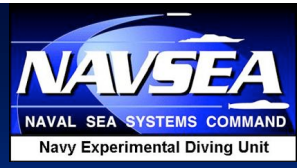

BUOYANCY OF THE MK10 SUBMARINE ESCAPE AND IMMERSION EQUIPMENT (SEIE) SUIT AND SAFE TIME LIMITS FOR REBREATHING FROM THE ENCLOSED HOOD VOLUME

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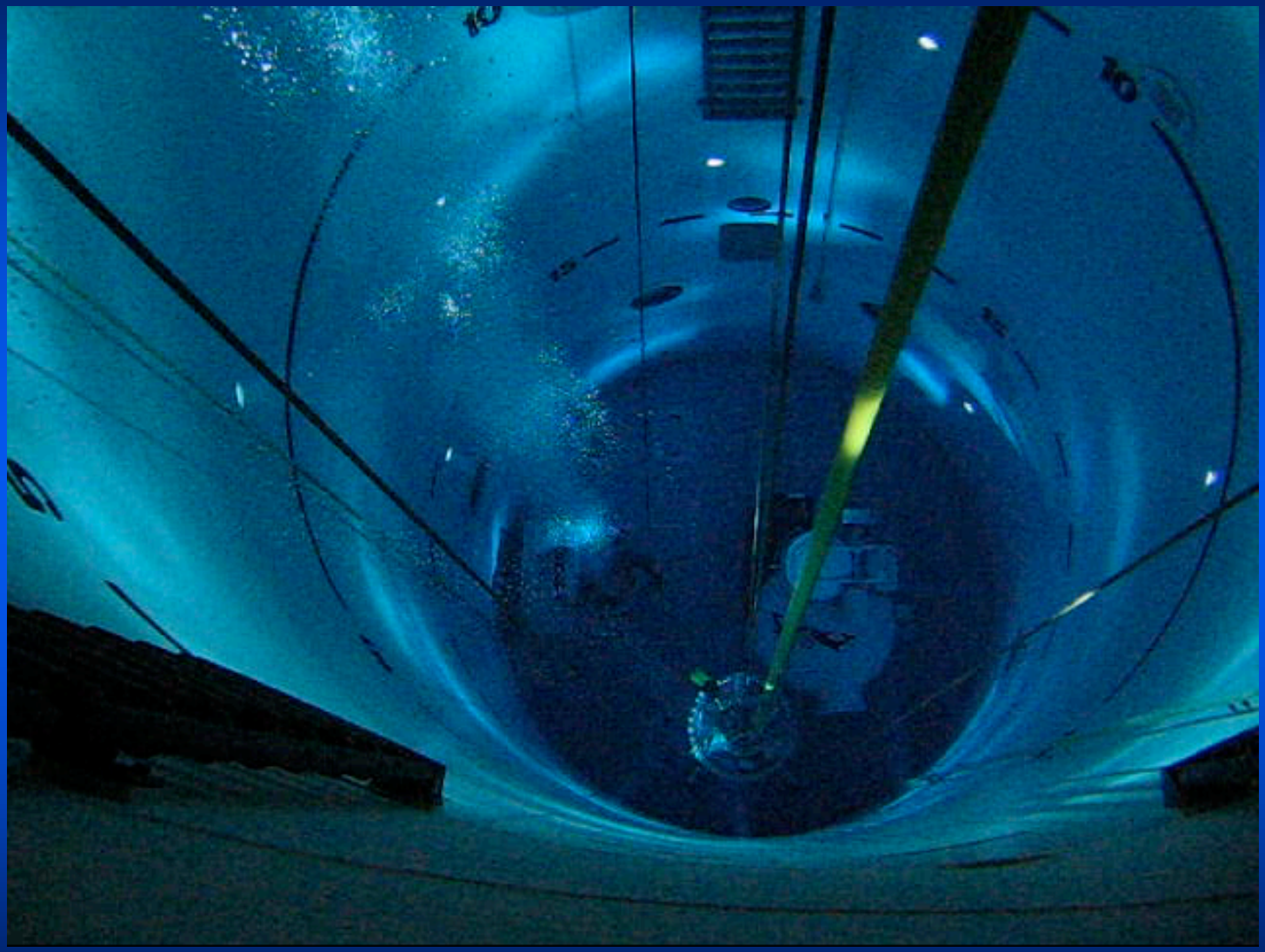
Background

The MK10 SEIE suit is designed to enable free ascent from a stricken submarine. It incorporates an enclosed ascent hood for buoyancy and breathable air during escape.



Submarine escape training with the MK10 SEIE at HMAS Sterling, Australia

Objectives

- Determine the change in concentration of O_2 and CO_2 over time within the ascent hood in resting partially immersed subjects rebreathing from the hood volume at 1 ATA.

- Provide safe time limits for rebreathing from the enclosed volume of the MK 10 SEIE suit hood to avoid incapacitating hypoxia and/or hypercapnia.

- Determine the buoyancy force of the MK10 SEIE suit in completely immersed subjects.

Materials and Methods

Subjects: 11 U.S. Navy trained divers and 1 submariner

Experiment 1: 1 ATA Rebreathing Tests

Conditions

A: While dry and unimmersed
B: Immersed in a water tank with the water level 2 inches above the hood vent.
C: Immersed in a water tank while floating erect.

Termination criteria

10 minutes of rebreathing or
FiO_2 < 13%
$FetCO_2$ > 9%
On subject request

Dependent measures

Inspired and expired O_2 and CO_2,
Minute ventilation

Materials and Methods

Experiment 2: Buoyancy Tests

Conditions

Fully immersed in fresh water tank with
A: Stole and hood fully inflated
B: Stole deflated and hood fully inflated

A pulley system was used to fully submerge the subject. The rope tension in the pulley system was measured using a force transducer attached to a A/D computer data acquisition system.

Buoyancy force was measured as the mean force (kg) over 3 s while the tension in the pulley system was slowly released to overcome friction.

Results for Experiment 1

Condition	Unimmersed A	Immersed B	Immersed C
Time (seconds)	600	**162 ± 29**	**198 ± 47**
PiO_2 (mmHg)	138 ± 4.8	**99 ± 1.3**	**99 ± 0.9**
FiO_2 (%)	18.0± 0.6	**12.9 ± 0.1**	**12.9 ± 0.1**
$PetO_2$ (mmHg)	109 ± 4.5	81 ± 4.3	84 ± 5.7
$FetO_2$ (%)	14.2 ± 0.6	10.6 ± 0.5	11.0 ± 0.7
$PiCO_2$ (mmHg)	19 ± 3.4	41 ± 1.5	42 ± 1.9
$FiCO_2$ (%)	2.4 ± 0.4	5.4 ± 0.2	5.4 ± 0.3
$PetCO_2$ (mmHg)	40 ± 1.5	49.6 ± 2.7	51 ± 2.3
$FetCO_2$ (%)	5.2 ± 0.2	6.4 ± 0.3	6.6 ± 0.3
V_E (l, BTPS)	16.5 ± 5.4	23.8 ± 5.0	26.1 ± 7.3

Table 1: Group statistics (mean ± SD) for the inspired and expired O_2 and CO_2 concentrations and minute ventilation (V_E) measured at the end of each rebreathing trial. (n=12)

Results for Experiment 1

Variable	Water level 2 inches above the hood vent Condition B	Floating erect Condition C
Height	-0.59*	-0.49
Weight	-0.86*	-0.74*
BSA	-0.86*	-0.74*
Body Vol.	-0.85*	-0.74*
BMI	-0.71*	-0.63*

Table 2: Pearson Product moment correlations between the time taken to reach the 13% FiO_2 limit during the immersion trials and selected anthropometric characteristics (n=12).
* $p<0.05$

Results for Experiment 2

Table 3: Buoyancy results for the MK10 SEIE suit. All buoyancy force data are presented in kg.

Condition	Mean ± SD	Min	Max	n	Pearson r with height
Stole+ Hood	36.6 ± 4.2	31.3	43.5	11	-0.64
Hood only	35.7 ± 5.3	27.1	43.4	9	-0.74

Only stature correlated significantly ($p<0.05$) with buoyancy force

CONCLUSIONS

1. Submariners breathing from the enclosed volume of the SEIE suit hood while partially immersed at 1 ATA will reach an FiO_2 of 13% after 2 to 3 minutes of rebreathing.

2. Larger submariners will reach critical hypoxia levels earlier than submariners of smaller body size.

3. During immersion at 1 ATA, rebreathing from the enclosed volume of the SEIE hood should be limited to less than 100 seconds to avoid significant hypoxia symptoms.

4. Submariners are expected to encounter buoyancy forces between 32.2 and 44.7 kg during an escape while wearing a fully inflated MK10 SEIE suit.

5. Submariners of shorter stature will experience the highest buoyancy forces.