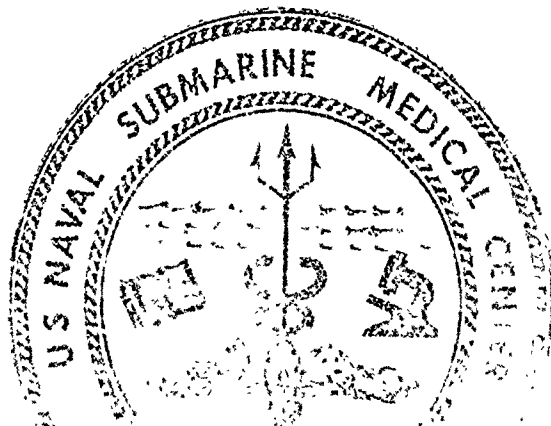


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U. S. NAVAL SUBMARINE MEDICAL CENTER

Submarine Base, Groton, Conn.

REPORT NUMBER 695

DESIGN CONSIDERATIONS FOR A MICROPHONE-EQUIPPED MOUTHPIECE
FOR NAVY DIVER COMMUNICATION

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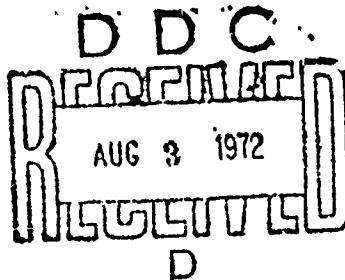
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Bureau of Medicine and Surgery, Navy Department
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13. ABSTRACT <p>This paper presents design considerations of a microphone-equipped breathing mouthpiece for enhanced underwater swimmer communications. Toward this objective, emphasis was placed upon providing increased freedom for articulatory movement as well as a larger "speaking" cavity for less restriction to the speech flow while maintaining protection from the dangers of CO₂ build-up in the breathing mixture.</p>			

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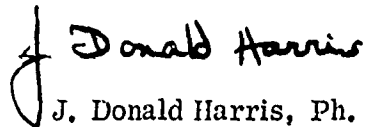
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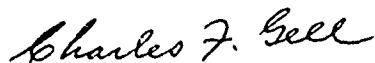
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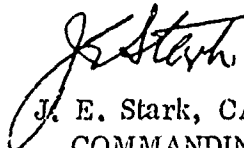
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SUMMARY PAGE

THE PROBLEM

A safe microphone-equipped breathing mouthpiece is essential for effective verbal communication under water. The conventional safe swimmer mouthpiece is unsuitable for speech production because of its restraints to articulatory movement and the restricted volume of air into which the speech is radiated.

FINDINGS

This paper describes a communication mouthpiece, the design of which provides full consideration of the mechanics and mechanisms of speech production and eliminates inherent deficiencies found in conventional models. Crucial to the design is the inclusion of a self-equalizing flexible diaphragm which reduces the residual volume of dead air in the breathing manifold by separating it from the rest of the mouthpiece. This then permits a larger extra-buccal space for improved speech production while minimizing the dangers of CO₂ build-up in the breathing mixture.

APPLICATION

Design considerations presented are of value to speech communications systems designers, manufacturers of diver/swimmer equipment, and engineers interested in the mechanisms of speech production including factors critical to intelligible speech production in confined cavities.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MF12,524,004-9010DA5G -- Auditory Performance in Underwater Environments and was approved for publication on 14 January 1972. It is number 16 on this work unit and designated as Naval Submarine Medical Research Laboratory Report Number 695.

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ABSTRACT

There exists a basic need for a safe microphone equipped breathing mouthpiece for effective verbal communications under water. The conventional swimmer mouthpiece is unsuitable for speech production because of its restraints to articulatory movement and the restricted volume of air into which the speech is radiated. This paper describes a mouthpiece designed to best meet requirements for increased freedom for articulatory movement within a larger "breathing" cavity while maintaining protection from the dangers of CO₂ build-up in the breathing mixture.

DESIGN CONSIDERATIONS FOR A MICROPHONE-EQUIPPED MOUTHPIECE FOR NAVY DIVER COMMUNICATION

INTRODUCTION

The need for effective verbal communication underwater becomes even more acute during prolonged operations in underwater environments. Essential to fulfilling this need is the development of a safe microphone-equipped breathing mouthpiece.

In normal speech production, a flow of air from the lungs, in some instances set into vibration by the laryngeal mechanism, is modified and restricted by articulatory movements in the mouth (buccal cavity). In order that resultant pressure pulsations which carry the acoustic speech signal be transmitted without distortion into the air, an infinite and unrestricted volume of air should exist outside the buccal cavity so that the vibrating articulated flow of air from the lungs can be freely expelled. Under normal speaking conditions, the surrounding atmosphere, which is for all practical purposes an infinite medium of air, serves as the extra-buccal cavity, and the breath flow of speech is radiated from man's head into the medium with ease. In the diver/swimmer situation, on the other hand, a conventional mouthpiece is attached to an air hose which serves as the extra-buccal cavity. During the act of speaking, the very small volume of this air hose interferes with normal patterns of the outflow of breath from the source to the medium, in this case from the diver to the cavity within the air hose. In fact, for this very small cavity into which a diver speaks there

is a noticeable distortion imparted to speech. For example, in the diver situation, the expelled flow of modulated air ultimately may be passed from the divers' breathing apparatus into the water and consequently there will be a much greater resistance to outflow of breath than is normal. The pulsations of pressure which contain acoustic vibrations of speech are superimposed on the outgoing breath. These pulsations become distorted when entering a cavity which is not infinite in size. In order to minimize such distortions, a larger extra-buccal cavity than the air hose is helpful. The greater the volume of this cavity, the more it acts like a cushion, not only for pressure pulsations in the normal spoken breath, but also for the random back-pressure changes caused by bubbles of gas being emitted into the water. This is an important factor when one considers distortions to the normal flow of speech which are caused by relatively high back-pressure peaks. In other words, the larger the cavity, the smaller are the unwanted changes of pressure variations in the breath flow which carries the acoustic vibrations of speech.

A basic problem inherent in speech production using a conventional breathing mouthpiece is its effect upon labial sounds (p, b, m) due to its restrictive position between the teeth and against the lips. For proper intelligibility, a breathing apparatus designed for speech production must allow free movement of the lips and mouth while maintaining a water-proof seal against the face.

Since a full face mask is not considered desirable in certain cases, the obvious solution appears to be in the development of a separate breathing cavity within which speech can be effectively produced. Such a cavity must allow the mouth to articulate freely.

A crucial factor in designing any breathing apparatus is the prevention of CO₂ build-up. For this reason, previous efforts in designing a breathing cavity into which a diver can speak have been subject to restrictions imposed by limiting the volume of dead air space around the mouth in which CO₂ accumulates. Since the extra-buccal cavity is filled during exhalation, its volume must be small so that the residual volume of exhaled breath does not over-contaminate the fresh breathing mixture being inhaled. Because of such volumetric limitations intelligibility has necessarily been sacrificed for diver safety.

Figure 1 is a diagram of a proposed face mask capable of meeting the above requirements for good speech better than presently available face masks with full consideration given to protecting the diver from the dangers of CO₂ build-up. Although the mask is equipped with a large extra-buccal cavity (D), undesirable features of such a cavity have been eliminated and free articulation allowed by the inclusion of a thin flexible rubber diaphragm (E). Flexibility of this diaphragm has been increased further by the use of concentric oval convolutions surrounding the lip region, along with annular parallel rings moulded into the vestibule (C) to the intake exhaust manifold (B). A small equalization port in the manifold

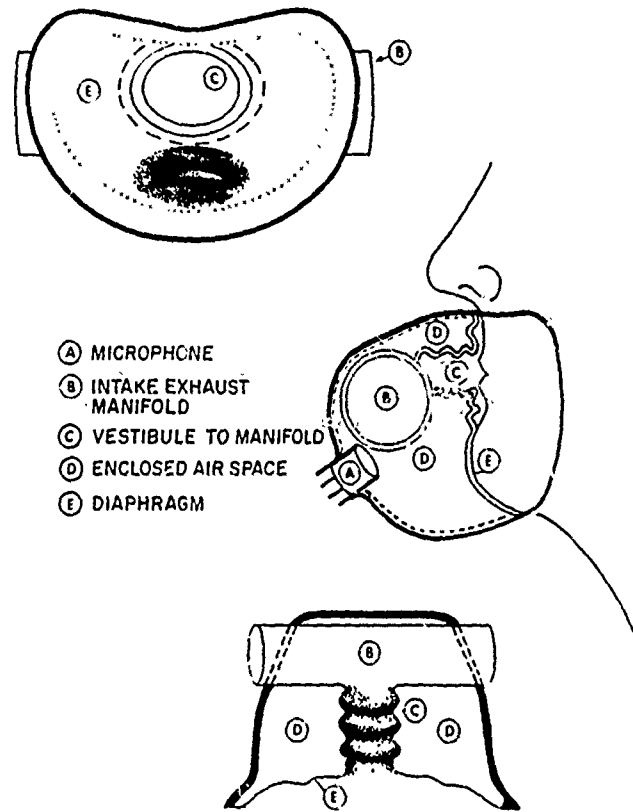


Fig. 1. Proposed microphone-equipped face mask for speech production

located on the intake side keeps the pressure in the extra-buccal cavity equal to the pressure of the breathing mixture. Once the static pressures on either side of the diaphragm are equal, small pressure pulsations which carry the acoustic signal can be transmitted through it. The diaphragm serves to reduce the volume of the breathing cavity while permitting the pressure variations produced in speech to be transmitted into the entire extra-buccal cavity.

Placement of the equalization port in the wall of the intake manifold requires special care to eliminate venturi effects which could occur with the rapid flow of air through the manifold during inhalation. If such effects exist, it may be necessary to raise the port above the level of the manifold wall and angle it slightly in the direction of the air flow. Location of this port on the uppermost point of the tubular intake wall is suggested as a precautionary measure to minimize seepage of the heavier CO₂ into the extra-buccal cavity.*

Microphone placement at (A) within the enclosed air space of the extra-buccal cavity is suggested for ease of manufacture; however, intelligibility may be highest with the microphone suitably waterproofed and located within the intake-exhaust manifold.

Figure 2a shows a collapsed mouthpiece which can be incorporated into the face mask with no change in its basic design. The emergency mouthpiece is stored in a folded position in the vestibule to the manifold, and recessed so as not to interfere with the diver's lip movements. However, under emergency conditions this mouthpiece can be extracted and shared by several divers.

* As an alternate method of cavity equalization, a flapper valve could be installed on the intake manifold wall which would seal the extra-buccal cavity from the breathing mixture during inhalation. A second flapper valve would then of course be necessary on the outside wall of the extra-buccal cavity which would seal on descent but allow the cavity to be equalized to the water pressure during ascent.

Figure 2b shows the mouthpiece in the extended position. Note that the mouthpiece flange is placed between the

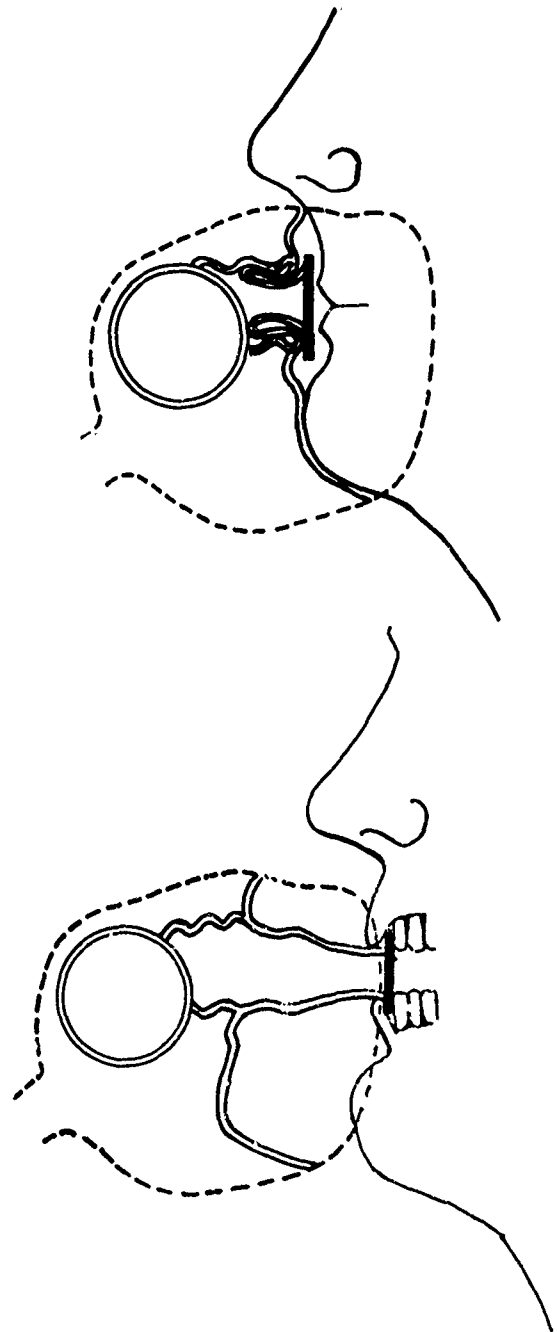


Fig. 2. Schematic representation of a self-contained emergency mouthpiece

lips and teeth in the conventional manner although space restrictions prohibit the inclusion of bits on either side of the mouthpiece opening. Such a mouthpiece, if properly moulded into the mask, should, when folded, follow the contours of the vestibule. A close fit is also essential to holding the folded mouthpiece in place during inhalation.

SUMMARY

Essential for effective verbal communications under water is a safe microphone-equipped breathing mouthpiece. The conventional swimmer mouthpiece is unsuitable for speech

production because of its restraints to articulatory movement and the restricted volume of air into which the speech is radiated. This paper describes the design of a mouthpiece to alleviate these deficiencies by providing freedom for articulatory movement as well as a larger "speaking" cavity for less restriction to the speech flow. The inclusion of a self-equalizing flexible diaphragm to reduce the volume of dead air space permits the necessary larger extra-buccal cavity for improved speech production while maintaining protection from the dangers of CO₂ build-up in the breathing mixture.