# BUOYANCY CHARACTERISTICS OF THE MK10 SUBMARINE ESCAPE AND IMMERSION EQUIPMENT (SEIE) SUIT

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## INTRODUCTION

The MK10 SEIE suit is designed to enable free ascent from a stricken submarine from depths down to 180 meters. The suit, which includes a stole and ascent hood, keeps the escapee dry and protected from cold shock during escape, and provides sufficient lifting force to take the escapee from the submarine to the surface. The MK10 SEIE is being introduced into the U.S Navy submarine fleet and a SEIE training program is being provided to submariners at NAVSUBSCOL, Groton, CT. The first U.S. Navy at sea escape exercise using the SEIE MK 10 was recently successfully conducted from the forward escape trunk of an SSN 688 class submarine at 100 fsw in Alaska in December of 2006. During this escape exercise the escapees commented on the large buoyancy forces that they experienced prior to exiting the escape trunk.

## OBJECTIVES

The aim of the current study was to determine the buoyancy force of the MK10 SEIE suit in completely immersed subjects.

## METHODS

*Subjects*

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

| | |
|---|---|
| Age (mean ± SD): | 37.8 ± 9.9 yrs, |
| Height (H): | 1.77 ± 0.05 m, |
| Weight (W): | 89.9 ± 9.3 kg. |
| Body Surface area (S): | 2.10 ± 0.13 $m^2$ |
| Body volume (V): | 87.2 ± 10.1 liters |
| BMI: | 28.5 ± 2.2 $kg/m^2$ |
| Total lung volume (TLV): | 6.68 ± 1.31 (l BTPS) |
| Functional Residual Capacity (FRC): | 2.47 ± 0.74 (l BTPS) |

*Anthropometric data*

Body surface area was calculated from height and weight using the method of Mosteller, *N Engl J Med* 317(17):1098 (1987) shown below:

$$S (m^2) = ( [\text{Height (cm)} \times \text{Weight (kg)} ] / 3600 )^{1/2}$$

Body volume (V) was calculated using the formula described by Sendroy and Collison, *J. Appl. Physol.* 21(1): 167-172 (1966)

$$V = S\,(51.44 \times (W/H) + 15.3)$$

Where V, S, W, and H are in liters, $m^2$, kg, and cm respectively

$$BMI = \text{Weight (kg)}/H(m)^2$$

*Procedures*

TLC and FRC were measured on a Vmax Encore 22 pulmonary function unit (VIASYS, Palm Springs, CA) using a nitrogen washout method performed in accordance with American Thoracic Society guidelines.

*Equipment Set up*

All buoyancy tests were performed in a fresh water tank (Fig 1) to which an islet was welded to the tank floor to allow attachment of a rope pulley system. One end of the pulley system was attached to the rear of a waist belt worn over the SEIE suit. The rope attached to the waist belt was threaded over a force transducer (TSD121C Hand Dynamometer, BIOPAC Systems Inc, Goleta, CA) via a series of pulleys to a block and tackle. Output from the force transducer, which measured the tension in the rope, was monitored continuously at 60 Hz via an MP100 BIOPAC A/D system. Acknowledge software (BIOPAC Systems Inc, Goleta, CA) was used to analyze the force trace to determine the buoyancy force.

*Buoyancy Test*

For the buoyancy tests subjects wore overalls, socks and the inner thermal liner beneath the MK10 SEIE suit. Throughout the tests subjects breathed from a second stage hookah regulator (Fig. 1 top photo). After fully zipping the hood the subject inflated the hood volume by allowing the exhaled breath to vent into the hood. Complete filling of the hood was indicated once air bubbled from beneath the hood vent. The buoyancy test as described in Fig 1 was then initiated by pulling on the block and tackle to submerge the subject.

Two buoyancy conditions were measured: 1) with the stole and hood fully inflated and, 2) with the hood fully inflated and stole completely deflated. At least two buoyancy measurements that were within 10% of each other were taken for each subject for each of the above conditions. The buoyancy force was determined from the mean force over a 3 second window while the tension in the pulley system was very slowly released to allow the SEIE suit to approach the surface.

## ACKNOWLEDGMENTS

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**Fig. 1:** Buoyancy testing of the MK10 SEIE suit in the immersion tank at NSMRL. After fully inflating the hood the subject was submerged via a pulley system attached to a waist belt until the top of the hood was approximately 4 inches below the water surface. The tension in the pulley system was then slowly released to just overcome pulley friction while forces in the line were measured using a force transducer.

## RESULTS

Table 1 shows the results of the buoyancy tests. There was no significant difference in the buoyancy force between conditions Stole +Hood and Hood only conditions. In sea water buoyancy forces will increase by approximately 2.69% over that measured in fresh water. The only anthropometric variable that showed a significant correlation with buoyancy force was height (see Table 2).

**Table 1:** Buoyancy results for the MK10 SEIE suit. All buoyancy force data are presented in kg

| Condition | Mean | Min | Max | n | SD |
|---|---|---|---|---|---|
| Stole+ Hood | 36.6 | 31.3 | 43.5 | 11 | 4.2 |
| Hood only | 35.7 | 27.1 | 43.4 | 9 | 5.3 |

**Table 2:** Pearson Product moment correlations between the buoyancy force and anthropometric variables. * $p<0.05$

| Variable | Stole + Hood (n=11) [1](n=10) | Hood only (n=9) [1](n=8) |
|---|---|---|
| Height | -0.64* | -0.74* |
| Weight | -0.40 | -0.26 |
| BSA | -0.49 | -0.40 |
| Body Vol. | -0.38 | -0.23 |
| BMI | -0.06 | 0.16 |
| TLC[1] | -0.54 | -0.67 |
| FRC[1] | -0.63 | -0.59 |

## CONCLUSION

During lockout escape, with a fully inflated SEIE suit (Stole + Hood), submariners are expected to encounter buoyancy forces between 32.2 and 44.7 kg (observed maximum and minimum buoyancy forces with correction for sea water). As the MK 10 suit is one-size fits all, submariners of shorter stature will experience the highest buoyancy forces.