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OF THE

UNDERWATER PHYSIOLOGY

SYMPOSIUM

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Loyal G. Goff, Editor

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ABSTRACT

These proceedings represent a compilation of those papers presented at a Symposium on Underwater Physiology, January 10-11, 1955, sponsored by the Office of Naval Research and the Panel on Underwater Swimmers of the National Academy of Sciences-National Research Council Committee on Undersea Warfare.

The range of interests covered includes oxygen toxicity, decompression and bends, and respiratory problems, with special emphasis on their implications in underwater swimming. Some of the earlier work in these areas of interest has been re-examined in the light of current problems.

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FOREWORD

Recorded here are the proceedings of a symposium on Underwater Physiology held at the New State Department Building, Washington, D. C., January 10-11, 1955, under the sponsorship of the Panel on Underwater Swimmers of the Committee on Undersea Warfare and the Office of Naval Research. The phases of underwater physiology considered at this symposium apply to all human underwater activities, but the emphasis has been placed on the special conditions met in the use of self-contained underwater breathing apparatus.

The general problems associated with deep-sea diving also apply to the self-contained diver or underwater swimmer. In addition there are numerous other problems peculiar to this activity as a result of a completely different type of breathing equipment, lack of constant attention and supervision from the surface and the missions performed.

Beginning with the advent of the underwater swimmer as an effective military unit during World War II, the applications of this skill to both civilian and military situations have increased at such a rate that neither the technology nor the basic scientific data have kept abreast of the needs in this field of activity.

The Panel on Underwater Swimmers of the Committee on Undersea Warfare and the Office of Naval Research agreed to sponsor jointly a symposium on underwater physiology with the following objectives:

a. to summarize what is currently known in the field of physiology as applied to underwater environment;

b. to direct the attention of those working in physiology to the various problems which exist;

c. to encourage consideration of these problems in the evaluation of related research;

d. to formulate proposals for future research and development leading to increased capabilities of underwater swimmers.

These proceedings are composed of the numerous papers presented at the meeting and the discussions which followed. While many of the papers refer to earlier work in the field of diving physiology, the basic information was reconsidered in view of the new problems which have arisen. The discussions represent a valuable re-assessment of much of this information. Included also are the basic references to the various topics considered. This reference list is not complete in that it contains only those works specifically cited by those authors whose papers were presented.

The formal presentations and discussions were supplemented by active demonstrations and displays at the U. S. Naval Experimental Diving Unit, affording an opportunity to examine some of the equipment available for use by underwater swimmers as well as to obtain first-hand information regarding special instrumentation and techniques employed in almost all phases of research in

underwater physiology.

In addition to Navy and Government representatives, the 1955 Underwater Physiology Symposium was attended by representatives from university and industrial research organizations, the Dominion of Canada, and the United Kingdom.

The Chairman of the symposium, Dr. Eugene F. DuBois, was unable to attend because of illness. Dr. C. J. Lambertsen (Chairman of the Panel on Underwater Swimmers), Captain A. R. Behnke (Radiological Defense Laboratory, San Francisco), and Dr. H. Rahn (University of Rochester) acting for Dr. DuBois, presided over the sessions on Oxygen Toxicity, Decompression and Bends, and General Respiratory Problems, respectively. The program committee consisted of Dr. Eugene F. DuBois (Cornell University Medical School), Dr. F. H. Quimby (Physiology Branch, Office of Naval Research), and Dr. C. J. Lambertsen (University of Pennsylvania). Mr. J. T. Wren of the Panel staff was responsible for the meeting arrangements. These proceedings were assembled and edited by Loyal G. Goff, Technical Assistant, Panel on Underwater Swimmers, and represent a contribution by almost everyone who attended the symposium and by the organizations which were represented. The members of the group express their appreciation to the staff of the Committee on Undersea Warfare for copy editing, production, and distribution of the final report.

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1.1 GENERAL WELCOME

C. J. Lambertsen
School of Medicine
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The Panel on Underwater Swimmers and the Physiology Branch of the Office of Naval Research welcome you to the first Symposium on Underwater Physiology. We had hoped to have Dr. Eugene DuBois present to act as chairman for the Symposium. Unfortunately he became ill and will not be able to attend. We shall all miss having the advantage of his many years of association with submarine problems and his interest in the growth of self-contained diving.

In the total effort of the Panel in the rapidly expanding military field of individual underwater operations, it is necessary to seek technical advances in underwater communication, navigation, ordnance, hydrodynamics, and photography, as well as in personnel selection and other specialized areas. The usual limiting factor, man himself, has for a considerable time presented the greatest obstacle to a major breakthrough in underwater potential. Several physiological barriers exist for man underwater. The most important of these will be discussed today. It is a significant fact to keep in mind at the outset that not one of these barriers has as yet been overcome.

Because now, as with the development of aircraft, it is easily possible to build mechanical equipment with a diving potential greater than that of its user, greatly increased attention must be given to the human aspects of diving. This is particularly true for self-contained diving and underwater swimming, where the diver carries his own supply of respiratory gases, serves as his own tender, and often is without connection to the surface.

We are fortunate in having Captain O. D. Yarbrough here to do the almost impossible job of summarizing in twenty minutes the important physiological barriers in diving. Captain Yarbrough is well known as a senior submarine medical officer, as an investigator in the field of diving physiology, and as one of the most articulate submariners who has ever schnorkeled his way through a symposium.

1.2 OUTLINE OF MAJOR PROBLEMS OF UNDERWATER SWIMMING AND SELF-CONTAINED DIVING

O. D. Yarbrough
Captain, Medical Corps, USN
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I am most appreciative of this opportunity to address so distinguished a conclave wherein has been assembled a hard corps cadre representing the sum total of scientific and practical knowledge, at least within these continental confines, with regard to individual underwater activity.

By way of introduction I should state that the title of this presentation according to the agenda is "An Outline of the Major Problems of Underwater Swimming and Self-Contained Diving". It is obvious that in the twenty minutes allotted such a presentation is beset with the difficulty of providing sufficient information for orientation and yet of not usurping the prerogatives of subsequent speakers.

Man's proclivity to invade those areas of environment for which he is physiologically ill adapted is well documented by the historical accounts of man's constant attempts through the centuries to penetrate, survive, and perform useful functions beneath the surface of the seas. The extensive and exhaustive efforts of the operational and scientific developmental echelons of those seeking to advance human ability to reside constructively under water have, as the diving archives reveal, gradually evolved a science that for the want of better nomenclature has become known as submarine medicine. It is evident that this title is somewhat misleading. It connotes to the uninformed a science that treats of the medical aspects of residence in submarines. Underwater medicine would perhaps be more explicit, in that the true implication of encompassing the medical aspects of all human underwater activity is revealed.

All individual underwater activity can be divided, with some reservations, into two categories, namely, deep-sea diving and shallow-water diving. The former category, deep-sea diving, is usually defined as that type of underwater operation that exceeds 100 feet in depth, performed in more or less open sea remote from land by means of the conventional deep-sea diving equipment. In contrast, shallow-water diving is a rather comprehensive category embracing many forms of individual underwater activity, such as skin diving, submarine escape, underwater demolition team activities, underwater swimming, mine detection and demolition, beach reconnaissance, individual aspects of miniature submersible craft operation, and so forth. Shallow-water diving may be defined as that type of individual underwater operation that usually does not exceed 100 feet in depth and is performed in water relatively adjacent to land, such as streams, rivers, bays, inlets, harbors, and so forth, and employs self-contained apparatus of some variety, of which there are many.

In the category of shallow-water diving the activities of underwater swimmers, whatever their function, have now become a greatly expanded field of offensive operations with considerable wartime potential against targets afloat and ashore. This phase of human underwater activity is to be the major topic of dis-

cussion during this symposium.

As a result of the exploitations of human underwater swimmers in groups, there has developed an extensive nomenclature; as examples the following names which are all somewhat synonymous are encountered in the historical accounts: underwater demolition teams, limpeteers, mine clearance and demolition teams, charioteers, frogmen, beach reconnaissance teams, underwater raiders, submarine assault teams, boom clearance parties, human torpedoes, X-craft crews, and more recently, underwater swimmers.

The history of World War II reveals that the U. S. Navy made a relatively small and isolated effort toward development and attainment of any substantial stature in the underwater swimmers' form of warfare. This seemed to be at least partially the result of opinion that the missions of underwater demolition teams were somewhat suicidal in nature and therefore were not endorsed or condoned in the U. S. warfare philosophy. European nations, on the contrary, devised and developed attacks by underwater swimmers to a considerable degree of perfection and attained a rather surprising amount of success. It is estimated that approximately 150,000 tons of allied shipping were destroyed by limpeteers and underwater demolition teams. Several Mediterranean harbors were the scene of the most signal success by swimmers. In fact, this method of attack rendered these harbors almost untenable by allied shipping and was a source of distress and alarm to the British as well as the Americans, calling for novel and unusual retaliative measures. The persistence of the underwater swimmers' attacks dictated that whenever a ship came to anchor in the allied Mediterranean ports, a watch system be imposed wherein divers traversed the keels of anchored ships on an hourly schedule to remove and dispose of the limpets or other explosive ordnance charges installed by the underwater swimmers. These wartime activities of the underwater demolition teams have engendered a few narratives, some of which were verified, others were not. Of the unverified variety the speculated veracity status renders them no less amusing. One such incident relates that a diver while making the routine Mediterranean anchorage night patrol of a ship's bottom encountered an enemy limpeteer attaching his charges. The ensuing struggle was perhaps the prime incidence of individual wartime combat underwater and thereby established a precedent for warfare in a new environment. The diver in this incident dispatched his adversary by ingeniously employing his only weapon, the diving knife, and placed this episode in the verified variety by producing the corpus delicti upon his ascent.

Europeans were not only operationally successful in this form of warfare, but were especially proficient in design and development of apparatus. However, emotional inaptitude resulted in failure of at least two UDT missions as is exemplified by the following incidents. A swimmer having successfully reached his target and attached his charge was, while reflecting on the sad fate of the personnel of his target, emotionally overwhelmed to the extent that he surfaced and boarded the ship, gave the alarm by ringing the ship's bell in time to prevent the explosion, and was happily interned as a prisoner of war. On another occasion, a swimmer had reached his target, but attaching his limpets required working near barnacle-covered piling which eventually lacerated his suit. Fearing doom by cold or drowning, he surfaced and surrendered without damage to the target ship.

I invite your attention to the fact that thus far this presentation has displayed little in support of the originally announced title to elicit the major problems of underwater swimmers. Please bear with me while I attempt to create a setting of the announced preliminary goal by making a few statements that at first blush might not appear pertinent.

It requires no great intellect to discern that the Armed Forces in all their peacetime activities point their research and development training and planning toward attaining a proficiency and readiness for war. John Paul Jones is credited with an utterance that seems as apropos as it is ungrammatical with its split infinitive, "In times of peace it is necessary to prepare and to always be prepared for war".

In view of this preamble let us now examine the major problems of underwater swimmers as influenced by war-readiness consideration.

I would propose that the prime problem of underwater swimmers today is countermeasures initiated and imposed by the enemy. It may surprise many among you that anyone would contend that enemy action composes the major problem of underwater swimmers. Since I have embarked on the issue of enemy action as a threat to underwater swimmers, it seems pertinent to mention that the element of detection, such as sonic signature, bubbles produced by apparatus leaks, and the need for silence and concealment, usually necessitating night operations, all pose underwater swimmer problems. Obviously, this problem is more physical than physiological. It is perhaps erroneous to place it at the top of the list and it is only so placed in this dissertation to emphasize its importance or to prevent minimization of its import. Anyone who has witnessed the extraordinary effectiveness of detonated submerged charges on the human body underwater needs no edification from this source to the effect that countermeasures currently are in need of improvement. To date our armamentarium contains little or nothing to provide a measure of protection in this particular vulnerability of the underwater swimmer. Personally, the only method of protection I have ever heard mentioned is for the swimmer, in the presence of underwater attack, to extrude as much of his body as possible from the water. Such surfacing is tantamount to failure of the mission and surrender. It is hoped that studies currently in progress at the Mine Countermeasures Station, Panama City, Florida, will furnish basic information concerning underwater blast that will point the way to providing some swimmer blast protection.

Oxygen toxicity demands a prominent position on the list of underwater swimmers' problems. Consideration of this entity, however, reveals that its implications are so intimately associated with the consideration of compressed air illness, it is probably prudent to discuss the two conditions simultaneously. These rather entrancing interrelationships are well exemplified by a narrative of British experiences during the late war. German mine-laying activities had drastically restricted shipping within the coastal waters surrounding the British isles to an extent that threatened survival of water traffic and overwhelmed the capabilities of conventional deep-sea diving to cope with these enemy activities. Utilization of shallow-water divers, with air as the breathing medium (from multiple small tender craft) dictated the need for portable compressors, air banks, hose, and other apparatus, much on a par with deep-sea diving. Further, since the area to

be searched for mines was considerable and the time factor critical, it was necessary to surface and submerge the divers frequently as the area amenable to search on a single sortie was of diminutive radius. This type of diving operation with frequent traversing of the depth in each direction was soon doomed by an unacceptable incidence of decompression sickness, even after the single-sortie radius was enlarged by resort to self-contained apparatus. Failure of the missions due to bends led to the adoption of oxygen as a breathing medium, despite the meager knowledge existent at that time regarding such utilization. Initial success and optimism soon faded when the specter of oxygen poisoning disabled the diver as a result of nausea or muscle spasms, or else this led to complete inactivation or loss of the diver with or without subsequent recovery of the bodies as a result of convulsions. Thus, on the one hand, we are confronted with the dilemma of bubble formation and its sequelae and the dramatic oxygen seizures on the other. Many students of the physiological aspects of diving contend that somewhere in the realm of gas mixtures as breathing media there is a happy and useful mean with a minimum of oxygen toxicity and bends incidence. Some success has been attained in this direction. However, full realization has not been attained and requires further exploration. Considerable investigative effort in this field is currently in progress. It is purposeless to dwell on the disabling, if not lethal, results of compressed-air illness before such a group as this. Oxygen convulsive seizures are dramatic, alarming, as well as disabling, but appear to have no eventual detrimental effects except to create in the victim a fear of future attacks.

Since there is factual evidence that cold affects compressed-air illness incidence, and I personally am convinced that cold through internal shunting of the blood stream affects oxygen tolerance under pressure, we must include temperature in the items that plague the underwater swimmer. This implication of the temperature effect on oxygen toxicity is aside and apart from the limitation of endurance by virtue of cold tolerance on human activities.

I fully realize that so far I have spoken of only a few of the main underwater swimmer problems, and time will not permit any further extensive treatment. However, in the interest of completeness, I shall portray very briefly the problem areas in regard to individual underwater activities, with a career cycle to highlight the problems.

The personnel selective procedure whereby a candidate acquires underwater swimmer status demands foremost the absence of physical defects or potential defects and the candidate must pre-eminently possess a stable psyche and phlegmatic personality. The possession of a temperament free of alarmist characteristics is essential. Ideally perhaps a personality bordering on a vegetative status might be the superlative.

In some quarters there is thought that a background of a thoroughly trained and experienced deep-sea and shallow-water diver is a prerequisite. At least the basic training period attempts to attain this status. A thorough knowledge and familiarity with all types of diving apparatus is sought. Those who have gadgeteer tendencies in this respect seem to possess the innate apparatus curiosity that connotes subsequent success. Once these preliminary hurdles are cleared, the swimmer obtains operational status by team and beach group assignment for his post-graduate training.