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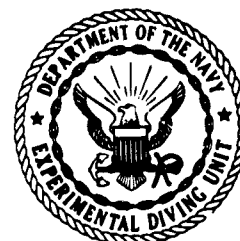
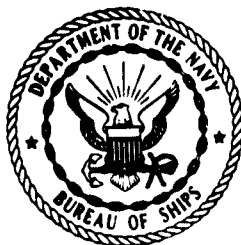
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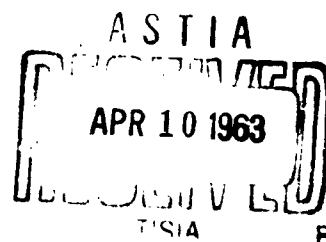
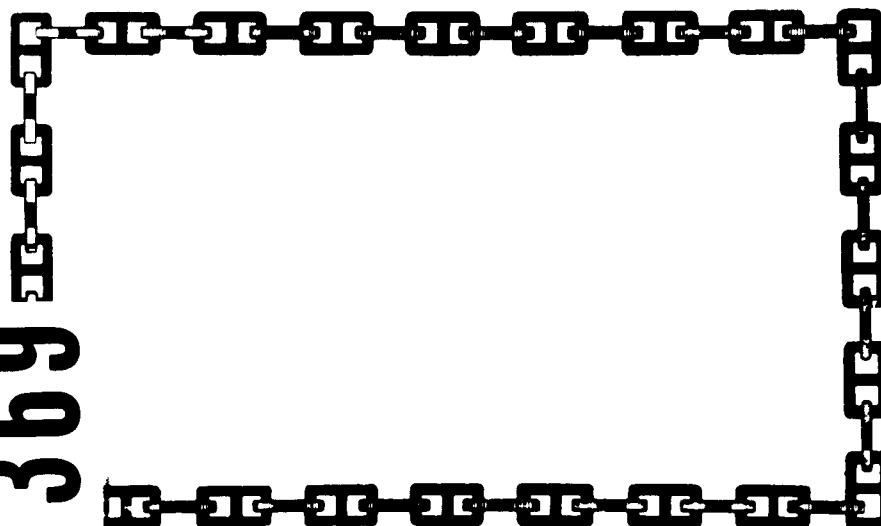
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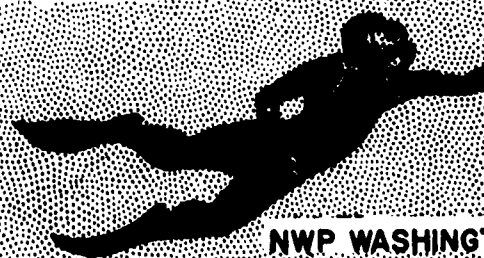
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U. S. NAVY
EXPERIMENTAL DIVING UNIT



NWP WASHINGTON 25, DC

U. S. NAVY EXPERIMENTAL DIVING UNIT
U. S. NAVAL STATION
(WASHINGTON NAVY YARD ANNEX)
WASHINGTON 25, D. C.

RESEARCH REPORT 5-61

A STUDY OF SWIMMER MOUTHPIECES

PROJECT NS 186-202 SUBTASK 1, TEST 5

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14 February 1963

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ABSTRACT AND SUMMARY

A prototype SCUBA- mouthpiece was developed through a joint project between the U. S. Navy Experimental Diving Unit, Washington 25, D. C. and the U. S. Naval Dental School, Bethesda 14, Maryland. The mouthpiece was designed to reflect the normal anatomical and physiologic relationships of the mouth, thus allowing a relaxed bite while providing for adequate gas flow required for pulmonary ventilation.

A full alveolar mold was prepared from a selected "average" individual. The mold was prepared using standard dental techniques and from this mold a test model mouthpiece was designed. The model was tested at the U. S. Navy Experimental Diving Unit and in field use. Many of the design features were found to be an improvement over the presently used SCUBA mouthpiece.

It is recommended that the design be incorporated into a new model standard SCUBA mouthpiece for use by the U. S. Navy.

ADMINISTRATIVE INFORMATION

Ref: (a) EDU Conference LT Linaweaver, (MC), USN; CAPT H. J. TOWLE, (DC), USN, March 1959

(b) BUSHIPS-EDU Conference, April 1959

This project was established by references (a) and (b) and was initiated on 15 April 1959.

VAIL, J. R., HMCA(DV), USN was designated as project engineer and LT Paul G. LINAWEAVER, Jr., (MC), USN as medical project officer.

The dental impressions, preparations of the mold, and fabrication of the prototype mouthpieces were performed at the U. S. Naval Dental School, Bethesda 14, Maryland, under the supervision of Captain Herbert J. TOWLE, (DC), USN.

The estimated manpower expended for this project was:

<u>DESCRIPTION</u>	<u>MANHOURS</u>
Fabrication of Mouthpiece	80
Testing	40
Photography and Drafting	25
Report Preparation	80
TOTAL	225

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1. INTRODUCTION

1.1 Background

1.1.1 The United States Navy, through the Bureau of Ships, has previously developed diving equipment, particularly the self-contained types to meet operational requirements in the fields of underwater demolition and explosive ordnance disposal.

1.1.2 Considerable research has gone into the engineering aspects of SCUBA equipment, i.e. pressure reducing valves, regulators and carbon dioxide removal equipment. Similarly, investigation of the physiological aspects of breathing resistance, respirable gas mixtures, oxygen toxicity, carbon dioxide effects, and decompression sickness associated with the operational use of this equipment has been carried out. The information obtained from these diverse areas of study has culminated in equipment which is both efficient and safe when properly used.

1.1.3 The human engineering aspects of equipment design has lagged behind that of the mechanical engineering with a few exceptions. Vests and holding straps can be readily modified to fit various anatomical differences. Face mask manufacturers and designers have used statistically determined "percentile faces and heads."

1.1.4 However, the design of mouthpieces has not allowed for adjustability or anatomical variability consideration. Hardness, flexibility, dimensions, and shapes vary with each manufacturer. It is apparent from the mouthpieces that have been produced that the basic anatomical characteristics of the human mouth have been largely over-looked. The presently used mouthbits produce trauma to the gums and frenum, and create fatigue in the muscles of mastication. This fatigue can reflexly create tension and more fatigue in other muscle groups in the head and neck. The result is a mouth trauma susceptible to secondary infection, fatigue, and a dissatisfied diver. This dissatisfaction may produce prejudice against an entire piece of breathing equipment.

1.1.5 It was deemed advisable to investigate the possibility of designing a mouthpiece which was based on measured anatomical dimensions and shapes and which would enable a diver to perform for hours with minimal fatigue and trauma.

1.1.6 To aid the Experimental Diving Unit in this endeavor, Captain Herbert J. TOWLE, Jr., (DC), USN of the U. S. Naval Dental School, National Naval Medical Center, Bethesda 14, Maryland was consulted regarding the problem of oral anatomy and physiology. In May 1959, at a conference at the Experimental Diving Unit, CAPT TOWLE agreed to make mouth impressions of an average subject, and to fabricate and submit several mouthpieces for a contrast evaluation with a mouthpiece of standard accepted design.

1.2 Objective

1.2.1 The objective of this study was to investigate the feasibility of applying measurable anatomical and physiological parameters to the design of a SCUBA mouthpiece which would be optimally suited for the majority of users. A mouthpiece was to be made from a mold obtained from the impression of an average diver's mouth by standard dental techniques, and to compare such a mouthpiece with other commercial mouthpieces for fit, comfort, and desirability for use on standard SCUBA.

1.2.2 The scope of this present study was limited to the development of a prototype mouthpiece for comparison with standard available mouthpieces.

1.3 Specific Criticism of Present Mouthpieces

1.3.1 Examination of a standard mouthpiece revealed that the biting or gripping surface presented two distinct faults:

(1) It was deficient in total bite area. This caused excessive biting pressure upon a limited number of teeth.

(2) It was too thick in its vertical dimension which undoubtedly diminished normal free-way space of the average person (Figure 1).

1.3.2 The free-way space is defined as "the distance between the occluding surfaces of the maxillary and mandibular teeth when the mandible is in its physiologic rest position." It is a fundamental concept of oral physiology that when the free-way space is violated over protracted periods of time, degenerative changes of the oral structures will occur. Hence, when the mouthpiece is worn during long periods, the divers are subjected to undue hours of discomfort manifested by pain in the temporomandibular joint and aching of the muscles of the face.

1.3.3 Further examination of the mouthpiece showed that the outer flanges which projected into the maxillary and mandibular mucco-buccal folds were formed in such a manner that they did not conform to the general anatomy of these areas. Hence, by causing undue pressures in these respective folds, they were an additional source of irritation to the divers, especially in the region of the frenum.

2. PROCEDURE

2.1 Design Concept

Upon the basis of the above appraisal of the old mouthpiece, personnel of the Naval Dental School set about in planning a new one. The new mouthpiece was designed in such a manner that the concepts of oral physiology were considered, as well as the anatomic structures of the oral cavity.

2.2 Construction

Specifically, the new mouthpiece embodied a biting surface which was considerably thinner and covered a much broader area (figure 2) than the original

mouthpiece. The biting surfaces were designed so that the inner flange was set further inward on the mandibular surface than on the maxillary, thus conforming to the normal occlusal anatomy. The biting surface being much thinner than the previous one, the general limit of the free-way space was not violated. This may be noted by the slight separation of the molar teeth (figure 3). Since it covered a much broader area, the pressures exerted by the diver in holding the mouthpiece in position were distributed to many teeth or over a much broader area. Hence, the forces of gripping were not concentrated to a few teeth as with the previous mouthpiece.

2.3 Flange Design

The outer flanges of the new mouthpiece were designed so as to conform to the general anatomy of this area (figures 4 & 5). As such, the entire flange, both maxillary and mandibular, had an inward slope from the area of the occlusal plane. Due consideration was also given to the maxillary and mandibular frenula.

2.4 Prototype Mouthpieces

Several prototype mouthpieces embodying all of the principles described (figure 6) were made at the U. S. Naval Dental School. They were delivered to the U. S. Navy Experimental Diving Unit where they were used on a limited basis.

2.5 Material Testing

Durometer readings were obtained on several of the standard mouthpieces of different manufacturers. It was intended to have several "hardness" types of mouthpieces commercially fabricated embodying the important features of the Naval Dental School prototype mouthpiece.

2.6 Final Design and Manufacture

The Dental School mouthpieces were taken to the Bureau of Ships for drafting purposes. Drawings were submitted for development bids on several mouthpieces of varying durometer readings. A contract was subsequently issued to Scott Aviation Corporation. The first model mouthpieces were delivered to the Experimental Diving Unit for test and evaluation.

3. TESTING

Testing of the Dental School prototype and Scott Aviation models consisted primarily of swimming the mouthpiece on standard SCUBA and obtaining comments on each from subject users. Observation by a physician was made of the condition of the subjects' mouths to determine the presence of irritation and/or excessive fatigue of head and neck muscles. Several mouthbits were sent to Underwater Demolition Team TWENTY-ONE and the U. S. Naval School, Underwater Swimmers for their impressions regarding comfort and suitability for use with SCUBA.

4. RESULTS

4.1 Results of Swims with Dental School Prototype

4.1.1 The following are comments by six diver's using the mouthpiece of two degrees of firmness. This was made in comparison with a mouthpiece of commercial design.

Comments:

R.J.A.: Likes feel of new mouthpiece, preferred the firmer of the two. The soft one seeps water and is difficult to keep in mouth. When using the commercial mouthpiece complains of soreness in masseter muscles.

J.H.: Much prefers the "new mouthpiece" in the medium firmness. Was unable to perform a sustained swim with the soft one; gave up after about 15 minutes. Does not care for the commercial mouthpiece. States it comes out of mouth too easy, is too hard and made gums sore around frenula (mild irritation visible).

J.R.V.: Finds the new mouthpiece comfortable but too flimsy in both models, the soft requiring far too much effort to keep in mouth while swimming. The commercial mouthpiece fits well but makes masseter muscle tired after sustained swim. The top is built up too much and irritates gum.

R.J.C.: Has no complaints with the commercial mouthpiece. Finds the new mouthpiece comfortable, but too flimsy in soft model. The medium firmness was good but had trouble after taking it out of his mouth. He finds it difficult to replace in his mouth because it was too wide.

H.A.B.: Had no complaints with the commercial mouthpiece. Does not care for the new model because it is not firm enough. Finds the fit comfortable.

C.W.S.: Finds the commercial mouthpiece comfortable to hold in mouth, but masseter muscles became sore after sustained swim. Thinks the new mouthpiece is very comfortable, but far too flimsy in soft model. The medium firmness is satisfactory.

4.1.2 Comments from some of the field units reveal dissatisfaction with all the mouthpieces submitted (Appendices A & B). Comments submitted in Appendix B were somewhat more favorable.

4.2 Durometer Measurements

4.2.1 The results of the durometer measurements of standard mouthpieces performed at the Naval Weapons Plant were:

(1) Standard Navy Mouthpiece

Durometer hardness "A"

Inside center ends 56, 57, 56, 58
 center 57, 56, 55, 58
Two wedges top 63, 64, 63, 63
 flares 57, 56, 57, 57
Outside ends opposite wedges 60, 60, 59, 61
Front lip center 49, 50, 49, 51
 ends 51, 52, 52, 53

(2) Commercial Mouthpiece

Durometer hardness "A"

Inside center ends 58, 57, 58, 57
 center 59, 60, 62, 61
Two wedges top 55, 54, 55, 55
 flare 49, 51, 50, 51
Outside ends opposite wedges 56, 55, 56, 56
Round tube surface 47, 48, 46, 47
Ends Connections 49, 49, 51, 50

4.3 Evaluation of Comments and Recommendations

It was felt that the Scott Aviation production model should be modified to produce more stability, but yet retain the anatomically sound features. Therefore, in an Experimental Diving Unit - Bureau of Ships conference it was agreed to modify the existing configuration as follows:

- (1) Increase thickness of the airway portion of the mouthpiece.
- (2) Decrease the cleft for the frenum by increasing the distance between the airway and the extreme margins by 3/8 of an inch.
- (3) Modify the gripping portion by anterior wedging of the gripping surface and by modifying the inner margin of the gripping tab. (Appendix C shows the configuration of the mouthpiece as modified.)
- (4) A compromise must be made regarding the thickness of the gripping tab. The space between the teeth must be increased in order to allow breathing during swimming and still permit firm gripping.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Modifications

The mouthpiece produced by the joint effort between the U. S. Naval Dental School and the U. S. Navy Experimental Diving Unit overcomes some of the objections to the present standard mouthpiece but needs modification to:

- (1) produce greater stability
- (2) reduce leakage
- (3) assure acceptance among the operational forces

5.2 Recommendation

It is recommended that the design principles developed in this project be incorporated into a new mouthpiece for standard U. S. Navy use.

APPENDIX A

COPY/COPY

UDU-2/RLS:wn
3900
Serial: 72
Nov 9 1960

From: Commander Underwater Demolition Unit TWO
To: Chief, Bureau of Ships (Code 638C)

Subj: Mouthpiece for Underwater Breathing Apparatus

Ref: (a) BUSHIPS ltr ser 638C-1417 of 21 Oct 60

1. Comments on three experimental mouthpieces for the Mk V mixed gas unit are herewith submitted in accordance with reference (a).

2. The three mouthpieces were found unsatisfactory in design and material.

a. Design. The mouthpiece is much too small to give adequate coverage between the lips and the teeth of the swimmer. Hence water enters the mouth.

b. Material. The rubber in the mouthpieces is too soft in all three instances. The pressure created by the swimmer's forward motion stretched all of the mouthpieces away from the swimmer's mouth allowing water to enter.

3. It is recommended that the original design of the Mk V mouthpiece be retained, but that a more pliable rubber be used. With the original design a rubber as pliable as the hardest of the experimental mouthpieces might be used to increase comfort while retaining satisfactory function.

R. L. SUTER
By direction

APPENDIX A

APPENDIX B

COPY/COPY

**5010-163-59
14 August 1959**

SPEEDLETTER

**From: Commanding Officer, U. S. Naval School, Underwater Swimmers,
U. S. Naval Station, Key West, Florida
To: Officer in Charge, U. S. Navy Experimental Diving Unit, U. S.
Naval Gun Factory, Washington 25, D. C.**

**OIC EDU LTR 9940 SER 143-59 OF 8 MAY 59 REFERS X EACH MOUTHBIT WAS USED BY
DIFFERENT STUDENTS FOR THE ENTIRE CLASS X ALL 12 MEN AGREED THE TWO NOTCH**

**WAS BETTER X NO MOUTH DISCOMFORT WAS ENCOUNTERED BY EITHER TYPE X IMPROVE-
MENT RECOMMENDED IS FEATHERING THE EDGES OF ALL FOUR CORNERS SLIGHTLY SO
THAT**

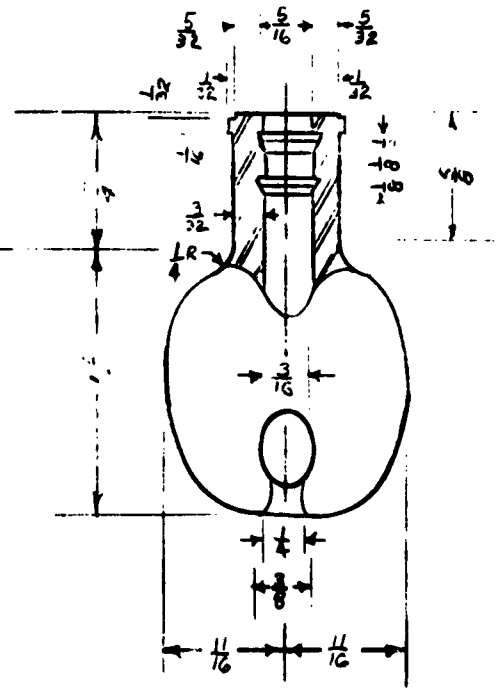
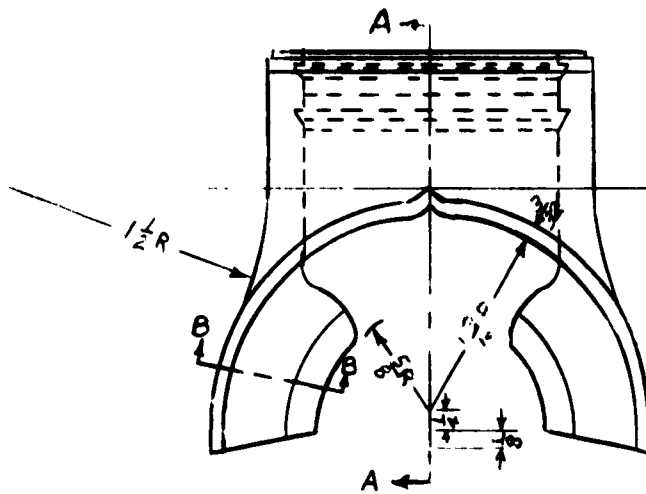
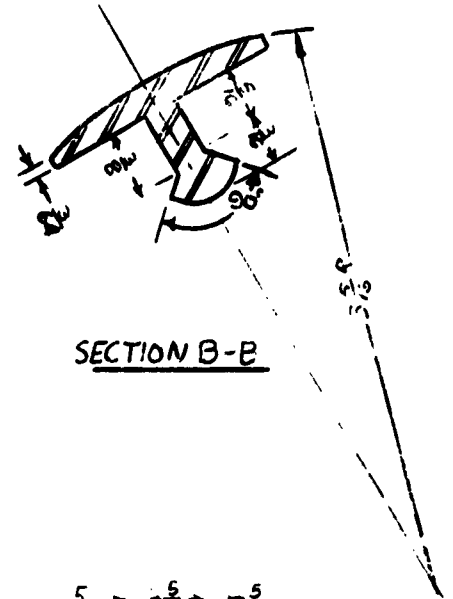
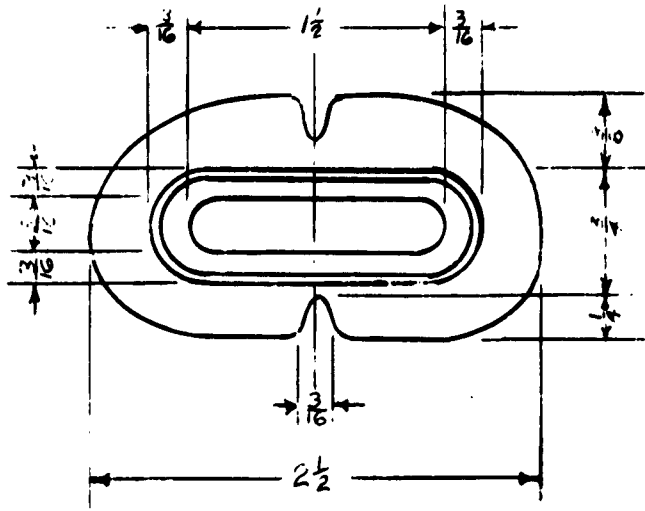
MOUTHPIECE WILL NOT CUT INTO GUMS X

**/s/J. J. LILIENFIELD
By direction**

**Copy to:
BUSHIPS (Code 638)
Medical Research Lab., NLondon Conn.**

APPENDIX B

APPENDIX C



SECTION A-A

MOUTHPIECE



FIGURE 1



FIGURE 2

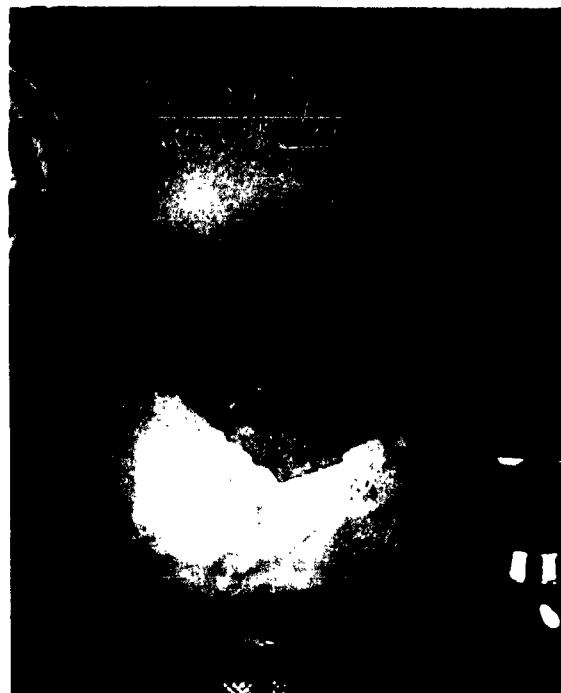


FIGURE 3

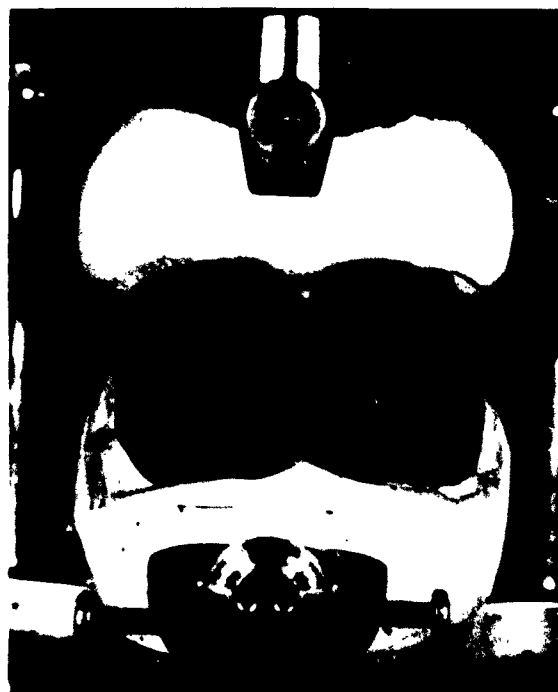


FIGURE 4



FIGURE 5



FIGURE 6