what approach to use should not be based on a company's particular orientation, but rather the compatibility of the equipment as it functions on the job. (Author's abstract)

383.
WILLMON, T.L. and A.R. Behnke.
Nitrogen elimination and oxygen absorption at high barometric pressures.
Am. J. Physiol. 131:633-638; 1940.

Excess nitrogen gas absorbed by divers exposed in a compression chamber to a simulated depth of 100 feet is usually eliminated more rapidly when oxygen is breathed at a level between 50 and 60 feet in comparison with higher or lower levels. The retardation in the elimination of nitrogen observed at the 100-foot depth when oxygen is breathed is attributed to the vasoconstriction and slowed circulation incident to oxygen inhalation. The increased oxygen absorption accompanying oxygen inhalation at high pressures can be accounted for on the basis of oxygen taken up by the tissues in physical solution. (Authors' summary)

384.
WOOD, S.C., J.D. Bloom and A. Messier.
Methemoglobin formation in humans during exposure to hyperbaric oxygen in a standard Navy decompression treatment table.
U.S. Nav. Submar. Med. Res. Lab., Rep. NSMRL 676, 6p. July 30, 1971.

[The problem was] to test the hypothesis that hemoglobin oxidation (ferro-to-ferri-hemoglobin) will occur at an increased rate if erythrocytes are exposed in vivo to hyperbaric oxygen at the level encountered while breathing O_2 during Standard Navy Decompression Treatment Tables. The hypothesis was accepted on the basis of two subjects exposed to hyperbaric oxygen in accordance with decompression treatment Table 6. Both subjects developed methemoglobin concentrations ranging from 6 - 9% of total hemoglobin during decompression from 60 FSW. Pre- and postdive values were 1 to 4% methemoglobin. The significance of these changes is that oxygen transport to tissues is compromised in the presence of methemoglobin by a) decreased O_2 content of arterial blood and b) increased oxygen affinity of arterial blood. These findings, while preliminary, deserve consideration by submarine medical officers dealing with decompression treatment or experimental compression of subjects breathing oxygen. Persons susceptible to methemoglobinemia, e.g., those taking antimalarial and certain other drugs and glucose-6-phosphate dehyodrogenase deficient individuals, should be identified before being exposed to OHP. (Authors' abstract)

385.
WORKMAN, R.D.
Calculation of air saturation decompression tables.
U.S. Navy Exp. Diving Unit Res. Rep. 11-57, iv. + 43p. June 20, 1957.

To develop a safe decompression table for longer exposures than allowed for on the existing standard air tables, as a protection for the trapped diver and other emergencies. On the basis of the results of 46 long exposure dives it was determined that control of slower half-time tissues as the 160 and 240 minute tissues was required to provide reasonably safe decompression. It was found that the 120 minute tissue could surface safely with 65 feet absolute inert gas tension and the 160 and 240 minute tissues could surface safely with 64 feet absolute. The control of the allowable tissue tensions at the decompression stops was determined on the basis of the relation of change (S) and differential (E) to known safe tissue tensions at 66 feet and 33 feet absolute for the various half-time tissues. Tables calculated on the basis of these controls agree well with those dives in this series which caused symptoms in only a few relatively susceptible subjects. It is believed that decompression tables to be safe for all subjects on long exposures would be unnecessarily long, compared to the decompression requirements of the greatest number of subjects. The increments of depth and exposure time provided in these decompression tables will provide safer, more efficient decompression than the present tables in use today. [Recommendations are made as follows:] 1) Approve the decompression tables for field use in emergency decompression for longer and deeper exposures than provided for by the revised standard air decompression tables. 2) Incorporate the tables presented into Part I of the U.S. Navy Diving Manual now in preparation. 3) Determine the feasibility of use of the submarine rescue chamber for decompression of the diver requiring long water stops. Provide oxygen decompression to shorten the shallower stops in the rescue chamber. 4) Determine the correlation of susceptibility of subjects in this series to altitude decompression sickness toward development of a practical susceptibility test for divers. 5) Test short and long exposures for subjects using decompression schedules based on a constant ratio for each half-time tissue in an attempt to shorten decompression requirements for long exposures. (From author's summary and conclusions)

386.
WORKMAN, R.D.

Oxygen decompression following air dives for use in hyperbaric oxygen therapy.
U.S. Navy Exp. Diving Unit Res. Rep. 2-64, 10p. Dec. 15, 1964.

Two decompression schedules with use of oxygen were tested to provide for 3 and 4 hour air exposures at 3 atmospheres absolute pressure required for use in hyperbaric oxygen treatment. Schedules for such long exposures have not been available previously to permit use of oxygen breathing that decompression time be shortened. Six subjects were exposed to air breathing in a dry pressure chamber at 70 feet equivalent depth in seawater for periods of 180 and 240 minutes, respectively. Decompression was carried out with oxygen breathing at 30, 20, and 10 foot stops. All six subjects exposed for 180 minutes were symptom-free following decompression. Of six subjects exposed for 240 minutes, one subject developed transient vertigo one hour postdive, which resolved promptly with oxygen breathing at a depth of 60 feet. Greater than average susceptibility to decompression sickness from such prolonged exposures in this subject is considered to be a severe test of adequacy for this schedule. Thus, the schedules tested should provide efficient decompression for these prolonged exposures with minimal risk of symptoms of decompression sickness. No manifestations of oxygen toxicity appeared during the oxygen decompression periods. Risk of toxicity should be minimal with use of these schedules since the exposure is well within the safe limits for subjects at rest. (Author's abstract)

387.
WORKMAN, R.D.

Calculation of decompression schedules for nitrogen-oxygen and helium-oxygen dives.
U.S. Navy Exp. Diving Unit Res. Rep. 6-65, 33p. May 26, 1965.

This report presents the theoretical basis for calculation of decompression schedules for nitrogen-oxygen and helium-oxygen mixtures used in diving. It includes definitions, theory of exponential saturation and desaturation, and theory of limiting values of excess saturation permitted at various ambient pressures with helium and nitrogen. An attempt has been made to simplify the presentation of the calculation procedure to implement the theoretical method. The necessary tables and worksheets used in calculations are present, together with sample calculations of dive schedules. The discussion describes and appraises other methods of calculation developed in recent years. (Author's abstract)

388.
WORKMAN, R.D. and J.L. Reynolds.

Adaptation of helium-oxygen to mixed gas, SCUBA.
U.S. Nav. Exp. Diving Unit Res. Rep. 1-65, 60p. Mar. 1, 1965.

A decompression procedure for use of helium-oxygen mixtures in mixed gas SCUBA to permit repetitive dives to a depth of 200 feet has been developed employing modified Haldane principles. The repetitive diving procedure provides a system by which a diver can determine the necessary increase in decompression time in successive dives. The amount of decompression required for use in this system is obtained from 4 tables: 1) decompression table; 2) decompression dive table; 3) surface interval credit table; and 4) repetitive dive table. A method for use of oxygen decompression at 30 and 20 foot water stops is also provided. The validity of this procedure is based on tests of 486 dives in which 28 three-dive series and 68 oxygen decompression dives were made. The procedure as reported is considered satisfactory and is recommended for further testing under operations conditions in the field before service-wide use. (Authors' abstract)

389.
WORKMAN, R.D.

Underwater research interest of the U.S. Navy.

In: Lambertsen, C.J., ed. Underwater physiology. Proceedings of the Third Symposium on Underwater Physiology, 23-25 March 1966, Washington, D.C., p.4-15. Baltimore, Williams and Wilkins Co., 1967.

The recent interests of the U.S. Navy have emphasized the Man-in-the-Sea Program and this has led to the development of the underwater station; the submersible decompression chamber (SDC); and the shipboard or decompression chamber (DDC). This operates as a complex and makes for longer working hours on the bottom, and easier, safer and more pleasant decompression. Several types of additional equipment have been developed for use by the divers as part of the complex. This type of underwater work has required modification of the decompression tables and routine. (CWS/BSCP)

390.
WORKMAN, R.D.

American decompression theory and practice.

In: Bennett, P.B. and D.H. Elliott, eds. The physiology and medicine of diving and compressed air work, p.252-290. Baltimore, Williams and Wilkins, 1969.

Safe decompression is governed by several considerations: a rate of ascent which will not permit the formation of inert gas bubbles in the tissues of the diver; oxygen exposure low enough so as not to induce toxic effects; gas density and the development of narcosis; breathing resistance; tissue solubility; operational consideration such as sea states and water temperature; logistics of handling different gases aboard ship; and fire hazard of bases such as oxygen and hydrogen. Early development of decompression procedures rested on the stage decompression method, but with extensive studies on supersaturation limits in decompression the safe ratio was changed from 2.25 to 1.8 to 1. Further work indicated that half-time for tissue saturation was such that one could ignore the five and ten minute tissues almost entirely and allow a safe ratio of 3.2 to 1 for the 20 minute tissues and 2.4 for the 40 minutes tissues but must hold to 1.8 for the 75 minute tissues. A special schedule was developed for repetitive diving with air by the scuba method. Also special air decompression schedules were developed for exceptional exposures to great depths. With the advent of the use of helium another set of special decompression schedules were developed for deep diving with this gas in the breathing mixture. Recently the advent of saturation diving and excursion diving from saturation exposures at depth has led to further modification of decompression schedules. Decompression using helium-nitrogen-oxygen mixtures has further complicated the picture. The article gives many decompression tables covering all of these various situations. (CWS/BSCP)

391.
WORKMAN, R.D.

Experience with modified U.S. Navy helium-oxygen decompression schedules, saturation decompression and evaluation of divers for aseptic bone necrosis.

In: The working diver - 1974. Symposium proceedings, March 1974, Columbus, Ohio. p.377-385. Washington, D.C., Marine Technology Society, 1974.

Modified U.S. Navy helium-oxygen decompression schedules have been employed for 768 dives to depths from 180 to 350 feet with an incidence of 0.5% bends resulting. Bottom times were 80 minutes at 180 feet to 40 minutes at 350 feet with hard work performed. Thirty-nine saturation operations have been conducted in 1973 with 234 men under pressure for a total of 2409 days. Four bends occurred in 234 men decompressed for an incidence of 1.7%. Over a period of three years, 400 bone surveys have been done for diver applicants with only six men determined to have lesions of aseptic necrosis of bone, all of which occurred in shoulder joints. None of the affected divers had participated in saturation diving. (Author's abstract)

392.
WORKMAN, R.D. and R.C. Bornmann.

Decompression theory: American practice.

In: Bennett, P.B. and D.H. Elliott. The physiology and medicine of diving and compressed air work; Second Edition, p.307-330. Baltimore, Williams and Wilkins Co., 1975.

"The most crucial, and still controversial, aspect of decompression is the mathematical treatment of inert gas transport in the body tissues. This must meet two key criteria: it must be capable of dealing adequately with the limitations imposed by operational diving and it must permit the extraction of information from diving experience that is of predictive value to increase the probability of successful decompression under diving conditions in which parameters of pressure exposure, time and composition of the breathing mixture have been changed." This survey of the subject covers the following subject areas: Early development of decompression procedures in the U.S. Navy; Development of the Haldane method of decompression; Further studies to define supersaturation limits in decompression; Development of repetitive dive schedules for air diving; Studies of the rate-limiting process in inert gas transport; Development of helium-oxygen decompression schedules for deep diving; decompression after saturation diving; Excursion diving from saturation exposures at depth; Deeper working dives with helium-oxygen, Decompression with helium-nitrogen-oxygen mixtures with constant PO_2 mixed gas scuba; Rationale for modifications made to the Haldane method of decompression calculation in the U.S. Navy; Appendix: Computations for decompression. (MFW/UMS)

393.
YOUNT, D.E., R.H. Strauss, E.L. Beckman and T.O. Moore.

The physics of bubble formation; implications for improvement of decompression methods.

In: Hong, S.K., ed. International symposium on man in the sea, Honolulu, July 1975, p.V-167 - V-178. Bethesda, Md., Undersea Medical Society, Inc. 1976.

Crushing of gas nuclei has been studied quantitatively in gelatin and it has been shown that the number of bubbles can be greatly reduced by rapid compression or by pressure spikes at the beginning of a dive schedule. As a result of these experiments, it is now possible to compute mathematically optimal decompression schedules that are safer and faster for gelatin at a given depth and duration than the U.S. Navy tables. . . . Methods for calculating optimal schedules for gelatin are discussed and experimental comparisons with other tables are summarized. In Section III, our first attempts to prepare decompression tables for humans a priori are described, and the results compared with other well-known procedures. . . . If the time constants used in calculating decompression tables have any physiological significance, then presumably the full range is present whether the dive is of short or long duration. It follows that the same set of time constants should be used universally in any general computational routine. The fact that the Yount-TEKTITE prescription gives sensible predictions for both the short dive of Table VB-1 and the saturation dive of Table VB-2 suggests that this constraint is compatible with, and perhaps even required by, the other assumptions of the a priori procedure. While the a priori procedure apparently requires a broad range of time constants, these need not be associated with tissue half times per se. In particular, it may be possible to generate sensible tables by assuming a broad range of restoration time constants and, for example, a single tissue type. Justification for such an approach can be found in the relatively long persistence of the acclimatization observed among compressed air workers. (Authors)

394.
ZAL'TSMAN, G.L.

Features in processes of saturation (desaturation) and oversaturation of organism and principle of estimating the decompression regimes during extended stay under pressure.

In: Azhazha, V.G., ed. Some results and prospects for the use of underwater habitats in marine investigations, p.15-24. Moscow, Izdatel'stvo Nauka, 1973. Translated by U.S. Joint Publications Research Service, Oct. 23, 1974. (JPRS 63261)

The author presents experimental data and advances generalizing concepts characterizing the processes occurring in an organism under conditions of increased pressures. He discusses the principles of estimating the regimes of safe decompression during brief and prolonged stay under pressure. The classical method of calculating the regimes according to the Haldane tables has been modified with allowance for the data presented. In interpreting the saturation processes in an organism, the authors proceeded from the fact that the dynamics involved in a cell's penetration by substances chemically neutral to metabolic processes are described by exponential curves and hence the entire diversity of an organism's cellular systems can be represented by a continuous set of exponents. In this way Haldane's form of reference tissues is retained but a new physiological content is included in them. (Author's abstract)

395.
ZANNINI, D.

Decompression tables used in Italy for caisson work.

In: McCallum, R.I., ed. Decompression of compressed air workers in civil engineering. Proceedings of an international working party held at the Ciba Foundation, London, 1965. p.34-40. Newcastle upon Tyne, Oriel Press, 1967.

Regulations in Italy for accident prevention and the hygiene of compressed air work, established in 1956, deal with daily working time, compression and decompression times, as well as rules covering working conditions. The work periods may be divided into two periods or may be continuous but according to USA standards the prescribed decompression times are unsafe. (CWS/BSCP)

396.
ZUNTZ, N.

Zur Pathogenese und Therapie der durch rasche Luftdruckanderungen erzeugten Krankheiten.

[On the pathogenesis and therapy of illnesses caused by sudden changes in air pressure]. Fortschr. Med. 15:632-639; 1897.

This article discusses the evidence for the efficacy of recompression in the treatment of compressed air illness, outlines the mechanical nature of the pressure insult, reviews evidence obtained from experimental animals, and recommends a treatment regime consisting of rapid recompression at "high" pressure (3 atmospheres), followed by a gradual reduction in pressure to atmospheric level. (MBK/UMS)

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ANALYSES

Introduction

A bibliography, even an annotated bibliography is of limited value in itself. The real value of any study is in the analysis of the literature at a sub-topic level of interest to the researcher or administrator.

To make this critical type of analysis requires studying the full text. However, in the case of the analyses that follow, in most cases we have read only the informative abstracts and have produced a few topics suggestive of the type of in-depth analysis which should be undertaken.

It cannot be too strongly emphasized that these analyses are but suggestions of what ought to be done, which we trust will stimulate interest, discussion and perhaps action.

TYPES OF LABORATORY ANIMALS USED

This analysis is remarkable from the fact that so few of the workers in the field used animals in their research. In fact only one in 10 (39 out of 406) used laboratory animals. Most of the research work on the development of decompression tables was done with human beings as the subjects. It is worthy of note that under the rules for use of human subjects in this country much of the research could not be undertaken at the present time.

The list of different animals used follows with an alphabetical arrangement and the abstract number of the work.

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GROWTH OF THE LITERATURE

The first paper to present the bubble theory of the cause of decompression sickness was that by Boyle in 1660 (Abstract #61). It was 200 years until the next paper appeared (Abstract #201). The abstract number has been noted for those appearing prior to 1925. It is interesting to note that in the single year, 1974, there were more (54) papers published than in the entire first 300 years. This remarkable increase in activity in the decade 1967-1976 is due to the commercial search for oil and the fact that the U.S. Navy tables were not satisfactory for the extreme depths and length of exposure being experienced by commercial divers.

	1660 –	1	(Abstract # 61)
	1857 –	1	(Abstract # 201)
	1878 –	1	(Abstract # 47)
	1897 –	1	(Abstract # 396)
	1900 –	1	(Abstract # 157)
	1906 –	1	(Abstract # 180)
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COUNTRY OF ORIGIN

The degree of interest and the level of sophistication in a particular scientific area of research is indicated by the number of scientific papers published. This is true, not only for a given individual, but for a nation as well.

The 406 scientific papers dealing with various aspects of the history of decompression have been analyzed for country of origin and are reported in the table that follows. The countries are rank-ordered by number of publications and each paper is numbered to coincide with the bibliographic entry for ease of identification.

LIST OF PAPERS PUBLISHED BY COUNTRY OF ORIGIN

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