29 May, 1944

Dr. A. H. Bulbulian
c/o Institute of Medicine
Mayo Clinic
Rochester, Minnesota

Dear Dr. Bulbulian:

It was a pleasure to talk with you regarding a mask for my underwater respiratory unit. I wish we could have had more time. This letter will probably have to suffice for now.

I am forwarding under separate cover:

One Mask complete with buckles, headstraps, lens and inner sealing flap.

One Mask with inner flap, buckles, enlarged lens.

One valve assembly for Mask.

One sheet of 1/8" Plexiglass.

You will doubtless recall the following points I mentioned as requisites for physiologic underwater respiration using a face mask. They are listed as much as possible in descending order of importance, as you requested.

1. The mask must prevent leakage of water between face and mask. The edge of a non-rigid mask is in effect a one-way valve which effectively seals water out. This action increases with an increase in pressure outside the mask over that of the inside. Almost no difficulty has been experienced with leakage of water in under-water work using any non-rigid inhaler. It is a considerable problem if a rigid mask is used.

2. Mask must prevent loss of oxygen from respiratory circuit. This leakage of gas from beneath mask edge was once the most difficult problem. Use of a rigid mask edge and increased strap tension is a disadvantage and impractical due to dissimilarity of faces and to severe pain during one to two hours under water. The problem has been overcome in several non-rigid masks by the use of a continuous rubber strip cemented to the outer edge of the inner surface of the mask, with the free edge directed inward. This flap thus becomes a one-way valve trapping oxygen within the mask even when the inhaler is partially lifted from the face. In under-water respiration it is necessary to place the lower extremity of the breathing bag at a

level roughly that of the average lung level in order to approximate the physiologic pressure fluctuations within the plural and intrapulmonary spaces. This creates a gas pressure in the breathing bag approximately equal to that of the average pressure on the chest. At any point in the respiratory system the gas is under a pressure equal to the water pressure at the lowermost point of the breathing bag. Gas pressure within the mask is therefore roughly 14 inches of water greater than the water pressure upon the outside of the mask.

The mask inner flap prevents oxygen from escaping in spite of this difference in pressure. To allow for the usual 50% margin of safety, the mask which is found satisfactory is capable of preventing loss of oxygen in spite of a pressure difference of 20 inches of water between inside and outside of the mask. Sudden movements of the head, traction of breathing tubes, and buoyancy of mask all make this added 50% necessary.

3. Mask must be sufficiently reinforced internally to prevent collapse by water pressure when diver is in the inverted or head-down position, in which case the normal pressure relationships of the mask are reversed. (Pressure is now greater outside than inside the inhaler due to reversal of relative positions of mask and breathing bag).

4. Vision must be adequate, especially for upward gaze. A flat lens is essential since a curved lens underwater causes marked distortion of vision, headache, vertigo, nausea, loss of directional sense and loss of sense of distance, due to inability to focus both eyes on a single point.

A non-breakable, preferably Plexiglass, lens is desirable.

Anti-fogging measures must be taken.

5. Dead space should be at a minimum. We discussed a separate oro-nasal compartment within the full-face mask, with communication between it and the mask proper.

6. The desirability of comfort is so obvious it need not be mentioned.

7. Mask must provide for attachment to valve assembly. The opening of the same diameter as that in the samples, and featuring a ridge as in the sample to prevent slipping.

8. An air valve mounted high on the mask, preferably in the midline or right hand side, which when closed prevents entrance of water and which when open permits respiration of atmospheric air without removing the mask, thereby conserving oxygen for under-water use. This valve is available for you in the approximate size that is required.

I hope this information may be of help to you in designing a thoroughbred mask for under-water respiration. I have built enough mongrels to satisfy myself of the requirements. It will be fine if you can combine all of these features into one fine mask.

Please do not hesitate to ask for further details on anything I have neglected to make sufficiently clear. I am looking forward to a better opportunity to discuss this problem with you than we had at our last meeting.

Yours very sincerely,

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