Annotated Bibliography

HUMAN PERFORMANCE IN THE UNDERSEA ENVIRONMENT

RAYMOND E. REILLY

prepared for

Naval Research Laboratory
Washington, D. C.

Under ONR Contract No. N00014-70-C-0052
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ACKNOWLEDGEMENT

Technical direction for this study was provided by Mr. C. L. Tipton, Head, Special Studies Group, U.S. Naval Research Laboratory (Code 4020).

Sincere gratitude is extended to the many researchers in the United States, Canada, and Europe who so generously provided reprints, bibliographies, and leads to further sources of technical information.

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INTRODUCTION

The purpose of this effort was to review technical literature concerning human mental and perceptual-motor performance in wet and dry hyperbaric environments. Recognizing that active researchers in this area span the globe and that publication lags are so great, a direct request was made to those individuals and agencies who it was thought might provide up to date information and references which might not be identified through normal data retrieval channels.

The response to this request was far beyond expectations. Consequently, despite severe time and fiscal constraints, it was decided to incorporate as much of this literature as possible into a bibliography in the hope that through rapid preparation and circulation, it would serve as a contribution to the research community.

Organization of the Bibliography

While some studies are limited to a single topic, many more range across several categories. Therefore, to provide the most rapid access to these references, they are listed alphabetically by author and then indexed by subject.

Abstracts and summaries were taken verbatim from reports which had them. These are marked AA indicating "author abstract."

Where no abstract was provided, material in some instances was taken directly from various points in the report to comprise a summary. These are labeled OM indicating "original material" essentially as it can be found in the report. Abstracts prepared by the reviewer are labeled RA ("reviewer abstract").

Researchers who had bibliographies available were kind enough to provide copies for use in the present review. While key articles were obtained wherever possible, it was far beyond the present scope to attempt acquisition

of all references identified. Accordingly, the bibliographies are referenced on the assumption that interested and qualified persons may obtain copies directly from the individuals who compiled them.

A listing of individuals actively engaged in underwater, hyperbaric, or associated research is provided at the end of the report.

1 Adolfson, J. Human performance and behavior in hyperbaric environment. Acta Psychologica Gothoburgergensia, 1967. p 5-75. 102 refs. (Almquist & Wiksell, Stockholm. Pub.)

Man's dependence on a respirable gaseous milieu is one of the major restrictions hindering him in his explorations of inner space or the earth's hydrosphere. At raised ambient pressures the air affects mental and psychomotor functions, resulting in symptoms such as reduced motor co-ordination ability, a diminution in sight and hearing, prolonged reaction time, reduced ability in forming an estimate, and a general reduction of the mental activity, probably caused by disturbances in the central nervous system. This "hyperbaric air intoxication", also called "nitrogen narcosis" or "depth narcosis", has cost a number of divers' lives since the introduction of modern deep diving, especially during the last decades.

Although a great number of investigations have been conducted in the field of hyperbaric air intoxication, opinion still differs as to what extent hyperbaric environment affects man and at what pressure level depth narcosis will start. In the present investigation an attempt has been made to obtain further data on human performance and behaviour in hyperbaric environments, including ambient pressures of 13 atmospheres absolute. (AA)

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2 Adolfson, J. Deterioration of mental and motor functions in hyperbaric air. Scand. J. Psychol., 1965, 6, p 26-32. 23 refs. (a)

The effects of hyperbaric air on manual dexterity and arithmetic calculation capacity were studied in 15 subjects at ambient pressures of 4, 7, 10, and 13 ata at rest, and at 4, 7, and 10 ata during exercise (300 kpm/min). A significant reduction of the performance in both tests was observed at 10 and 13 ata at rest. During exercise in manual dexterity the reduction was significant at 4, 7, and 10 ata and in arithmetic calculation capacity at 7 and 10 ata. At 13 ata (at rest) a number of marked behavioural symptoms were observed, including changes in mood, impairment of consciousness, disturbance of perception, and deterioration of motor functions. These changes were readily reversible as soon as the pressure was lowered. (RA)

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3 Adolfson, J., & Muren, A. Air breathing at 13 atmospheres. Psychological and physiological observations. Forsvarsmedicin, 1965, p 31-37, 18 refs. (b)

Fifteen pressure chamber experiments each involving a single subject free-breathing air (no mack) were conducted. A series of mental and motor tests were given at pressure depths of 98, 197, 295, and 374 feet, respectively. Exposure time was usually 40 minutes.

Observations of general behavior including alterations of consciousness, abnormal perceptual and psychosensorial phenomena were recorded. Physiological data including heart activity and cathecholamines of the urine were also obtained.

Manual dexterity, arithmetic conputation, word association frequency and speed all deteriorated at 197 feet and deeper. (RA)

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4 Andersen, B. G. Diver performance measurement: Underwater navigation, depth maintenance, weight carrying capabilities. Prepared by General Dynamics, for Office of Naval Research, Washington, D.C. U-417-68 -030. July 1968, 9 refs.

This report presents the results of an initial field test program in a study of diver performance measurement currently being conducted by the human factors section of Electric Boat division of General Dynamics. The purpose of this study was to develop and apply measurement techniques to determine a free-swimming scuba diver's ability and capacity to carry specified weighted objects underwater while maintaining a given depth and swimming a prescribed compass course. A diver-worn telemetry unit was used to measure diver depth and air tank pressure.

a. Navigation Accuracy

An average compass course error of 5.21 degrees equivalent to 71 feet over the 780-foot course was recorded. Individual performance improved with practice. Neither the amount of weight carried by the diver nor the location of the weights affected performance on the navigation task.

b. Swimmer Speed

Average swimmer speed over the test range was 1.20 knots. While large individual differences existed, the amount of weight carried or the location of the weight on the diver had no significant effect.

c. Air Consumption

Overall average air consumption rate was 1.40 cubic feet per minute as calculated for the average swimming depth of 21.4 feet. Air consumption increased progressively as a function of increased weight. The rate of air consumption also increased over time during the run.

d Depth Maintenance

Swimmer depth was maintained at an average of 21.4 feet or 1.4 feet deeper than the ordered reference depth; however, performance level decreased significantly with added weight. Depth maintenance also differed significantly over time during the run. (OM)

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5 Anon. The nature and significance of Project Tektite. Naval Research Review, 1969, 22(7), p 1-5. (a)

Tektite 1 was a cooperative multi-agency/industry/university program designed to place four marine scientists, under saturated diving conditions, on the ocean floor for 60 continuous days. It involved the Departments of the Navy and Interior, the National Aeronautics and Space Administration, and the General Electric Company with assistance from the Coast Guard, the University of Pennsylvania, and other government, industry, and academic organizations. It was under the overall cognizance and management of the Chief of Naval Research. Among its principal objectives were psychological and physiological studies of crew behavior, marine scientific investigations, and advancement in undersea technology and engineering.

This article describes many significant events of this highly successful project. (OM)

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6 Anon. Tektite I. 1440 hours on the bottom of the sea. Naval Research Review, 1969, 22(2), p 1-14. (b)

This report describes the composition and goals of Tektite I, "...a multi-agency/industry program to determine the capability of a small group of men to satisfactorily perform a scientific research mission while living isolated on the ocean floor under saturated diving conditions for a long period of time." (RA)

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7 Baddeley, A. D. Diver performance. 42 refs. To appear in "Underwater Science". J. D. Woods & J. N. Lythgoe (Eds.) Oxford University Press (in press).

Baddeley observes that, "With the exception of pressure chamber studies of inert gas narcosis, little work has been done on diver performance, and any attempt to produce a systematic survey of the field would rapidly become a catalogue of unanswered questions."

Accordingly, the chapter is devoted primarily to the visual performance of divers, and the effects of inert gas narcosis.

The material on vision covers diver visual fields and visual acuity. In discussing inert gas narcosis, Baddeley provides an incisive discourse on the methodology and experimental control problems associated with research of this kind. (RA)

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8 Baddeley, A. D. Visual acuity underwater--a review. Underwater Association Report 1968, p 45-49. 8 refs.

Five experiments on underwater visual acuity are reviewed. Four showed acuity to be poorer than in air, bearing in mind the magnification of the target produced by the diver's face mask. The fifth gave comparable acuity scores, but divers took much longer to make the discrimination underwater. In three studies the acuity of short-sighted subjects tended to be less impaired underwater. Poorer performance underwater is attributed to (1) loss of definition

due to the absorption and scattering of light from the target; and (2) difficulty in focusing accurately due to conflicting visual cues. (AA)

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9 Baddeley, A. D. Diver performance and the interaction of stresses. Underwater Association Report 1966-67, p 35-38. 14 refs.

A number of experiments on the interaction between inert gas narcosis and the stresses associated with deep diving are discussed. The first two studies described show a much greater drop in diver efficiency at depth in the open sea than would be expected on the basis of performance at an equivalent pressure in a dry chamber. A third experiment did not show this exaggerated open sea effect. Examination of diving conditions during the three studies suggests that the marked drop in efficiency at depth is probably associated with anxiety. (AA)

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10 Baddeley, A. D. Time-estimation at reduced body-temperature. The American Journal of Psychology, 1966, 79(3), p 475-479. (a)

In the first of two experiments 20 Scuba divers were asked to count up to 60 at a 1-sec. rate at various times during a week of diving in cold sea water. Rate of counting was found to be correlated significantly and positively with body-temperature, but not with pulse-rate or with order of test. A second experiment tested the hypothesis that this result was due to pre-dive anxiety causing S to count more rapidly before a dive. When other divers counted a minute before and after a warm but stressful dive involving the placement of explosives, there was no change in counting rate. It may be concluded that body-temperature affects time-estimation in the manner predicted by Hoagland's chemical-clock hypothesis. (AA)

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11 Baddeley, A. D. Nitrogen narcosis and the working diver. Triton, 1966, p 24-26. 3 refs. (b)

A series of experiments concerning the effect of nitrogen narcosis on mental and motor functions is reviewed.

Of particular concern is the minimum depth at which performance decrements may be correctly attributed to the narcotic effect of nitrogen under pressure. (RA)

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12 Baddeley, A. D., de Figueredo, J. W., Curtis, J. W.H., & Williams, A. N. Nitrogen narcosis and performance under water. Ergonomics, 1968, 11(2), p 157-164. 13 refs.

Eighteen divers were tested four times under water, twice at a depth of 5 ft and twice at 100 ft. They performed three tests--digit copying, a sentence comprehension test and a manual dexterity test. All three showed a significant drop in efficiency at depth. This was small for digit copying (7.9 per cent) and manual dexterity (3.5 per cent), and somewhat larger for sentence comprehension (15.3 per cent). In all three cases the drop in efficiency was approximately the same as found at the equivalent pressure in a dry pressure chamber. This contrasts with previous results where impairment in the open sea has been considerably greater than in a dry chamber. Possible reasons for this discrepancy are discussed and it is suggested that level of anxiety may be a crucial factor. (AA)

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13 Baddeley, A. D., & Flemming, N. C. The efficiency of divers breathing oxy-helium. Ergonomics, 1967, 10(3), p 311-319. 14 refs.

Eight divers performed an addition test and a screwplate test of manual dexterity in the open sea under four conditions--breathing either air or an oxy-helium mixture and working at a depth of either 10 or 200 ft. Speed of addition was impaired at depth for both air (19.9 per cent) and helium (14.8 per cent), while errors increased only on air (from 5.9 to 21.1 per cent). The manual dexterity test also showed a decrement in speed for both air

(46.7 per cent) and helium (31.8 per cent), and air divers lost more screws at depth (11.1 per cent) than at 10 ft (4.7 per cent). While a decrement at depth was expected in the air dives, the considerable impairment shown on oxy-helium dives was not. A further experiment was therefore run in a dry pressure chamber to study the effects of breathing oxy-helium at pressure when the additional stresses associated with deep diving in the open sea were absent. At a pressure equivalent to 200 ft of water, there was a 10 per cent impairment in speed on both the screwplate ($p < 0.01$) and the additional test ($p < 0.05$). It is concluded that the diver's efficiency on either breathing mixture is impaired at depth, but that at 200 ft the helium diver works slightly faster and considerably more accurately than the air diver. (AA)

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14 Barnard, E. E. P. Visual problems under water. Proceedings of the Royal Society of Medicine, 1961, 54, p 755-757.

This paper discusses restriction of the visual field by underwater face masks and goggles. It is observed that while masks restore normal refraction by restoring the air-corneal interface, they produce a refraction at their outer surface which has three secondary effects: (a) narrowing of the visual fields due to the incident rays being refracted away from the normal on entering a less dense medium, (b) the magnification of objects which upsets judgment of size and distance, and (c) a less important effect, the distortion of verticals and horizontals.

At 48.6 degrees (the critical angle) light rays are totally reflected from the water-air interface. This phenomenon of total reflection sets a limit to the cone of vision which can be obtained through a plane surface in any underwater aid. (RA)

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15 Beckman. E. L. A review of current concepts and practices used to control body heat loss during water immersion. Presented at Aerospace Medical Panel Fourteenth General Assembly of Advisory Group for Aeronautical Research and Development. Lisbon, Portugal. Prepared by Naval Medical Research Institute, Bethesda, Maryland. September 1964. 21 refs.

The problem of providing adequate clothing for personnel who either during normal operations or accidently are immersed in cold water has continued to challenge clothing manufacturers. In the past decade the development of foamed plastics and other clothing materials has offered new possibilities. Likewise advances in energy conversion and storage systems offer new solutions to this critical operational problem.

The basic physical and physiological concepts which relate to the problem of limiting thermal loss from the immersed human are reviewed. Newer technical developments in insulative clothing and supplemental heating systems are discussed with relation to these basic concepts. (AA)

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16 Behnke, A. R., Forbes, H. S., & Motley, B. P. Circulatory and visual effects of oxygen at 3 atmospheres pressure. Am. J. Physiol. 1935, p 436-442. 7 refs.

Oxygen at a pressure of 3 atmospheres (30 lb. gauge) can be breathed by healthy men for 3 hours without distressing symptoms. During the 4th hour a progressive contraction of the visual field with dilatation of the pupils and some impairment in central vision is the most constant criterion of oxygen toxicity.

Circulatory changes indicative of peripheral vascular constriction are associated with the visual impairment, and culminate during the 4th hour in an abrupt rise of systolic and diastolic blood pressure, increase in pulse rate, and extreme pallor of the face. At this stage the subjects experience dizziness and a feeling of impending collapse. A condition of partial stupefaction is indicated by the facial expression and the slowed mental responses.

Rapid and complete recovery attended by a feeling of alertness and stimulation takes place within an hour after air is substituted for oxygen. (AA)

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17 Behnke, A. R., Johnson, F. S., Poppen, J. R., & Motley, E. P. The effect of oxygen on man at pressures from 1 to 4 atmospheres. Department of Physiology, Harvard School of Public Health, Boston, Massachusetts. 1934. 9 refs.

The mental and physical effects induced by breathing 96 to 99 per cent oxygen were studied in man at pressures of 1, 2, 3, and 4 atmospheres.

Healthy men between the ages of 22 and 40 can breathe pure oxygen with comparative safety as follows: 4 hours at 1 atmosphere; 3 hours at 2 atmospheres; 2 hours at 3 atmospheres.

The symptoms induced by oxygen are referable mainly to the nervous system. At 4 atmospheres' pressure convulsions occurred in one subject and syncope in another after exposures of approximately 45 minutes. Only 2 subjects were tested at this pressure. At a pressure of 1 atmosphere, impaired neuromuscular coordination and the power of attention or an increased effort to maintain these functions occurred after 1 to 3 hours' exposure in 3 out of 4 subjects tested. Hyperpnea occurred after 3 hours' exposure to oxygen in 2 out of 11 subjects.

The irritative effect of oxygen on the lungs was noted in only 1 subject on a single occasion. The symptoms were substernal pain, dry cough, and a high leucocyte count. The subjects exposed to the higher oxygen pressures were singularly free from pulmonary symptoms.

Oxygen consumption is high during the first 20 minutes, and then decreases to a level which is constant for periods up to 4 hours at atmospheric pressure.

In all of the oxygen exposures, the blood pressure, the respiratory rate, and the minute volume (with two exceptions) were constant at 1, 2, 3, and 4 atmospheres' pressure. (AA)

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18 Bennett, P. B. Measurement and mechanisms of inert gas narcosis. Journal of Occupational Medicine, 1969, 11(5), p 217-222. 15 refs. (a)

After commenting on the difficulties and frequent inadequacies of narcosis experiments, Bennett shows how the evoked auditory potential (electrical activity of the brain in response to an auditory stimulus) can serve as a valid and reliable indicator of the level of inert gas narcosis.

He proceeds to describe a series of well controlled experiments concerning the relative narcotic effect of various gases and concomitant changes in perceptual and motor performance. Bennett interprets his results as lending further support for the hypothesis that nitrogen and inert gas narcosis are due to the adsorption of the narcotic agent on cell membranes which in turn effects their permeability to cat-ions to produce a reversible ion imbalance. He suggests further that oxygen too may act in a similar manner until enzyme functions are inhibited leading to the onset of convulsions. (RA)

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19 Bennett, P. B. Hazards of inner space. Science Journal (Dorset House, London. Pub.), April 1969, p 64-69. 3 refs. (b)

The author reviews the hazards and difficulties of diving, pointing out similarities to obstacles encountered in the space environment. (RA)

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20 Bennett, P. B. The narcotic effects of air. Science Journal (Dorset House, London, Pub.), 1968, 4(1), p 53-58.

The behavioral effects and possible physiological basis of compressed air narcosis are discussed. Drawing upon his own research and the findings of other investigators, Bennett suggests that nitrogen at high pressure penetrates intercellular membranes causing an increased permeability to ions which results in narcosis.

It is observed that helium does not have this effect and it may not be narcotic making it appropriate for very great depths. (RA)

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21 Bennett, P. B. Human performance at high pressures of air and other gases. J.R.N.S.S., 1966, 21(1), 10 pp. 41 refs.

The author reviews a number of studies concerning inert gas narcosis and oxygen toxicity in relation to physiological and psychomotor effects, and the practical aspects of diving. (RA)

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22 Bennett, P. B. The effects of high pressures of inert gases on auditory evoked potentials in cat cortex and reticular formation. Electoenceph. clin. Neurophysiol. 1964, 17, p 388-397, 30 refs. (Elsevier Publishing Co., Amsterdam, Holland).

1. The effect was examined of 150 lb/in^2 of nitrogen, argon or helium in the presence of 35 lb/in^2 oxygen on auditory evoked potentials in the mesencephalic reticular formation and cerebral cortex of cats under either Chloralose or Nembutal anaesthesia.

2. Helium had no effect on either evoked potentials or spontaneous activity.

3. Nitrogen and argon at raised pressures induced a reversible reduction of spontaneous activity in both the cortex and brain-stem.

4. Raised pressures of argon and nitrogen caused a reversible depression of auditory evoked potentials.

5. The initial brain-stem potential was depressed by 65-70% in 25-30 min by argon and by 60-70% in 15 min by nitrogen.

6. The fast initial cortical potential was at first augmented 10-25%, followed by a 35% depression in a time similar to that of the brain-stem potential.

7. The slow secondary component of the brain-stem response remained unchanged at pressure. At the cortex this component was progressively depressed by 80-85% in 25 min with argon and 60-70% in 15 min with nitrogen.

8. A mixture of 75 lb/in^2 nitrogen and 18 lb/in^2 oxygen caused a 20-30% depression of the initial cortical potential and a 30-40% depression of the

initial brain-stem component in 40-50 min.

9. The evidence supports the suggestion that the action of raised pressures of inert gases is on polysynaptic systems such as those of the ascending reticular activating system of the brain-stem and the cortical mantle.

10. The depression of the various components of the evoked potentials is discussed in connection with the relative oxygen requirements of their generating mechanisms and a mechanism of histotoxic hypoxia. (AA)

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23 Bennett, P. B., Ackles, K. N., & Cripps, V. J. Effects of hyperbaric nitrogen and oxygen on auditory evoked responses in man. Aerospace Medicine, 1969, 40(5), p 521-525, 16 refs. (a)

The auditory evoked response (AER) is examined as a measure of narcosis induced at depth in diving personnel. Experimental AER data were obtained using electrodes attached to the scalps of experienced divers by computer averaging techniques. Auditory signals (clicks) at 60 dB were presented biaurally at a rate of 60 per minute for 1 min or 5 min. An arithmetic performance test was given before and during compression to depths between the surface and 300 ft (10 atmospheres absolute). The subjects breathed compressed air, oxygen, oxygen-helium and oxygen-helium-nitrogen mixtures. Compressed air caused decrements in both the AER and arithmetic efficiency which correlated with depth. Hyperbaric oxygen depressed the AER but did not affect arithmetic performance. Evidence is presented to show that nitrogen is the major cause of compressed air narcosis and that oxygen is not synergistic. It is concluded that the AER technique affords a reliable and reproducible measure of narcosis. The AER decrement with oxygen is discussed in relation to conduction deficiencies in the human brain and convulsions due to hyperbaric oxygen. (AA)

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24 Bennett, P. B., & Brock, A. J. Action of selected drugs on decompression sickness in rats. Aerospace Medicine, 1969, 40(6), p 607-610. 16 refs. (b)

Carbachol, prostigmin, adrenalin, hyoscine, doriden, phenacetin, aspirin, methedrine, megimide, leptazol, alcohol, gamma-aminobutyric acid, and thiethylperazine were administered to rats prior to compression with air at 60 ft/min to 400 ft (13 atmospheres absolute) for 1 hour, followed by decompression at 45 ft/min. The animals were observed for 30 mins after decompression and the numbers of rats that died or developed spinal bends were counted. A total of 50 rats were exposed to each of the 13 drugs and also to compression without drugs involving a total of 700 rats. Carbachol, doriden, phenacetin, adrenalin, and leptazol caused significant increases in deaths or spinal bends. Megimide and hyoscine showed a definite tendency to potentiate decompression sickness, although the results were not statistically significant. The remaining drugs had no effect. These results are compared with the action of the same drugs on nitrogen narcosis and oxygen toxicity. (AA)

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25 Bennett, P. B., & Elliott, D. H. (Eds.) The physiology and medicine of diving and compressed air work. Baltimore: Williams & Wilkins Co., 1969. (c)

This major book contains an edited collection of reviews of the biomedical problems of life at high pressures, each contributed by an internationally recognized authority. Where, however, there is a significant interaction of human factors and engineering requirements, such as in tunnelling and the design of underwater breathing apparatus, authors experienced in engineering have also contributed. The book is illustrated by numerous graphs, tables, and photographs, and there is a comprehensive index. (OM)

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26 Bennett, P. B., & Glass, A. Electroencephalographic and other changes induced by high partial pressures of nitrogen. Electroenceph. clin. Neurophysiol., 1961, 13, p 91-98. 19 refs. (Elsevier Publishing Co., Amsterdam, The Netherlands. Pub.).

Men have been subjected to compressed air in a pressure chamber and their electroencephalograms recorded while they solved arithmetical problems.

At atmospheric pressure these problems elicited a blocking of the alpha rhythm, but after a variable time at increased pressures no such alpha blocking occurred. The time from the beginning of their exposure to high pressures, until abolition of the alpha blocking response, was found to be inversely proportional to the square of the pressure, i.e. $P\sqrt{T}$ is a constant. If after blocking abolition, an oxy-helium mixture was substituted for the compressed air, blocking reappeared, implicating nitrogen as the agent responsible.

A diminution of the amplitude of the alpha activity was observed at 7 atm absolute which was severe at 10 atm absolute. At these pressures, when the time to abolition of blocking was very short signs and symptoms of narcosis were present. Correlations between the EEG findings and the mental state are discussed, together with their possible connection with the ascending reticular formation of the brain stem. (AA)

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27 Bennett, P. B., & Hayward, A. J. Relative decompression sickness hazards in rats of neon and other inert gases. Aerospace Medicine, 1968, 39(3), p 301-302. 14 refs.

The comparative incidence of decompression sickness was ascertained in 160 female Wistar rats (210-240 grams) compressed at 0.9 ATA (30 ft) per minute to 9.7 ATA (290 ft gauge) for one hour followed by decompression at 0.9 ATA. Rats were exposed in groups of 20 at a time to one of a number of inert gas mixtures. These consisted of 20 per cent oxygen and 80 per cent inert gas using either helium, neon, nitrogen, or argon. The relative decompression sickness incidence as shown by the number of rats either dying or developing spinal bends was 45 per cent for oxygen-helium, 50 per cent for oxygen-neon, 57.5 per cent for oxygen-nitrogen, and 100 per cent for oxygen-argon. The relation of these findings to various theoretical predictions is discussed and it is suggested that a mixture of neon, helium, and oxygen is likely to be one of the best mixtures for deep diving. (AA)

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28 Bennett, P. B., Poulton, E. C., Carpenter, A., & Catton, M. J. Efficiency at sorting cards in air and a 20 per cent oxygen-helium mixture at depths down to 100 feet and in enriched air. Ergonomics, 1967, 10(1), p 53-62. 19 refs.

Eighty men sorted packs of cards twice, once at the surface, and once at a depth of 33 or 100 ft (2 ats or 4 ats abs) or at the surface, breathing the equivalent partial pressure of oxygen at these depths. The gases breathed were air and 20 per cent oxygen in helium. Significantly more errors were made at a depth of 100 ft in air than at the surface in air ($p < 0.02$). No such effect was found when breathing air at 33 ft or 20 per cent oxygen in helium at either depth. The oxygen-enriched mixtures breathed at the surface also showed nothing. On the first trial all groups working at depth sorted faster and less accurately on average than all groups working at the surface ($p < 0.05$). There was also a carry over of the rate of work from the first trial to the second ($p < 0.05$). A similar carry-over was found in a previous experiment, but in this the men normally worked more slowly in proportion to the depth. The increased rate of work reported here may be attributed to an increase in the level of arousal at depth. (AA)

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29 Berghage, T. E. Oxygen percentages for selected partial pressures at various depths. Res. Report 2-68. U.S. Navy Experimental Diving Unit, Washington Navy Yard, Washington, D.C., April 1968, 86 pp.

This report was written to promulgate a set of tables to be used by divers and diving supervisors for quick and easy conversion of depth and partial pressure combinations into usable oxygen percentage figures. The tables can also be used for making necessary depth measurement conversions between depth of sea water, atmospheres absolute, millimeters of mercury absolute, and pounds per square inch absolute. (AA)

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30 Blair, W. C. Human factors in deep submergence vehicles. Marine Technology Society Journal, 1969, 3(5), p 37-46. 5 refs.

The application of human factors engineering to the design of deep submersibles has been sporadic at best. Private vehicles have received little attention during their design although some interesting redesign has been accomplished. Navy vehicles, typified by DSRV-1 and DSSV have received a considerable human factors effort, starting with design concept formulation.

The DSRV-1 has a requirement to operate at angles of up to 45° from the horizontal and work began early with full scale mockups to develop requirements for personnel seating and rescuee loading and restraint systems. This activity continued throughout the design phase until verified by the actual hardware.

The DSSV with its 34-hour search and small object recovery requirement presents new challenges to the human factors engineer. Among them are provision for adequate equipment and crew volume, definition of work-rest cycles and stations, and provision for maximum direct visual search. Extensive use of mockups was made during preliminary design studies and a full-scale hard mockup of the pressure capsule was used in a manned 34-hour mission simulation.

Human factors is now a distinctly competitive aspect of deep submersible design and there is an obvious need for a "Human Engineering Guide for Underwater Systems". (AA)

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31 Bowen, H. M. Diver performance and the effects of cold. Human Factors, 1968, 10(5), p 445-464. 27 refs.

The capability of divers was tested by a test battery composed of tests of tactile sensitivity, grip strength, manual dexterity, tracking, assembly of a structure of groups, mental arithmetic, symbol processing, simple problem solving and memory. At a diving tower and a flooded quarry, test data were collected for performance on dry land (control) and at water temperatures between 44° and 72°F. A limited sample of post-dive urine temperatures and skin temperatures were recorded. Divers wore a complete 3/16" wet suit, except that, during the tests, the hands were bare. The results show: hand

impairment--losses in tactile sensitivity, grip strength and manual movement; the losses were proportional to degree of cold and exposure time; the losses follow a similar course to skin temperature decrease and hence are considered due mainly to peripheral physiological attenuations; psychomotor impairment --losses in manual dexterity, tracking and group assembly were proportionate to water temperature; mental impairment--losses in mental capability occurred in those cases where the task required intense attention and involved considerable short-term memory; "blocking" effects occurred at the lower temperatures. The causes of the losses in capability are discussed in terms of peripheral and central impairments, in terms of "water" effects and "cold" effects, and in terms of a hypothesis that immersion in cold water serves to distract the diver. Some practical and theoretical implications of the study are reviewed. (AA)

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32 Butler, H. S., Jr., & Payne, R. H., Jr. Thermal conductance of diver wet suit materials under hydrostatic pressure. Interim Report 2903. Naval Ship Research and Development Laboratory, Panama City, Florida, March 1969.

One characteristic of foam neoprene used in fabrication of diving suits is its compressibility and resulting loss of thermal insulating qualities with increasing depth. Test apparatus was devised and constructed for determining thermal conductance of a number of foam neoprene samples while under pressure at discrete intervals from 1 to 20 atmospheres. These tests resulted in numerical values for thermal conductance of foam neoprenes throughout the range of test pressures. One sample, an experimental material, showed no reduction of insulating value while under pressures from 1 to 20 atmospheres. (AA)

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33 Christianson, R. A., Weltman, G., & Egstrom, G. H. Thrust forces in underwater swimming. Human Factors, 1965, 7(6), p 561-568. 9 refs.

Instantaneous and mean static thrust levels were measured for eight underwater swimmers restrained in a submerged force platform. Swimming was examined barefoot and with two types of fins. The main beneficial effect

of the fins was to eliminate the substantial negative thrust component associated with barefoot swimming. Higher maximal thrust outputs were achieved with curved fins than with straight-bladed ones. There were also significant differences between barefoot and finned swimming in the relationship of instantaneous thrust to leg position during the kick cycle. Kick rate and foot acceleration were both proportional to thrust output, but the relationship depended on diver size and experience. (AA)

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34 Clarke, G. L., & James, H. R. Laboratory analysis of the selective absorption of light by sea water. J. Opt. Soc. Am., 1939, 29, p 43-55. AD 613 017.

(1) The absorption of light by preserved samples of sea water collected at coastal and at off-shore stations in the North Atlantic was measured in the monochromater previously employed by James and Birge. One sample from each station was left unfiltered at the time of collection and was measured (a) after moderate shaking, (b) after settling for forty-eight hours, and (c) after Berkefeld filtering. Other samples were passed through paper or Berkefeld filters at the time of collection.

(2) Artificial sea water exhibited an absorption practically identical with distilled water except at the shorter wave-lengths where the absorption was greater probably because of impurities.

(3) The absorption per meter of the shaken samples was much greater than the average value per meter for the absorption observed at sea. This fact, undoubtedly caused by the action of the preservative on organic particles, demonstrates the necessity of field observations for an accurate knowledge of submarine illumination.

(4) The absorption of "pure" sea water, as represented by Berkefeld-filtered off-shore samples, was found to be practically identical with distilled water measured in the same tube. Thus no support is furnished to previous reports by others of lower absorption and additional evidence is obtained that the values of Sawyer for distilled water in the ultraviolet may be too high.

(5) The difference between the absorption of unfiltered samples of sea water and of distilled water is caused chiefly by suspensoids for wavelengths 8000A to 4730A, and for 4730A to 3650A in the off-shore areas. In coastal areas both filter-passing material and suspensoids are effective and each exerts a highly selective action on light with greatest absorption at the shorter wavelengths. (AA)

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35 Coles, R. R. A. Noise in compression chambers. Prepared for Hearing Sub-Committee of Royal Naval Personnel Research Committee. Prepared by Royal Naval Medical School, Alberstoke, Hants, England. January 1964. 6 refs.

Sound level measurements have been taken at the onset of compression in three compression chambers, and subsequently repeated in two of them after fitting of "prototype silencers".

"Silencing" is desirable in order to avoid effects of the noise on human performance, hearing and communication. It can probably be achieved by comparatively simple and inexpensive means. (AA)

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36 Communication Sciences Laboratory. Man's performance in the sea: Underwater communication. Progress Report 7.2, Vol. 7, No. 2, 1969. Communication Sciences Laboratory, University of Florida, Gainesville, Florida.

This report describes the Communication Sciences Laboratory, Department of Speech, at the University of Florida, Gainesville, Florida.

Included is a description of their comprehensive research program in diver communication. This report contains summaries of numerous studies performed at CSL. Major areas of investigation include (1) studies of divers' speech production, (2) reception of speech, (3) miscellaneous studies in underwater speech propagation, (4) research on communication equipment and procedures, and (5) development of specialized instrumentation. (RA)

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37 Comroe, J. H., Bahnson, E. R., & Coates, E. O. Mental changes occurring in chronically anoxemic patients during oxygen therapy. J. Am. Med. Assoc., 1950, 143(12), p 1044-1048. 13 refs.

In one patient with pulmonary insufficiency due to emphysema oxygen therapy was followed by coma and eventual death.

In a group of 65 patients with chronic anoxemia, mental changes occurred in eight when high concentrations of oxygen were inhaled; none of them died. The possible mechanisms responsible for these reactions are discussed. (AA)

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38 Comroe, J. H., et al. Inhalation of oxygen by normal man: Effect on arterial oxygen saturation, content, and tension. Chapter 1 of Oxygen Therapy. 1945, p 3-18.

The role and characteristics of the human pulmonary system are discussed in relation to normal breathing and in the presence of elevated partial pressure of oxygen as in oxygen therapy. (RA)

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39 Corriol, J. H., & Rohner, J. J. New facts about bradycardia in breath-holding divers. R. Subaq. Phys. Hyperb. Med., 1968, 1(1), p 24-27. 30 refs. (Published in Paris, France.)

A study of bradycardia in apnea, with and without immersion of the face, was made on 26 persons, some of whom had never dived, while others were professional divers:

--apnea and immersion of the face are the main factors of bradycardia,

--training increases bradycardia caused by apnea, but has no effect on bradycardia due to immersion of the face.

The authors define the afferent and efferent ways of the reflex arc involved. (AA)

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40 Cousteau, J-Y. Working for weeks on the sea floor. The Journal of the National Geographic Society, 1966, 129(4), p 498-537.

The story of Conshelf Three, where men lived and worked continuously for three weeks at a depth of 328 feet, is related in detail. (RA)

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41 Cousteau, J-Y. At home in the sea. The Journal of the National Geographic Society, 1964, 125(4), p 465-507.

This report describes the events of the classic "Conshelf Two" undersea project headed by Capt. Cousteau. The divers lived and worked underwater for a month without coming to the surface. The primary habitat "Starfish House" lay 36 feet beneath the surface of the Red Sea. A second habitat, "Deep Cabin", held two men for a week at a depth of 90 feet; free divers worked to a depth of 165 feet. (RA)

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42 Craven, J. P. Ocean technology and submarine warfare. Astronautics and Aeronautics, 1969, 7(4), p 66-70.

Dr. Craven is Chief Scientist for both the Deep Submergence Systems Project and the Polaris program. He summarizes his main points as follows:

1. To date, the law and strategy of the sea have been conditioned and controlled by the effects of the free surface.

2. No substantial change in the major constraints of the free surface is foreseen, and hence no major change in the law or strategy of the free surface.

3. In the future, military and commercial systems will be developed which are completely divorced from the free surface, which will therefore condition and control the law and strategy of the undersea.

4. This new technology will result in the establishment of national or international jurisdictions over portions of the sea bed and portions of the ocean not now under control.

5. It will be possible to develop barrier lines which detect a high percentage of clandestine underwater transitors.

6. It will not be possible to develop area-surveillance systems which can track a significant percentage of clandestine systems deployed in the broad ocean.

7. It will therefore be possible to exclude military systems from limited areas of the ocean which are clearly fenced in and clearly exploited or exploitable for human needs.

8. It will not be possible to exclude military systems from the broad ocean areas, unless immediate forces are exerted at a barrier line or unless the exclusion is by mutual consent or restraint.

9. By analogy it appears that the competition for control of the undersea is similar to the privateering and anti-privateering dilemma which extended from the 14th to the 19th century. It will therefore be protracted and evolutionary in its development.

10. Following this analogy, it is concluded that the ultimate stable solution is one in which arms-controllable undersea systems are deployed in the broad ocean under tacit or formalized agreement; at the same time, significant areas of the ocean will be placed under national or international jurisdiction in which the deployment of military systems is at the will and sufferance of the possessor of jurisdictional authority. (OM)

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43 Dubach, H. W., & Taber, R. W. Questions about the ocean. Publication G-13. Published by the U.S. Naval Oceanographic Office, Washington, D.C., 1969. 121 pp.

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44 Duntley, S. Q. Light in the sea. J. Opt. Soc. Am., 1963, 53, p 214-233. 37 refs.

Light in the sea may be produced by the sun or stars, by chemical or biological processes, or by man-made sources. Serving as the primary source of energy for the oceans and supporting their ecology, light also enables the native inhabitants of the water world, as well as humans and their devices, to see. In this paper, new data drawn from investigations spanning nearly two decades are used to illustrate an integrated account of the optical nature of ocean water, the distribution of flux diverging from localized underwater light sources, the propagation of highly collimated beams of light, the penetration of daylight into the sea, and the utilization of solar energy for many purposes including heating, photosynthesis, vision, and photography. (AA)

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45 Dougherty, J. H., Jr., & Schaefer, K. E. Pulmonary functions during saturation-excursion dives breathing air. Aerospace Medicine, 1968, 39(3), p 289-292. 11 refs.

Saturation-excursion dives in compressed air were carried out with 12 subjects in a dry chamber. The diving schedule consisted of (1) 24 hours exposure to 35 feet, (2) one-half to two hour excursion dives to 100-165 feet and (3) stage decompression at 35 feet and at 10 feet, including one hour of breathing pure oxygen prior to reaching the surface. Pulmonary functions were measured at frequent intervals with the flow-volume technique (Wedge spirometer). Data on vital capacity, inspiratory capacity, expiratory reserve volume, tidal volume, and maximum inspiratory and expiratory flow rates obtained during saturation-excursion dives are compared with those collected during acute exposure to increased pressures of equivalent depth. Maximal inspiratory and expiratory flow rates showed a slight increase during the 24-hour saturation period at 35 feet. The subsequent excursion dives reduced the maximal inspiratory flow rates to a significantly lesser degree than during comparative acute exposures to equivalent depths, indicating the development of an adaptation during the 24-hour saturation period. (AA)

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46 Egstrom, G. H., & Weltman, G. Assessing work performance underwater. Marine Sciences Instrumentation, 1968, 4, Plenum Press, p 387-392. 4 refs.

A system for the assessment of underwater work has been under development during the past three years. The system includes an underwater ergometer, a digital spirometer, continuous gas analyzers and specialized communications apparatus. The larger models are being reduced in size with the goal of a man rated package that will permit divers to perform normal work tasks while data that can be utilized for the calculation of the energy requirements for the task is being telemetered to surface recorders.

Other studies which bear directly on man's capability to perform useful work underwater are related to problems such as visual fields of divers, the effects of environmental stress on performance and problem solving capabilities in single and teamwork operational modes. (AA)

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47 Felig, P., & Lee, W. L., Jr. Effects of sodium lactate on oxygen toxicity in the rat. Annals New York Academy of Sciences. Prepared by Aerospace Medical Research, Wright-Patterson AFB, Ohio, under Contract R-87 for NASA. p 829-835. 19 refs.

Sodium lactate increases survival when administered daily to rats exposed to 98 per cent oxygen. It is suggested that the mechanism of lactate protection may be related to alterations in the redox state of pyridine nucleotides. (AA)

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48 Foley, M. F., Billings, C. E., & Huie, C. R. Development of techniques for direct measurement of metabolism under water. Aerospace Medicine, 1967, 38(2), p 153-155. 17 refs.

In previous studies of metabolism and ventilation in flight, the Müller-Franz portable breath-powered respirometer has been found to be a precise and simple tool. The concept embodied in this instrument has been adapted for use in studies of the metabolic cost of activity under water. The criteria specified for a device for these studies were: it must utilize commercially available SCUBA (self-contained underwater breathing apparatus) gear; there

must be no connections to the surface and the swimmer must not be hindered in any way; it must be usable at any depth capable of attainment using SCUBA, and in any activity engaged in by divers. A device has been developed which meets these criteria. Pilot studies of metabolism in divers swimming at various rates have been conducted. (AA)

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49 Frankenhaeuser, M., Graff-Lonnevig, V., & Hesser, C. M. Effects on psychomotor functions of different nitrogen-oxygen gas mixtures at increased ambient pressures. Acta physiol. scand., 1963, 59, p 400-409. 20 refs.

In order to differentiate and evaluate possible factors responsible for compressed air narcosis, changes in psychomotor performance (simple and four-choice visual reaction times and mirror drawing) induced through exposure to different nitrogen-oxygen gas mixtures at raised barometric pressures were studied in 12 subjects. By comparing data from five different experimental conditions evidence was obtained that, at rest, (1) nitrogen pressures up to 3.9 atmospheres absolute have but slight effects on objective performance, and (2) oxygen excess has a potentiating effect on the narcotic action of nitrogen at high pressure. It was concluded that oxygen excess acts indirectly by interfering with elimination of carbon dioxide from the tissues, and that compressed air narcosis is not due to interference with oxidation in the tissues by nitrogen excess. (AA)

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50 General Electric. Undersea and space correlation study performed under NASA Contract NASW-1660. Vol. II-Technical Report. DIN 68SD4212. General Electric, Missile and Space Div., Valley Forge Space Technology Center, Philadelphia, Penna. January 1968.

Details of an analysis performed in defining the commonality between undersea and space environments, the selection of mission parameters, and the definition of design concepts associated with the requirements derived from these parameters are discussed. (AA)

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51 Gilbert, G. D. Deep-sea light attenuation measurements at 2,000-meter depths. NOTS TP 3994. U.S. Naval Ordnance Test Station, China Lake, Calif. December 1965. 20 pp. 3 refs.

The null-balance transmissometer (NBT) is an instrument being developed to measure the volume attenuation coefficient of light in the sea to depths of 2,000 meters. In earlier tests (reported in NOTS TP 3748), the operation of the NBT was tested in its working environment to depths of 700 meters. In this report, the first deep sea tests of the NBT, in which measurements were made to the 2,000-meter maximum depth capability of the instrument, are documented. The tests were conducted at 10 locations in the North Pacific from the Aleutian Islands to the island of Oahu in the Hawaiian Archipelago. (AA)

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52 Goldman, R. F., Breckenridge, J. R., Reeves, E., & Beckman, E. L. "Wet" versus "dry" suit approaches to water immersion protective clothing. Aerospace Medicine, 1966, 37(5), p 485-487. 13 refs.

Immersion protective flight clothing can be of either a skin diver, "wet" suit type or waterproof, "dry" suit. A waterproofed copper manikin was used to study the insulative properties of both types of suits, in air and also during water immersion. The bulkier characteristics of the dry suit studied, the Mark 5A, provided greater insulation in air than either a 1/4" or 3/16" unicellar sponge, neoprene wet suit. However, during water immersion, compression of the "dry" suit by the water reduced the insulation by 75 per cent. The insulation of the "wet" suits was also reduced but these suits are less compressible and thus during water immersion provide significantly more insulation than the "dry" suit. (AA)

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53 Goodman, M. W., & Workman, R. D. Minimal-recompression, oxygen-breathing approach to treatment of decompression sickness in divers and aviators. U.S. Navy Experimental Diving Unit, Washington, D.C., Research Report 3-65, November 1965. 40 pp. 35 refs.

With growing awareness of the incremental frequency with which difficulties are encountered in recompression treatment of severely injured patients, and

the grossly inadequate decompressions now characterizing the civilian diver casualty population applying to USN recompression facilities, evaluation and clinical trials of therapeutic procedures, alternative to USN treatment tables, were undertaken. These techniques are particularly suitable for recompression management of aviators' dysbarism when descent to sea level has not provided complete palliation. The proportion of good results obtained with initial recompression trials with these procedures has significantly exceeded that obtained in recent years, with the Diving Manual tables, although the current series of 79 cases surpassed comparable casualty groups in average case severity. Hypothetical and practical aspects of the treatment concept and technique are presented, and contraindications noted. There were no adverse responses to the 2.8 atmospheres absolute PO_2, and nine normal volunteer subjects showed no impairment of timed vital capacity following test exposures. (AA)

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54 Gupta, R. K., Winter, P. M., & Lanphier, E. H. Histochemical studies in pulmonary oxygen toxicity. Aerospace Medicine, 1969, 40(5), p 500-504. 14 refs.

The importance of an extra-pulmonary factor, dependent on arterial rather than alveolar oxygen tensions, in the development of pulmonary oxygen toxicity has been reported in a previous study. Dogs with surgically produced venous admixture of 50-55 percent of cardiac output were shown to be significantly protected against pulmonary oxygen poisoning. Histochemical quantification of damage reveals that it is not possible to separate observed pathology into a direct component dependent on alveolar gas pressures and indirect effects dependent on arterial tensions. The nature of damage to reticulin and elastic tissue and the development of hyaline membranes is discussed. (AA)

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55 Hamilton, R. W., Jr. Keeping men alive under water. Oceanology International, Jan/Feb 1967. 4 pp.

The physiological requirements and associated implications for life support systems are considered in the light of operating at increased depths for prolonged periods of time. (RA)

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56 Hamilton, R. W., MacInnis, J. B., Noble, A. D., & Schreiner, H. R. Saturation diving at 650 feet. Technical Memo B-411. Prepared by Ocean Systems, Inc., Tonawanda Research Lab., Tonawanda, N. Y., March 1966. 72 refs.

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. (AA)

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57 Hamilton, R. W., & Schreiner, H. R. Putting and keeping man in the sea. Chemical Engineering, 17 June 1968, p 263-269.

The authors review "some of the engineering and medical problems that man has to cope with as he attempts the practical exploitation of seabed resources." (RA)

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58 Harrington, J. V. The relationship of physiology to engineering for Man-in-the-Sea. Marine Technology Society Journal, 1969, 3(5), p 31-36. 8 refs.

This paper discusses the interdependence of engineering and physiology in designing systems for Man-in-the-Sea. (AA)

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59 Hartmann, H. Prolonged exposure (50 hours) under 4 to 8 ata in mixed nitrogen-oxygen atmospheres. Rev. Subaq. Phys. Hyper. Med., 1969, 1(3), p 188-191. (Published in Paris, France.)

Nitrogen narcotic action has been studied in subjects exposed to pressures varying from 4 to 8 ata within periods going from 40 to 50 hours.

Subjects inside lockers are being watched through direct observation, through E.C.G. and biochemical normals regular recordings, through examination of psychosomatic behaviour and reaction phases.

Up to 5-6 ata reaction phases stay noticeably normal. From 7 ata to 8 ata they increase as much as 50%. Behaviour modifications with an important slowing down of psychical and physical reactions have been obtained. (AA)

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60 Helmreich, R., Radloff, R., & Ervin, C. Social psychological determinants of nitrogen narcosis: A theoretical formulation. Prepared by Department of Psychology, The University of Texas, for Office of Naval Research, Group Psychology Branch. May 1968. 26 refs.

Based on Schachter's (1964) theory of emotions, it is suggested that some of the effects of nitrogen narcosis in diving may be produced by cognitive labelling of a state of physiological arousal. Research into this question is proposed and implications for technology are discussed. (AA)

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61 Hollien, H., & Brandt, J. F. Effect of air bubbles in the external auditory meatus on underwater hearing thresholds. The Journal of the Acoustical Society of America, 1969, 46(2), Part 2, p 384-387. 8 refs. (a)

Thresholds of human hearing were obtained underwater for two conditions: (1) with the external auditory meatus completely water filled and (2) with a bubble

of air trapped against the tympanic membrane. The first condition was accomplished by forcibly irrigating the external meatus underwater; the second, by placing plugs in the ears in order to encapsulate air in the meatus until the head was underwater and the test (with the plugs removed) initiated. Subjects were seven divers who were tested in DICORS at a depth of 12 ft; threshold SPLs were obtained free field by a modified Bekesy technique for the frequencies 125 Hz, 250 Hz, and 1, 2, and 8 kHz. Threshold shifts (re: air) for both conditions of underwater hearing were consistent with those previously reported. SPLs for the two experimental conditions were virtually identical for all frequencies except 250 Hz, where hearing was 6 dB better for the water-filled meatus condition. Apparently, the presence or absence of air bubbles in the external meatus contributes little if anything to underwater hearing thresholds. (AA)

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62 Hollien, H., Brandt, J., & Dew, D. Man's performance in the sea seminar. CSL/ONR Report #26. Prepared by the Communication Sciences Lab., University of Florida, Gainesville, Florida, for Office of Naval Research, Physiological Psychology Branch. September 1969. (b)

A Seminar was conducted in order to inform and stimulate young workers of high research potential with respect to appropriate research concepts, design and methodology--and current oceanographic projects. The focus of the seminar was on man's performance in the sea and it was developed with respect to five major areas of underwater research: perception, physiology, work performance, communication and habitats. (AA)

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63 Hollien, H., Brandt, J., & Doherty, E. T. Underwater hearing thresholds in man as a function of water depth. CSL/ONR Report #16. Prepared by Communication Sciences Lab., University of Florida, Gainesville, Florida. 1 August 1969. 6 pp. 3 refs. (c)

Thresholds of human hearing were obtained underwater at depths of 35, 70, and 105 feet. Subjects were six divers experienced in taking underwater hearing threshold tests by a modified Bekesy technique. No significant effect

due to depth was noted. Threshold shifts (re: air) for the three conditions of underwater hearing were consistent with those previously reported. (AA)

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64 Hollien, H., Brandt, J., & Doherty, E. T. Intelligibility of diver communication systems. CSL/ONR Report #11 (Progress Report). Prepared by Communication Sciences Lab., University of Florida, Gainesville, Florida, for Office of Naval Research. 15 December 1968. 19 pp, 2 refs. (a)

The purposes of this project were (1) to develop a method for evaluating the intelligibility of underwater communication systems and (2) to make comparative evaluations of the systems currently available (both military and civilian). Speech materials consisted of Campbell PB_{25} lists read by 4-12 diver/talkers positioned within a specially constructed Diver Communication Research System (DICORS); these word lists were recorded on the surface and presented to listeners for intelligibility scoring. Underwater communicators of three types were evaluated: (a) amplitude modulated (Aquasonics, MAS, PQC); (b) acoustical (Raytheon Yack-Yack, Bendix Watercom); and (c) hard line (Aquaphone, British Buddy Line). The most significant finding was that all of the evaluated communicators transmitted speech with somewhat low intelligibility; secondary findings indicated that type of muzzle and regulator employed with a communication system contributes substantially to the level of intelligibility. Of the 11 configurations compared, no single approach to underwater communication (modulated, hard line, acoustic) completely dominated the results. (AA)

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65 Hollien, H. Brandt, J., & Malone, J. Abstracts of four studies in underwater communication. CSL/ONR Report #20, Progress Report. Prepared by Communication Sciences Laboratory, University of Florida, Gainesville, Florida, for Office of Naval Research. 1 March 1968. 10 pp. (b)

Abstract reports of four experiments are presented; these reported include:

1. Speech Intelligibility as a Function of Helium-Oxygen Breathing Mixtures.

2. Speech Intelligibility in High Ambient Pressures.

3. Intelligibility of Filtered Underwater Speech in Quiet and Noise.

4. Intelligibility Underwater of Different Speech Modes. (AA)

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66 Hollien, H., Brandt, J., & Malone, J. Exhibit of diver communication research system (DICORS). CSL/ONR Report #14, Progress Report. Prepared by Communication Sciences Laboratory, University of Florida, Gainesville, Florida, for Office of Naval Research. 1 February 1968. 7 pp. (c)

A Diver Communication Research System (DICORS) was the primary focus of two recent exhibits presented by Communication Sciences Laboratory: 1) at the University of Florida Engineering Fair, March 10-12, 1967 and 2) at the American Speech and Hearing Association Convention, November 1-4, 1967 (where it received the First Award for excellence of presentation).

In addition to a fully equipped DICORS (including a mannequin which represented a diver/subject), the exhibit included displays ranging from underwater communication equipment and response units to a slide-show and photographs of facilities, equipment and procedures. A final display demonstrated the applicability of DICORS by presenting data from three studies representative of the research now underway, i.e., research on 1) underwater hearing thresholds, 2) comparative evaluation of underwater systems and 3) speech intelligibility in the milieu of helium-oxygen mixtures and high ambient pressure. (AA)

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67 Hollien, H., Brandt, J., & Malone, J. Semi-annual report of underwater speech communication. CSL/ONR Report #12, Progress Report. Prepared by Communication Sciences Laboratory, University of Florida, Gainesville, Florida, for Office of Naval Research. 31 December 1967. 7 pp. (a)

A Semi-annual report of studies completed and research in progress on the project: Underwater Speech Communication. (AA)

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68 Hollien, H., Brandt, J., & Malone, J. Underwater speech reception threshold and discrimination. CSL/ONR Report #7, Progress Report. Prepared by Communication Sciences Laboratory, University of Florida, Gainesville, Florida, for Office of Naval Research. 1 December 1967. 10 pp. 14 refs. (b)

Absolute thresholds for pure tones at octave frequencies between 125 and 8,000 Hz, Speech Reception Thresholds (SRT), and Speech Discrimination Scores were obtained from scuba divers submerged 35 feet underwater. Apparently, once the absolute threshold of hearing is reached for the underwater listener, the relationships among speech reception and discrimination are similar to those in air. (AA)

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69 Hollien, H., Brandt, J. F., & Murry, T. A method for analyzing phonemic errors in underwater speech intelligibility testing. CSL/ONR Report #24, Progress Report. Prepared by Communication Sciences Laboratory, Gainesville, Florida, for Office of Naval Research. Sept. 1969. 12 pp. 6 refs.

A method for analyzing listeners' phonemic confusions of monosyllabic words was developed in order to determine the type as well as the number of consonant errors made in divers speech. This method, which deals exclusively with consonants, allows for the listeners' responses to be written in phonetics or traditional orthography. Therefore, it can be used with experienced or naive listeners which, in large scale intelligibility testing, is desired or necessary. From the listeners' responses, the errors are grouped into simple consonant-for-consonant substitutions, substitutions involving consonant clusters, and omissions, and additions. The results of the analyses are presented in terms of the percent correct for each phoneme relative to the total possible number of correct phonemes at a certain condition. In this way, the relative intelligibility of each phoneme may be obtained and compared with other phenomes in the same test or with the same phenome in various testing situations. Preliminary data indicate that the reliability of transforming the orthographic responses to phenomes ranges from 86.7 to 93 percent. Some results of the initial application of this procedure to the phonemic confusions of divers' speech

in Helium-oxygen environments indicate that majority of confusion occur among sounds produced with the same voicing component within the same manner and place of articulation categories. With regard to the errors of place of articulation, the confusions were approximately random. (AA)

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70 Hollien, H., Brandt, J., & Thompson, C. Preliminary measurements of pressure responses to low frequency signals in shallow water. CSL/ONR Report #9, Progress Report. Prepared by Communication Sciences Laboratory, University of Florida, Gainesville, Florida, for Office of Naval Research, August 1, 1967. 34 pp. 8 refs. (a)

The purpose of this study was to determine the magnitude of changes in sound pressure level (SPL) produced by interference patterns (phase effects) in shallow water. For an empirical procedure, relative SPLs were measured in response to sinusoidal signals of 18 frequencies at one-third octave increments for 100 to 5000 Hz. In a total water depth of 32 meters, the projector was set at depths of 1, 16, or 30 meters and the hydrophone at depths of 3, 16, and 31 meters. Measurements were taken of six horizontal ranges (1, 16, 31, 100, 320, and 525 meters). Relative SPLs were computed according to a formula derived by P.A. Barakos. Formula parameters were based on measurements associated with the empirical procedure.

Both sets of data were compared; minimal agreement was found. The frequency regions where constructive or obstructive interference occurred were different for each method. In addition, the magnitude of interference effects was less for the measured than the computed method in most cases. However, the study does indicate that, under certain conditions, SPL may vary up to 40 dB as a function of frequency. (AA)

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71 Hollien, H., Brandt, J., & Thompson, C. Semi-annual report on underwater speech communication. CSL/ONR Report #8, Progress Report. Prepared by Communication Sciences Laboratory, University of Florida, Gainesville, Florida, for Office of Naval Research, 30 June 1967. 6 pp. (b)

Semiannual review of research completed, and in progress for ONR

contract Nonr 580(20) Underwater Speech Communication. Included is an evaluation of the project by a consultant. (AA)

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72 Hollien, H., Brandt, J., & Thompson, C. Underwater speech communication. CSL/ONR Report #3, Progress Report. Prepared by Communication Sciences Laboratory, University of Florida, Gainesville, Florida, for Office of Naval Research, 1 April, 1967. 20 pp. 15 refs. (c)

The audibility threshold performance of the human ear submerged in water at ear depths of 12 and 35 feet was compared to its performance in air. Threshold SPLs at 125, 250, 500, 1000, 2000, 4000, and 8000 Hz from 5 male and 3 female divers wearing open circuit SCUBA equipment were obtained by the Bekesy technique. Differences between water and air conduction thresholds ranged from 18 dB SPL re: 0.0002 microbar at 125 Hz to 56 dB at 8000 Hz. Water conduction thresholds ranged from between 58 and 74 dB SPL with maximum sensitivity around 500 Hz. Maximum sensitivity for air conduction thresholds was obtained at 2000 Hz. Slightly higher thresholds were obtained at the 35 foot depth than at the 12 foot depth (about 1 dB at 250 Hz and 10 dB at 8000 Hz). Threshold SPL for male divers tended to be lower than female divers below 1000 Hz but higher than female divers above 8000 Hz in both air and water. Tentatively data suggest the importance of bone condition mechanisms in underwater hearing. (AA)

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73 Holli H., Brandt, J., & Thompson, C. Underwater speech communication. (L/ONR Report #4, Progress Report. Prepared by Communication Sciences Laboratory, University of Florida, Gainesville, Florida, for Office of Naval Research. 1 February 1967. 3 pp. (d)

Semiannual review of research completed, in progress and planned for ONR contract Nonr 580(20) Underwater Speech Communications. (AA)

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74 Hollien, H., Brandt, J., & Thompson, C. Underwater speech communication. CSL/ONR Report #1, Progress Report. Prepared by Communication Sciences Laboratory, University of Florida, Gainesville, Florida, for Office of Naval Research. 22 December 1966. 4pp. 1 ref.

This report is of a pilot study focused on the evaluation of a commercial diver communication system and on the development of standardized and precise methods for such system evaluation. Seven divers, at 30 feet, read PB word lists over the Bendix Watercom system. Sixty-one listeners (12 divers and 49 college students) were used to evaluate system intelligibility. Results are discussed; also included is a description of information which will be needed before highly efficient underwater communicators can be developed. (AA)

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75 Hood, W. B., Jr., Murray, R. H., Urschel, C. W., Bowers, J. A., & Goldman, J. K. Circulatory effects of water immersion upon human subjects. Aerospace Medicine, 1968, 39(6), p 579-584. 35 refs.

Changes in hemodynamics were studied in five human volunteer subjects during two separate eight-hour periods of bed rest and total water immersion. During immersion subjects showed a decline in pulse rate, arterial blood pressure, and peripheral vascular resistance, and elevation of stroke volume compared to the control state. Central venous mean blood pressure fell with immersion, presumably in response to the relative negativity of the airway pressure supplied to the subjects. These findings suggest that water immersion results in these circulatory changes: (1) relative bradycardia, with a secondary increase in stroke volume and (2) peripheral vasodilatation, with secondary decline in arterial pressure. These findings are not explained either by loss of plasma volume or by relative negative pressure breathing, and presumably are a consequence of exposure to the "buoyant state." (AA)

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76 Hornick, R. J. (Ed.) Deep ocean dives in preparation of Sealab III. Human Factors Society Bulletin, 1967, 10(5), p 1-8.

The U.S. Navy Experimental Diving Unit pressure facilities and training dives for Sealab III are described. (RA)

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77 Hulburt, E. O. Optics of distilled and natural water. Journal of the Optical Society of America, 1945, 35(11), p 698-705. 8 refs.

This technical paper describes laboratory measurements of the absorption and scattering of distilled water and of the water of the Chesapeake Bay and the Atlantic Ocean, and relates these measurements through theory to observations of the Bay and the Ocean. (RA)

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78 Interagency Committee on Oceanography. Undersea vehicles for oceanography. ICO Pamphlet No. 18, Interagency Committee on Oceanography of the Federal Council for Science and Technology, October 1965.

This report has been prepared by the Interagency Committee on Oceanography (1) to identify scientific investigations that might benefit from the use of manned undersea vehicles; (2) to indicate capabilities required; and (3) to consider the limitations in the design and operation of these new research tools. It is designed to inform members of government, industry, and the scientific community of the problems and opportunities inherent in the use of research submersibles for exploration and development of the ocean's deep frontier. (AA)

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79 Keller, H. A method of deep diving with fast decompression by alternating different inert gases. Rev. Subaq. Phys. Hyperb. Med., 1968, 1(2), p 127-129. (Published in Paris, France.)

The author reports on the pilot experimental study of future diving methods without necessity of employing decompression chambers and using various inert gases (N_2, He, Ar, etc.).

Such methods prove to be faster than standard decompression methods.

Electrical 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 8 hours and to work during 45 minutes at 700 feet in depth. (AA)

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80 Kiessling, R. J., & Magg, C. H. Performance impairment as a function of nitrogen narcosis. Research Report 3-60. Navy Experimental Diving Unit, Washington, D.C., June 1960. 13 refs.

Ten subjects were trained to a constant level of performance in a choice reaction time test, a motor coordination test, and a reasoning test. The amount of impairment was determined as a function of increased partial pressure of nitrogen, equivalent to 100 feet of sea water.

The results indicated: (1) significant decrease in performance for all subjects on all tests when compared with their individual sea level efficiency; (2) a positive relationship between degree of impairment and the complexity of the task; (3) an initial loss in efficiency as pressure is increased and this loss remains relatively constant with increased duration of exposure. (AA)

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81 Kent, P. R. Vision underwater. Report No. 498. U.S. Naval Submarine Medical Center, Groton, Connecticut. July 1967. 5 refs.

Visual resolution of Landolt Ring targets in clear water at short range was found to be better than in air at the same physical distance, when target luminances were equated for the two conditions, but fell below predictions based upon the magnification of underwater targets. This is ascribed to a greater lens fogging problem underwater and the lack of sufficiently small targets for some observers. Both size and distance were overestimated underwater, except for short ranges. Fluorescent paints were found to be more visible underwater than non-fluorescent types. (AA)

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82 Kinney, J. S., & Cooper, J. C. Adaptation to a homochromatic visual world. Report No. 499. U.S. Naval Submarine Medical Center, Groton, Connecticut. July 1967. 10 refs.

In a simulation of the underwater visual world, subjects adapted to a diffuse visual field of blue-green light and, for a control, a field of red light. Measures were then made both of the shift in color appearance of objects and of the subject's speed of reaction to these shifted colors. The amount of change

in the appearance of colors was sizable, easily accounting for the reports sometimes made by SEALAB divers, who said they could sea yellows and reds when there were none present. There was, however, no change in the subjects' speed of reaction to the colors. (AA)

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83 Kinney, J. S., Luria, S. M., & Weitzman, D. O. Effect of turbidity on judgments of distance underwater. Perceptual and Motor Skills, 1969, 28, p 331-333. 6 refs.

Judgments of the distance of an underwater target at various locations were obtained as a function of water-clarity. When the target was close to S, its distance was underestimated. Judgments changed to overestimation as the actual physical distance was increased. Estimates were invariably greater in turbid water than in clear water. These data resolve the apparent conflict between expectations from optical considerations and actual distance estimates made in natural waters. (AA)

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84 Kinney, J. S., Luria, S. M., & Weitzman, D. O. The underwater visibility of colors with artificial illumination. Report No. 551. U.S. Naval Submarine Medical Center, Groton, Connecticut. Oct. 1968, 8 pp. 3 refs. (a)

The visibility of various colors underwater with artificial illumination has been measured in three different bodies of water chosen to sample a continuum from clear to turbid. Subjects were SCUBA divers who observed the colors at night, using a mercury or an incandescent light source. The visibility results show numerous interactions among color, fluorescence, type of light source, and type of water; from them, it is possible to select the optimum combination to be used under a wide variety of conditions. Colors are specified that will (1) maximize visibility, (2) provide the best camouflage, and (3) allow distinct color differences in appearance for use in color coding. These results are summarized in terms of the colors that are most effective for use under various operational conditions encountered underwater. (AA)

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85 Kinney, J. S., Luria, S. M., & Weitzman, D. O. Responses to the underwater distortions of visual stimuli. Report No. 541. U.S. Naval Submarine Medical Center, Groton, Connecticut. July 1968. 13 refs. (b)

This report is an account of underwater experiments on size and distance perception and hand-eye coordination, conducted to find, first, what the diver perceives, and secondly, means of aiding him to respond adequately to his unusual environment.

Results are reported on two aspects of underwater vision, apparent distance and hand-eye coordination. The accuracy of distance estimates underwater varies greatly from underestimation at near distances, to overestimation at far distances. Viewing through turbid water rather than clear water greatly increases the tendency toward overestimation. The ability of subjects to perform motor responses adequately, using the distorted stimulation underwater, has been measured and shown to vary with the time spent in underwater activities. (AA)

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86 Kinney, J. S., Luria, S. M., & Weitzman, D. O. The visibility of colors underwater. Report No. 503. U.S. Naval Submarine Medical Center, Groton, Connecticut. October 1967.

The underwater visibility of various colors, both fluorescent and non-fluorescent, was measured in four different bodies of water. The waters were selected to sample the continuum from very murky to clear. SCUBA divers observed with a horizontal path and other subjects on the surface looked down vertically. Fluorescent colors were always more visible than non-fluorescent, but the specific colors that were easiest and most difficult to see depended upon the body of water. (AA)

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87 Kinney, J. S., Luria, S. M., Weissman, S., & Matteson, H. H. Underwater visibility of fluorescent and non-fluorescent paints. Memo Report No. 65-11. U.S. Submarine Base, Groton, Connecticut. September 1965. 8 refs.

The percent of targets correctly identified was always greater for

fluorescent paints than non-fluorescent of the same color, at both depths and viewing distances.

Yellows, including greenish-yellow and orange-yellow, were the most visible colors among the various fluorescent paints tested.

It is expected that fluorescent paints will generally be more visible than non-fluorescent in all bodies of water but that the specific fluorescent which is most visible will vary with the spectral characteristics of different waters. (AA)

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88 Kylstra, A. Liquid breathing: An experimental approach to deep diving without inert gas narcosis and decompression sickness. R. Subaq. Phys. Hyperb. Med., 1968, 1(1), p 45-49. 10 refs. (Published in Paris, France.).

To avoid the troubles due to oxygen under pressure, which are the main obstacles to a protracted stay at great depths, Kylstra wondered whether it could not be expedient to fill the diver's lungs with physiological serum....

With such a method, it might be possible to obtain one day an independent, entirely free fish-man.

Experiments in this direction have been made by Kylstra on mice and dogs, breathing in salted water containing O_2 under pressure, and they are encouraging.

On the author's film, mice could be seen breathing oxygen from the "physiological water" for half an hour. A dog could also be seen breathing for 45 minutes.

At the moment, Kylstra pursues his experiments with a liquid very rich in oxygen: Fluocarbon. This work seems to be very promising. (AA)

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89 Lambertson, C. J. Limitations and breakthroughs in manned undersea activity. Triangle, The Sandoz Journal of Medical Science 8, 1968, p 167-177. 36 refs.

Man remains at the same time the greatest asset and a serious limitation

to work at extreme depths. Even with the present expansion of interest and the solid base of the past series of contributions, a considerable number of barriers must still be surmounted to permit further advance in practical diving, including: physical problems associated with great depth in the cold sea, toxic effects of chemically active substances breathed under high pressure, and the management of pathological or medical conditions resulting from diving accidents. In actual diving most of these problems are closely interwoven and interact upon each other. The implications of these factors and others are discussed. (OM)

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90 Lanphier, E. H. Physiological limits to the extension of underwater operations. Department of Physiology, State University of New York, Buffalo, New York. Undated. 12 refs.

Optimal underwater work requires direct application of man's senses and dexterity. It is thus necessary to find out how deep man can go as a useful diver exposed to the pressure of depth. The final limit may be imposed by familiar problems such as gas density, inert gas narcosis, CO_2 retention, or interactions of such factors. Much less is known about the effects of very high pressure in itself. Artificial gills or liquid breathing could circumvent inert-gas effects but not those of hydrostatic pressure. Much physiological research and many new or improved instruments will be required for further exploration and extension of underwater capability. (AA)

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91 Lanphier, E. H., & Rahn, H. Man . Water . Pressure. (Publications in Underwater Physiology). Department of Physiology, State University of New York, Buffalo, New York. November 1966. 436 refs.

Papers collected here reflect activities of the Department related to the physiological effects of high pressure and submergence. The period covered is from 1960 through 1966. The report includes:

--General summaries.

--Effects of oxygen under high pressure.

--Breath-holding diving.

--Respiratory effects of submergence and pressure.

--Gas pockets.

--Liquid breathing; Gills. (RA)

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92 Larson, H. E. A history of self-contained diving and underwater swimming. Publication 469. National Academy of Sciences, National Research Council, Washington, D.C., 1959, 48 refs.

With the dramatic appearance of military underwater swimmers during World War II, a newly-coined word appeared in the scientific vocabulary--SCUBA, or self-contained underwater breathing apparatus. The connotation of man free-swimming under water for hours at a time was a startling one and focussed attention on the underwater world to a greater extent than ever before. Although the abbreviation SCUBA is of recent origin, the concept has been traced back to the fourth century B.C. The purpose of this report is to attempt to follow the development of SCUBA from that time to the present in a coherent manner.

The historical development of SCUBA can be divided roughly into three main periods.

I. The period of the diving bell, dating from Aristotle in the fourth century B.C. to about 1800, when the diving bell progressed out of the SCUBA class as defined.

II. The period of the self-contained underwater diver, dating from about 1770 to 1930.

III. The period of the self-contained underwater swimmer, dating from about 1930 to the present. (OM)

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93 Libber, L. M. High pressure biomedical research in Genoa and La Spezia. ONR London Report R-21-69. U.S. Office of Naval Research, London Branch. 5 May 1969. 13 pp. 25 refs. (a)

Visits to two laboratories in Italy engaged in high pressure physiological research are described. The one located in Genoa is conducting research in the etiology of bends, aseptic bone necrosis and oxygen toxicity as well as the use of high pressure oxygen therapeutically. The other laboratory, located near La Spezia, is chiefly interested in the mechanisms of oxygen toxicity and protective agents against these toxic effects. (AA)

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94 Libber, L. M. Diving research interests at Gers, Toulon Naval Base. ONR London Report R-19-69. U.S. Office of Naval Research, London Branch Office. 7 April 1969. 8 pp. 4 refs. (b)

The current research and development projects in diving being undertaken at the Groupe d'Etudes et Recherches Sous-marines (GERS) laboratory at the Naval Base, Toulon, France, are reviewed. Items such as the new diver support vessel nearing completion, development of heated diver's suit and current research on the physiological interaction of inert gases with high pressure oxygen are discussed. (AA)

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95 Libber, L. M. Diving research at Compagnie Maritime D'Expertises (COMEX), Marseilles, France. ONR London Report R-11-69. U.S. Office of Naval Research, London Branch Office. 5 March 1969, 15 pp. 2 refs. (c)

This report covers the organization, facilities, staff and research of the Campagnie Maritime d'Expertises (COMEX) of Marseilles, France. Special attention has been paid to the physiological results obtained in the saturation dive at 85 m with working excursion dives to 120 m made by COMEX under the operational name, Ludion II. (AA)

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96 Libber, L. M. Visit to Dr. Gaspare Albano, Laboratorio Internazionale Di Medicina Subacquea, Palermo, Italy. Technical Report ONRL-49-68. U.S. Office of Naval Research, London Branch Office, 11 July 1968. 9 pp. (a)

This report reviews the high pressure physiological research work and theoretical interests of Dr. Albano. His investigations deal with the mechanism of bends production, the effect of oxygen respiration on lung surfactant and the definition of the limits on the use of oxygen in diving conditions. (AA)

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97 Libber, L. M. Aviation and underwater research activities at the DVL Institut Für Flugmedizin. Technical Report ONRL-29-68. U.S. Office of Naval Research, London Branch Office, 7 May 1968. 17 pp. 16 refs. (b)

The research work of some of the investigators at the DVL-Institut fur Flugmedizin (DVL Inst. of Aviation Medicine), Bad Godesberg, Germany, is reviewed in this report. Interests of this very active scientific group are centered about problems related to physiological and/or psychological decrements with respect to circadian rhythms, aviation stresses, high pressure environments and weightlessness. (AA)

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98 Libber, L. M. Diving research in Switzerland. Technical Report ONRL-32-68. U.S. Office of Naval Research, London Branch Office. 16 May 1968. 11 pp. 4 refs. (c)

This report describes the current interests of two people who have been very prominent in advancing man's deep diving capabilities: Mr. Hannes Keller and Prof. A. A. Bühlmann. Although Keller is now devoting his efforts to the design, development, and manufacture of improved diving equipment, Bühlmann continues to work on physiological problems related to deep diving and saturation diving. These efforts are reviewed. (AA)

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99 Luria, S. M. Stereoscopic acuity underwater. Report No. 510. U.S. Naval Submarine Medical Center, Groton, Connecticut. 27 February 1968. 14 refs.

The ability of individuals to tell which of several objects is closer or farther away was tested in water of varying clarity and compared with the same performance in air. It was found that, even when the water was very clear, performance was worse than it was in air, and it became poorer as the water got more turbid. When the subjects were working near the limits of visibility, the difference in distance which had to exist between two targets before the subjects could see that the targets were not at the same distance was around ten times as great as in clear water, and much greater than that when compared with performance in air.

The decrease in the "depth acuity" was attributed to the loss of visual cues along the edges of the visual field underwater. The further drop in acuity with increased turbidity of the water was attributed to the loss of relative brightness of the targets.

Divers should be made aware that their ability to tell which of two objects is closer to them deteriorates underwater, --increasingly, as the clarity of the water decreases. Performance of divers may be improved, if artificial cues can be provided. (AA)

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100 Luria, S. M., & Kinney, J. S. Visual acuity under water without a face mask. Report No. 581. Prepared by U.S. Naval Submarine Medical Center, Groton, Connecticut. 19 May 1969. 5 refs.

Visual acuity was measured under water for subjects without face masks and was compared with their acuity in air. The loss of acuity was around 90 percent for the entire group, but there were marked differences for the various sub-groups. Emmetropes suffered the greatest loss in the water; they required targets more than 20 times as big as those they could see in air. Myopes suffered the least loss; they required an increase in target-size by a factor of only seven. There was no correlation between emmetropic acuity in air and in water.

Acuity was also measured at various luminances in air while the subjects wore negative lenses of various powers to induce the same type of out-of-focus vision found under water. High and low contrast targets were used. Calculations were made of the approximate target sizes which can be seen under water at various light levels and at the two levels of contrast. (AA)

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101 Luria, S. M., & Kinney, J. S. Stereoscopic acuity underwater. The American Journal of Psychology, 1968, 81(3), p 359-366.

Stereoscopic acuity was compared for a target in air and under water in Experiment I, and in Experiment II it was measured in water of varying clarity. Stereoacuity was found to be degraded in water, increasingly so as the clarity of the water decreased. The function of acuity vs. clarity was found to be similar to the reported for stereoacuity vs. brightness-contrast, which suggests that a main cause of the drop in stereoscopic acuity with decreasing water clarity is the decrease in target-contrast. In Experiment III, stereoacuity was found to decrease in air when there was a loss of peripheral visual cues. It was concluded that the loss of peripheral cues in water is a significant cause of the drop in stereoscopic acuity underwater. (AA)

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102 Luria, S. M., Kinney, J. S., & Weissman, S. Estimates of size and distance underwater. The American Journal of Psychology, 1967, 80, p 282-286, 10 refs.

Estimates of both the size and the distance of unknown objects in air and in water were compared. A 4-in. square was placed at distances of 5 and 12 ft. from "O" for the size-estimates and at 4.15 ft. for the distance-estimates. The observations in air were made out-of-doors, and the underwater observations were made from a porthole in a submerged tower. Estimates of size were reasonably accurate in both air and water, but they were somewhat larger in water, the increase corresponding to the increase in the size of the retinal image resulting from the refraction of light waves passing from water to air. At the same time, distances were overestimated in water as compared to estimates in air, and overestimations increased with distance. It is concluded

that these results are not explained by size-distance invariance, and that in the absence of distinct cues, distance will be overestimated. (AA)

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103 MacInnis, J. B. Living under the sea. Scientific American, 1966, 214(3), p 24-33.

The author reviews several completed and ongoing research programs concerned with extending man's ability to live and perform useful work beneath the sea. (RA)

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104 McLean, W. B. A bedrock view of ocean engineering. Astronautics and Aeronautics, 1969, 7(4), p 30-36.

Dr. William B. McLean Technical Director of the Naval Undersea Warfare Center, San Diego, California, presents his views on ocean research and technology. Topics range from undersea bases and submersibles to government regulation of undersea activities. (RA)

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105 Merer, P. Physiological aptitude to diving. Rev. Subaq. Phys. Hyperb. Med., 1968, 1(2), p 94-102. 4 refs.

The medical investigation in order to determine the autonomous submarine aptitude to diving must be particularly complete in four areas:

--neuro-psychical,

--respiratory,

--cardio-vascular,

--O.R.L.

The author shows the functional tests applied to practice in order to explore these three late systems and defines the temporary and permanent contra-indications for diving. (AA)

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106 Miller, G. E., Schoelkopf, F., & Corover, D. Underwater vision demonstration of display viewing techniques for free flooding submersibles. MFI-67-U-1, Man Factors, Inc., San Diego, California, September 1967.

In free-flooding submersible craft the operator's line of sight to his instrument panel may be substantially occluded by murky water. This experiment sought to demonstrate the feasibility of using a clear medium "see-through" container as a means of providing underwater vehicle instrument legibility during high turbidity conditions. Both clear air and acrylic plastic "see-through" containers provided satisfactory visual contact with the test targets in water of sufficient turbidity to make them illegible under normal viewing conditions. (RA)

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107 Milligan, S. Sample test exposures to examine corrosion and fouling effects on materials in the deep ocean. TM No. 359. Prepared by U.S. Naval Underwater Ordnance Station, Newport, Rhode Island. January 1966. 6 refs. AD 477-273.

Information needed in selecting materials for use in construction of deep ocean installations has been gathered.

Test samples representative of these materials were exposed at depths of approximately 5000 feet in the Atlantic from July 1962 to February 1965 and in the Pacific from March 1962 to Febuary 1965.

Upon retrieval, no signs of marine borer action were found in any of the samples except for a slight attack on wood. A light attachment of minute crustaceans occurred generally over most samples. Normal corrosion of metals was observed. Certain aluminum alloys were found to be unsuitable for ocean use. The protective value of coatings over corrodible materials at deep depths was emphasized.

It is recommended that in the future, additional emphasis be placed on examining the deep sea environmental effect on materials placed in direct contact with the ocean bottom. (AA)

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108 Mosby, R. C. Philosophy of Man-in-the-Sea. Ocean Industry Magazine, 1967, 2(2), p 1-16. 7 refs.

The philosophy of ocean exploration encompassing the application of a systems design concept is presented as a logical point from which the petroleum industry in particular can continue to expand into the oceans.

The system analysis and design approach provides a sense of direction to the ocean exploration endeavor. Perfect functioning of each component is required of a space vehicle during launch and orbit. It has been attained many times. Perfect performance may not be required in the ocean exploration work, but it is a direction to aim.... (AA)

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109 Nelson, J. G. Effect of water immersion and body position upon perception of the gravitational vertical. Aerospace Medicine, 1968, 39(8), p 806-811. 26 refs.

The purpose of this study was to measure the accuracy, particularly the sensitivity or short-term repeatability, with which humans can use their vestibular sense to perceive the gravitational vertical, and how this ability varies with body (head) position. Equipment and procedures to reduce or eliminate nonvestibular cues were selected through an iterative process of design, development, test, and evaluation.

Subjects were restrained upon an underwater 2-axis tilt table, and required to position themselves, via signals to Experimenters, in one of 6 cardinal positions of the body (head) with respect to gravity. Seven subjects, in 3 immersions each, made 3 judgments per immersion at each of the 6 positions.

The group responses showed some large and significant constant errors, most notably a pitch-forward bias shared (unequally) by all of the medial-plane positions, exceeding 30° in the nominal head-down position. A Probable Error, (PE), uninflated by constant errors, was computed for each of the 2 orthogonal directions of deviation for each of the 6 positions. The results supported the classical concept of reduced sensitivity in the head-down as compared with the head-up positions. However, PE ranged from 15° to 40°,

indicating only a marginally useful sensitivity in any position. In addition, sensitivity at any one position was not necessarily symmetrical as to direction of deviation, and some sensitivities at intermediate values of tilt overlapped head-up or head-down sensitivities. (AA)

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110 Panel on Underwater Swimmers. Status of research in underwater physiology. Publication 468. National Academy of Sciences, National Research Council, Washington, D.C. 1956.

This report has been prepared by the Physiology Group of the Panel on Underwater Swimmers as a general review of the current status of underwater physiology. In this discussion of existing information, emphasis is placed upon the interrelationship of various factors and upon a number of important questions which appear at present to be unanswered. Large new areas of underwater physiology have been opened by recent studies and should be susceptible to further investigation. The possibility now exists of a breakthrough in one or more of these areas. There is reason to expect that it will not always be necessary to base predictions of potential diving depth and duration upon the "physiological barriers" which now restrict underwater activity. (AA)

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111 Panel on Underwater Swimmers. Report of the cooperative underwater swimmer project. Office of Naval Research, Washington, D.C., 1952. 10 refs.

A small team of civilian scientific and naval operational personnel conducted during August and September 1952, a field-laboratory research project on several physiological problems in swimming with self contained underwater breathing apparatuses (SCUBA). Among other findings, it was noted that the average speed for underwater swimming with SCUBA in the open sea is about 1.1 mph with an average respiratory minute volume of 28 liters while breathing compressed air; that during exercise, the respiratory minute volume was significantly smaller while breathing oxygen that while breathing air; and that ventilation during exercise while breathing air was much smaller at greater depths than predicted theoretically. For protection against cold water, the group demonstrated quantitatively, the validity of the principle of using

a "wet" underwater swim-suit made of unicellular foam rubber, in which no attempt is made to prevent water entry but rather only to restrict its free flow over the body surface. Annexed to the group's findings are suggestions for safety precautions and training procedures similar to those used by the group, and a proposal for an analogue computer type swimmer's decompression gauge. A separately bound classified annex presents the group's findings on swimmer's "signatures" or those phenomena that enable one to distinguish underwater man from his background. (AA)

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112 Penzias, W., & Goodman, M. W. Performance in the ocean environment. Chapter 17. Man in the Sea. To be published by Wiley & Sons, New York.

Problems of sensory perception (vision, audition, vestibular functions), underwater communication, motor performance, and equipment are discussed briefly in this chapter. (RA)

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113 Poulton, E. C., Catton, M. J., & Carpenter, A. Efficiency at sorting cards in compressed air. Brit. J. Industr. Med., 1964, 21, p 242-245. 10 refs.

At a site where compressed air was being used in the construction of a tunnel, 34 men sorted cards twice, once at normal atmospheric pressure and once at 3-1/2, 2-1/2, or 2 atmospheres absolute pressure. An additional six men sorted cards twice at normal atmospheric pressure.

When the task was carried out for the first time, all the groups of men performing at raised pressure were found to yield a reliably greater proportion of very slow responses than the group of men performing at normal pressure. There was reliably more variability in timing at 3-1/2 and 2-1/2 atmospheres absolute than at normal pressure. At 3-1/2 atmospheres absolute the average performance was also reliably slower.

When the task was carried out for the second time, exposure to 3-1/2 atmospheres absolute pressure had no reliable effect. Thus compressed air

affected performance only while the task was being learnt: it had little effect after practice. No reliable differences were found related to age, to length of experience in compressed air, or to the duration of the exposure to compressed air, which was never less than 10 minutes at 3-1/2 atmospheres absolute pressure. (AA)

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114 President's Committee on Marine Resources and Engineering Development. Marine Science Affairs--A Year of Broadened Participation. January 1969. 251 pp.

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115 President's Science Advisory Committee. Effective use of the sea. Report of the Panel on Oceanography, President's Science Advisory Committee. June 1966. 144 pp.

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116 Reilly, R. E., & Cameron, B. J. An underwater human performance measurement system. Published by The American Society of Mechanical Engineering, New York, N.Y., prepared by BioTechnology, Inc., ASME 69-UNT-13. December 1968. (a)

A newly developed underwater test battery containing 26 measures of human cognitive and perceptual-motor performance is described. Measures range from simple reaction time to complex manual tracking and higher mental functions. Designed for use in the environmental chambers at the Navy Experimental Diving Unit, the subject's equipment will operate in wet or dry surroundings at an ambient pressure of up to 450 psi, equivalent to a depth of 1000 ft. (AA)

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117 Reilly, R. E., & Cameron, B. J. An integrated measurement system for the study of human performance in the underwater environment. Prepared for Office of Naval Research, under contract N00014-67-C-0410, prepared by BioTechnology, Inc., December 1968. 88 pp. 15 refs. (b)

This report describes a system to measure human mental and perceptual-motor functions at ambient pressures of up to 450 lb/in^2, equivalent to a depth of 1000 feet. Designed for use in the environmental chambers at the Navy

Experimental Diving Unit, the subject's equipment will operate in wet or dry surroundings.

The system permits remote administration and scoring of 26 specific tests ranging from simple reaction time to complex manual tracking, and from monitoring a simple display to solving difficult mental arithmetic and symbolic problems.

As a formal test battery and general research tool, the system is expected to have extensive application in the areas of (1) specification of human underwater performance capabilities, (2) delineation of factors of the diving environment which affect performance, and (3) development of diver selection criteria. (AA)

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118 Reinhard, F. M. Examples of corrosion of materials exposed on STU II-1 in the deep ocean. Prepared by U.S. Naval Engineering Laboratory, Port Hueneme, California. 26 February 1965. 7 refs. AD 614-903.

Preliminary results of corrosion of materials, based solely upon visual examinations, exposed in 2340 feet of water in the Pacific Ocean for 197 days showed only a few cases of deterioration different from those usually found in moving surface sea water. The Clad layers on two aluminum alloys corroded at a much faster rate than normal for surface sea water. The lacework and undersurface types of attack on certain stainless steels appear to be similar to types of attack by stagnant surface sea water; this could be attributed to low oxygen content as well as lack of a significant movement of deep sea water. Other materials, both metallic and nonmetallic, were not seriously deteriorated and some showed absolutely no evidence of deterioration. In order to obtain meaningful results, considerable critical examination of the various specimens will be required. (AA)

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119 Ross, H. E. Adaptation of divers to curvature distortion under water. Ergonomics, 1969, 12, 11 pp. 30 refs.

A diver's face-mask causes 'pin-cushion' distortion for objects seen under water. The apparent curvature in depth of a straight line was measured for seven divers in air and water before and after a half-hour dive in the sea. Approximately 25 per cent of full adaptation to the optical distortion occurred during the dive, with a corresponding negative after-effect in air.

The apparent curvature of the line was also measured for 16 novices and 15 experienced divers both in air and immediately on entering the water. The experienced divers showed some initial adaptation, while the novices showed none. This result suggests that the experienced divers had acquired a 'situation-co. ingent' visual response. (AA)

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120 Ross, H.E. Personality of student divers. Underwater Association Report, 1968, p 59-61. 19 refs. (a)

The personality profiles of 54 undergraduate students who were members of an underwater (scuba diving) club were compared with 54 controls. Personality data was obtained using the Maudsley Personality Inventory. Information from other non-diver student populations was also utilized for comparison purposes.

The object was to determine the type of student who takes up diving and whether there are any useful criteria for predicting success at diving.

As far as the experimental population was concerned, it was concluded that, "Any personality variables which might distinguish the university diver from the normal population are probably due to his being an intelligent male scientist..."

"Unless the diver is interested in some underwater activity such as photography or observing marine life, he will quickly become bored." (RA)

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121 Ross, H. E. Judging distance underwater. Triton, 1968, 13(2), p 64-66. (b)

The cues by which one usually estimates size and distance of visual targets on land are either eliminated or distorted underwater.

The effect of the underwater environment on size and distance perception is examined and implications for perceptual learning are discussed. (RA)

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122 Ross, H. E. Water, fog and the size-distance invariance hypothesis. British Journal of Psychology, 1967, 58(3 and 4), p 301-313. 28 refs.

Objects generally appear too large under water. The usual explanation for this is that they are magnified by the change of refractive index between air and water. However, they are only magnified because they are optically nearer. If size constancy operates normally they should be seen the correct size but nearer, or enlarged in size but farther that the optical distance. The problem was investigated by requiring sixteen divers to make size and distance judgements of a range of white disks of different sizes set at various distances. Judgements were made for the same display both under water and on land. It was found that size judgements were greater under water, and that this corresponded to relative overestimation of distance. A weak form of size-distance invariance was found both under water and on land, but the relation between size and distance judgements was not the same in both conditions.

Overestimation of size and distance was also found in a fog on land. It was suggested that the overestimation of distance in a fog and under water was due to the exaggerated reduction of brightness contrast with distance, which increases "aerial perspective". (AA)

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123 Ross, H. E. Stereoscopic acuity under water. Underwater Association Report 1966-67, p 61-64. 7 refs.

Divers were required to judge the relative distance to two white square targets underwater and on land as a means of assessing stereoacuity for the two conditions.

It was concluded that under fairly typical Mediterranean diving conditions, stereoacuity is likely to be reduced by a factor of at least three. The reduction may be much greater for deeper dives or murkier water, because of lower illumination and contrast. Poor-sighted subjects may virtually lose all stereopsis well before the limits of visibility hav been reached. (RA)

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124 Ross, H. E. The size-constancy of underwater swimmers. Quarterly Journal of Experimental Psychology, 1965, 17(4), p 329-337. 16 refs.

The size-constancy of divers was measured by requiring them to adjust the distance between two disks of unequal size so that they appeared phenomenally equal. In clear water divers showed greater const y-ratios than on land. In murky water, where visibility was reduced by suspended particles, constancy-ratios were the same as, or less than, on land. It is suggested that these effects may be due to changes in apparent distance: in clear water objects appear nearer through refraction, but in murky water th y appear further away because of the distance cues provided by the visibility gradient.

The orientation of the display, or of the diver's body, did not affect constancy under water, though it does on land. It is argued that the effect on land is due to visual and proprioceptive cues which are absent in the water. (AA)

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125 Ross, H. E., Crickmar, S. D., Sills, N. V., & Owen, E. P. Orientation to the vertical in free divers. Aerospace Medicine, 1969, 40(7), p 728-732. 25 refs. (a)

SCUBA divers were tested in clear water off Malta. They were required to turn a somersault with their eyes closed, and then orientate their bodies and point up or down with or without vision. Two divers photographed the subjects simultaneously from the side and back, while another diver held a weighted rope behind him to mark the vertical. The subject's maximum angular deviation from the vertical in any plane was calculated from the paired photographic measurements. Results for five subjects showed that performance

was worse when inverted than upright, and worse blind than with vision. Another experiment in which the subject looked through a roughened perspex (plexiglass) faceplate showed that "whiteout" vision gave worse performance than no vision. The mean errors over all conditions in both experiments ranged from 8^{o}-33^{o}, suggesting that a free diver normally has adequate knowledge of the vertical for safety. (AA)

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126 Ross, H. E., Franklin, S. S., & Weltman, G. Adaptation of divers to distortion of size and distance underwater. Report No. 68-61. Prepared by Department of Engineering, University of California, Los Angeles, California, under contract sponsored by Office of Naval Research, Washington, D.C., January 1969. 14 refs. (b)

This report describes a series of five experiments conducted during summer 1968 to examine adaptation of divers to size and distance distortion underwater. Visually perceived distortions of size and distance are produced by the diver's facemask which introduces an air-water interface between the eye and the object of regard. The effect of this interface is to decrease image distance by about one-fourth. Under these conditions objects are likely to be reported as closer or larger, or closer and larger than they actually are. Adaptation to distortions of size and distance were investigated by two techniques: 1) the method of adjustment where a diver adjusted the size of a horizontal line, set in the frontal plane at a fixed distance, to a length of 12 inches, 2) the method of estimation where the diver recorded his judgments of the size and distance of a series of targets which varied on these dimensions.

Of the five experiments conducted in the Underwater Research Facility tank and swimming pool at UCLA and in the ocean, three were successful in demonstrating adaptation. (AA)

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127 Ross, H. E. & Lennie, P. Visual stability during bodily movement underwater. Underwater Association Report, 1968, p 55-57. 13 refs.

In an ingenious experiment scuba divers wearing blacked-out face masks were asked to report the location and relative motion of two visual stimuli during active or passively induced body movement underwater. The stimuli consisted of a Betalight (small self radiant light source) affixed to the mask and a retinal afterimage produced by exposure to a flashlamp. Thus one stimulus (Betalight) was fixed relative to the head while the afterimage was fixed relative to the eyes.

Reported variations in relative position and motion of the two visual stimuli during body movement were examined in the light of neurological processes which control our perception of relative motion while cancelling spurious inputs due to eye movement.

The results suggested that divers compensate quite well for active movement but poorly (if at all) for slow passive movement. The authors conclude that further work is necessary to show whether the failure to compensate is due to the fact that movement is passive or because it is merely slow. They speculate that compensation for fast passive movement might be expected; some perceptual learning for slow passive movement might also be expected provided there was an adequate degree of sensory feedback. (RA)

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128 Schachter, S. The interaction of cognitive and physiological determinants of emotional state. In L. Berkowitz (Ed.), Recent Advances in Experimental Social Psychology, Vol. I, New York: Academic Press, 1964, pp 49-80.

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129 Schreiner, H. R. Advances in decompression research. Journal of Occupational Medicine, 1969, 11(5), p 229-237. 27 refs. (a)

The toxicity of oxygen at high partial pressures makes it mandatory that an inert diluent be used to supply the diver at depth with oxygen at a

physiologically acceptable partial pressure. Unless the use of liquids becomes practical, there is no alternative to the use of inert gases for this purpose.

It is possible to discern three broad aspects of decompression research. These are: the transport of inert gases in the body, gas phase separation and the growth of bubbles, and the pathophysiology of decompression sickness. This report will deal largely with the gas transport aspect of decompression research. (OM)

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130 Schreiner, H. R. Physical limits of manned underwater activity. Prepared for presentation before a Symposium "NEW FRONTIERS". Second International Conference on Medical Physics, Boston, Massachusetts. August 1969, 79 refs. (b)

The physiological capabilities and limitations of man's activity beneath the sea are discussed in a thoroughly documented presentation. The account also includes a comprehensive summary table of chamber and open sea saturation dives 1962-1969. (RA)

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131 Schreiner, H. R. Ein kritischer Überblick über den gegenwärtigen Stand der angewandten Tieftauchphysiologie. (A critical review of the current state of applied deep diving physiology.) Int. Z. angew. Physiol., 1969, 27, p 76-98. 60 refs. (c) (Published in Kiel, Germany)

The physical facts of submergence determine the physiological problems which limit man's ability to dive successfully to great depths. Chief among these is the hydrostatic pressure to which the deep diver is exposed, and which must be compensated by the pressure of the diving gas mixture which he is breathing. Since oxygen exerts toxic effects even at relatively low pressures, it becomes necessary to employ inert diluents such as nitrogen or helium to achieve this pressure compensation.

The physiological limitations of useful human existence under water are being explored by determining the mental and work performance of divers exposed to elevated environmental pressures for extended periods of time.

Since 1962 more than 90 such saturation exposures (exposures lasting at least 24 hours) have been carried out in laboratory chambers and in undersea habitats at pressures ranging up to 27 ata (1 ata = 735.6 mm Hg). Under these conditions no serious detriments to human performance have been determined to data as long as environmental parameters such as temperature, composition of breathing gas mixtures, etc., remained carefully optimized. (AA)

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132 Schreiner, H. R. Safe ascent after deep dives. R. Subaq. Phys. Hyperb. Med., 1968, 1(1), p 28-37. 14 refs. (Published in Paris, France.)

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 periods and levels of decompression. (AA)

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133 Science and the sea. U.S. Naval Oceanographic Office, Washington, D.C. (Publishers) 1967. 80 pp.

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134 Scientific American. The Ocean. Scientific American, 1969, 221(3), 290 pp.

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135 Shilling, C. W., & Willgrube, W. W. Quantitative study of mental and neuromuscular reactions as influenced by increased air pressure. U.S. Naval Medical Bulletin, 1937, 35(4), p 373-381. 5 refs.

Data which included problems, number cross-out tests, and light-to-touch reaction time worked at both atmospheric pressure and under increased air pressures, have been presented.

These data give quantitative evidence of the slowing effect that increased air pressure has upon the normal mental and neuromuscular responses.

Experience in work under pressure tends to lessen this effect, and low mental ability undoubtedly enhances early and extreme failure under high air pressure. (AA)

The cause of this effect was discussed in this report.

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136 Smit, P. J. Influence of apneic diving before and after meals on certain physiological processes. Rev. Subaq. Phys. Hyperb. Med., 1968, 1(2), p 88-93. 15 refs.

Seventeen male subjects performed a series of apneic dives involving states that ranged from inactivity to muscular exertion. The results show that diving bradycardia is generally reduced after a heavy meal and that muscular exertion may arrest diving bradycardia. Maximal heart rate of apneic divers kicking vigorously under water was found to be approximately 100 beats/minute as compared with the maximum of approximately 185 beats/minute of athletes on dry land. (AA)

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137 Snyder, R. G. Human tolerance limits in water impact. Aerospace Medicine, 1965, 36(10) p 940-947. 25 refs.

The wide but overlapping range presented between human levels of clinical impact trauma, as measured in the laboratory on volunteer subjects, and the extreme limits of survival which may occur in free-fall, has long presented a scientific enigma. This study has been an attempt to identify and evaluate factors critical to protection and survival in human water impact. Theoretical mathematical bases for impact loadings on the body were noted, along with discussion of stunt jumper techniques. Fifty (39 males, 11 females) cases of free-falls survived by individuals aged 7 to 80 years impacting water environments at over 55 ft/sec during the past three years were intensively investigated and analyzed. These represented over 25 per cent of the 281 known water free-falls survived during this period. In addition, autopsy data in fatal falls occurring under similar environmental conditions during this time was compared. It was found that fatal cases sometimes presented a problem

as to whether death was caused by drowning, and if so, whether the impact trauma could have been survivable. The most survivable body orientation, by a factor of 5-7 times, as found to be a ($+G_z$) feet-first deceleration, in which critical velocity for human survival was slightly over 100 ft/sec. (116 ft/sec max.). In fatal cases a high proportion of rib fractures in lateral and transverse impact orientations was found to cause fatal penetration of the lungs and other internal organs. Patterns of injury and relationships of factors found to influence human survival tolerances are presented and compared with impact trauma on non-water surfaces. (AA)

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138 Streimer, I., Turner, D. P., & Volkmer, K. Study of work-producing characteristics of underwater operations. North American Rockwell Corporation. Prepared for Office of Naval Research, Washington, D.C. May 1968. 19 refs.

The work output characteristics of divers were tested during the performance of manual tasks which generally fell into three classifications:

1. A complex maintenance task involving the disassembly and reassembly of a water filtration unit.

2. A simple repetitive rotary task requiring continuous torque production against known resistances.

3. A simple repetitive discontinuous flexion/extension task requiring the exertion of linear forces against known resistances.

During the task execution, heart rate and three skin temperatures were continuously monitored and electronically recorded.

The underwater results were compared with performance values obtained from these tasks executed in normally tractive "dry" environments and the observed decrements discussed in terms of biomechanical considerations and certain water effects. (AA)

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139 Taber, R. W., LaPorte, L. R., & Smith, E. C. An oceanographic curriculum for high schools. Published by U.S. Naval Oceanographic Office, Washington, D.C., 1968.

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140 Teas, D.C., & Henry, G. & G. Auditory nerve responses as a function of repetition rate and background noise. International Audiology-Audiologie Internationale, 1969, 8(1), p 147-163. 7 refs.

The magnitudes and latencies of whole nerve responses to 2 kHz and 6 kHz tone pips were studied. The effects of stimulus repetition rate and of the addition of background noise are described. A range of intensity levels for noise and signal was included for repetition rates from 2/sec to 160/sec. The experimental design allowed assessment of interactions between signal and noise as well as an assessment of their separate effects. Our analysis shows that for neural responses to narrow band transients at moderate strength, an increase of repetition rate to 10/sec can produce an increase in response magnitude. Above 10/sec response magnitude decreases with increasing repetition rate. At the repetition rate of 2/sec the addition of weak background noise produced enhancement of the neural responses to the 2 kHz tone pip. The response to the 2 kHz signal was more frequently enhanced by background noise while the response to the 6 kHz signal was more frequently enhanced by repetition rate (from 2/sec to 10/sec). Along with the enhancement at 10/sec for the neural response to the 6 kHz signal, there is a heightened susceptibility to interference by background noise. (AA)

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141 Thompson, L. J., McCally, M., & Hyde, A. S. The effects of posture, breathing pressure, and immersion in water on lung volumes and intrapulmonary pressures. AMRL-TR-66-201. Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio. May 1967. 38 pp, 38 refs.

Lung volumes were measured by spirometry and single breath helium dilution in five subjects under various combinations of posture, breathing pressure, and headout neutral temperature immersion. Tidal volume was unaltered. Vital capacity was reduced significantly only by negative pressure

breathing during seated immersion. Seated immersion decreased total lung capacity and functional residual capacity, but the supine posture underwater partially restored these decreases. Positive pressure breathing increased total lung capacity and residual volume for the seated subject in both air and water. A wide range of transthoracic pressure gradients is subjectively more comfortable than a slight increase in the transpharyngeal pressure gradient, suggesting that during immersion, intrapulmonic pressures are selected by the subject to minimize the transpharyngeal pressure gradient. (AA)

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142 Tyler, J. E. Water properties. Applied Optics, 1964, 3(5), p 582-583.

This paper deals with the computation of the inherent and apparent contrast of objects underwater when they are illuminated by natural light from the sun and sky. (RA)

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143 Uhl, R. R. Aseptic bone necrosis in divers. Aerospace Medicine, 1968, 39(12), p 1345-1347. 16 refs.

Four cases of aseptic bone necrosis are presented. These cases, plus those of other authors, are analyzed in relation to distribution of lesions, previous history of decompression sickness, diving history, and other possible contributing factors. The author recommends abandoning the notion that this disease does not occur with the use of accepted diving procedures until a scientific investigation of the occurrence of this disease is made. (AA)

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144 Weltman, G., & Egstrom, G. H. Heart rate and respiratory response correlations in surface and underwater work. Aerospace Medicine, 1969, 40(5), p 479-483. 11 refs.

An exercise test battery composed of surface bicycling, surface and underwater weight lifting, surface and underwater block moving, and underwater pipe structure assembly was administered to two 7-man groups of divers. High rank-correlations were observed between levels of heart rate

and inspiratory minute volume exhibited in various surface tests and the levels of these variables exhibited in strenuous underwater activity. A high degree of concordance was also observed among heart rate, inspiratory minute volume, and respiratory rate over the range of surface and underwater tests. Using the heart rate and respiratory volume measures, it was possible to order with respect to imposed workload tasks of known and unknown physical requirements. The main implications were that it is feasible to estimate underwater work capacity through surface tests, and that basic physiological measurements, particularly heart rate, taken during diving operations can permit reasonable estimations of imposed workload. (AA)

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145 Weltman, G., & Egstrom, G. H. Underwater heart rate telemetry using an ultrasonic voice communication system. Underwater Research Technical Paper No. 1. Department of Engineering, University of California, Los Angeles, California. Prepared for Office of Naval Research. April 1968. 4 refs.

An underwater heart rate telemetry system was devised by modifying a standard underwater voice communicator. In the modified system the diver's microphone is replaced by a matched circuit which produces a 150 msec burst of 1,000 Hz signal for each ECG complex appearing across a set of skin electrodes. The propogated bursts are detected by a shipboard receiver. The 1,000 Hz signals may be counted over fixed intervals to derive heart rate. (RA)

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146 Weltman, G., & Egstrom, G. H. Measuring work effectiveness underwater. Presented at Marine Technology Society, Los Angeles Region Section Symposium: "Useful Work in the Sea." 11-12 December 1967. 8 refs.

This paper describes in part the goals, research philosophy, methodologies and facilities employed in the study of underwater work performance at the University of California, Los Angeles. (RA)

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147 Weltman, G., Egstrom, G. H., Elliott, R. E., & Stevenson, H. S. Underwater work measurement techniques: Initial studies. Prepared by Engineering Department, University of California, Los Angeles, for Office of Naval Research, Washington, D.C. Report No. 68-11. March 1968. 19 refs.

This report reviews initial progress in an ongoing study of underwater work measurement. The objective of the study is to determine new ways of defining and measuring diver work effectiveness, and to develop measurement techniques for general application in research and operational programs. Examination of measurement techniques was divided into three main areas: procedural, physiological and psychological. The report describes the development of a pipe construction task and a laboratory bioinstrumentation system. In addition, it presents the results of a series of sub-studies dealing with work methodology and physiological response underwater. The studies were conducted in the diving tank at the UCLA Underwater Research Facility. A summary of findings and recommendations is included. (AA)

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148 Winter, P. M., Gupta, R. K., Michalski, A. H., & Lanphier, E. H. Modification of hyperbaric oxygen toxicity by experimental venous admixture. Journal of Applied Physiology, 1967, 23(6), p 954-963. 16 refs.

The development of oxygen poisoning was compared in 10 normal dogs and in 10 with large venoarterial shunts produced by anastomosis of the inferior vena cava to the right inferior pulmonary vein 2 weeks before exposure to oxygen. The control dogs breathed oxygen in a hyperbaric chamber at 2.5 atm abs until convulsions (5.1 ± SD 2.12 hr) and at 2 atm until death (total 12.3 ± 1.4 hr). The operated dogs were exposed to 2.5 atm abs for 5.1 hr and to 2.0 atm abs until death. They experienced no convulsions and survived 21.1 ± 2.3 hr ($P < 0.001$). The lungs of both groups showed severe damage characteristic of pulmonary oxygen toxicity. Minimal lung changes were found in seven of eight operated dogs exposed on the same schedule but sacrificed at the median survival time of control dogs. Venous admixture largely prevented elevation of arterial PO_2 in the operated dogs during oxygen

exposure. Delayed development of lung damage and near doubling of survival time are consistent with the hypothesis that pulmonary oxygen toxicity is not governed by alveolar oxygen pressure alone but involves factors related to arterial PO_2. (AA)

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149 Yanda, R. L., & Egstrom, G. H. Carbon dioxide excretion through the skin at 4 atm. Paper presented at Third International Conference on Hyperbaric Medicine, National Academy of Sciences, Washington, D.C. 1966. 13 refs.

Recognizing the importance and possible inefficiency of our normal carbon dioxide excretory system under the stress of diving the authors sought to determine the extent to which carbon dioxide transfer occurs through the skin under circumstances of 1) immersion in water, 2) cutaneous vascular bed dilated, 3) normal or increased cardiac output, and 4) the presence of an adequate carbon dioxide gradient across the skin.

To test their hypothesis, they conducted a series of animal experiments, then experiments in normal humans, and finally experiments in patients with pulmonary disease.

In three limited trials using animals and humans, evidence suggested that carbon dioxide must be escaping from the system by a route other than the respiratory tract. The assumption that excretion through the skin as the main secondary route is implied, however, rather than proven by the data. (RA)

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13. ABSTRACT

This report is an annotated bibliography of 149 references concerning human performance and physiology in the undersea and dry hyperbaric environment. Also included are lists of additional bibliographies and scientists engaged in undersea research.

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