U. S. NAVAL SUBMARINE MEDICAL CENTER

Submarine Base, Groton, Conn.

REPORT NUMBER 644

HUMAN FACTORS EVALUATION OF SUBMARINE ESCAPE:
II-A Top Egress with the British Submarine Escape Immersion Suit and the Steinke Hood

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Bureau of Medicine and Surgery, Navy Department
Research Work Unit MF12.524.006-9025B.38

Approved and Released by:

J. E. Stark, CAPT MC USN
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NAVAL SUBMARINE MEDICAL CENTER REPORT NO. 644

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Transmitted by:

George Moeller, Ph.D.
Head, Human Factors Engineering Branch
NavSubMedRschLab

Reviewed and Approved by:

Charles F. Gell, M.D., Sc. (Med)
Scientific Director
NavSubMedRschLab

Reviewed and Approved by:

J. D. Bloom, CDR MC USN
Officer-in-Charge
NavSubMedRschLab

Approved and Released by:

J. E. STARK, CAPT MC USN
COMMANDING OFFICER
Naval Submarine Medical Center

SUMMARY PAGE

THE PROBLEM

To evaluate the compatibility of the British Mark VII Submarine Escape Immersion Suit (SEIS) with existing United States Navy top egress escape trunk configurations.

FINDINGS

The SEIS may be successfully used with existing top egress escape trunk configurations. Escape time is linearly related to the number of men in an escape team. When compared to side and tube egress, top egress results in substantial reductions in escape time.

APPLICATION

The research described in this report should contribute to the development of an improved submarine escape system incorporating top egress, exposure protection, and other desirable features of the British SEIS.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MF12.524.006-9025B--Assessment of Factors Related to Submarine Habitability, Escape and Rescue and New Equipment. The present report is No. 38 on Work Unit MF12.524.006-9025B. It was approved for publication on 22 October 1970 and designated as Submarine Medical Research Laboratory Report No. 644.

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ABSTRACT

The British Mark VII Submarine Escape Immersion Suit (SEIS) which provides thermal protection and the Steinke Hood which does not were evaluated for single man and group escape (2 and 3 man teams) from a simulated top-egress United States Navy escape trunk. For both escape appliances, egress time increased linearly as a function of team size. Three-man teams and two-man teams escaped faster with the SEIS than with the Steinke Hood; there was no difference for one-man escapes. Single man escape times with the SEIS were comparable to those obtained by the British. When compared with side and tube egress, top egress offers a substantial reduction in escape time and therefore in total bottom time. Safe escapes from depths in excess of 450 feet by teams of more than two men are feasible from a top hatch configuration but are not possible from a side or tube egress configuration. A submarine escape system employing top egress and the exposure protection of the SEIS is recommended.

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INTRODUCTION

The United States Navy's submarine escape system consists of an escape trunk, which provides egress from the submarine, and an escape appliance, which facilitates ascent to the surface. Escape trunk configurations are of three types: side egress, tube egress, and top egress (Figure 1). Top and tube egress trunks are designed to hold four men; side egress trunks hold three men. The escape appliance currently in use is the Steinke Hood (Figure 2).* While these systems have augmented safety of escape from depth, they offer the submariner little protection from the hostile environment through which he must pass prior to reaching the surface, and virtually no protection once he has reached the surface (Hall, Noble, and Santa Maria, 1968). This study is part of a series of studies directed toward the development of a submarine escape system which affords the escapee increased safety as well as exposure protection.

** Approved for service by CNO Instruction 10470.11, 22 November 1961.*

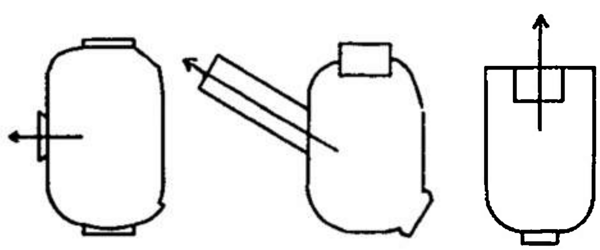

Fig. 1. Schematic representation of the side, tube, and top egress escape trunk configurations found in United States Navy submarines. Arrows indicate direction of escape.

The British Royal Navy utilizes a submarine escape system incorporating a Submarine Escape Immersion Suit (SEIS) and a Single Man Escape Tower which provides for top egress. The SEIS, shown in Figure 3, is composed of a stole portion, similar to the Steinke Hood, which is inflated prior to escape, and an exposure protection component inflated when the escapee reaches the surface. Figure 4 illustrates the difference in exposure protection provided by the Steinke Hood and the SEIS.

In an investigation of the compatibility of the SEIS with the two most common United States Navy escape trunks, side and tube egress, Ryack, Rodensky, and Walters (1970a, 1970b), obtained mean single man escape times of 11.63 seconds for side egress and of 11.94 seconds for tube egress. The comparable escape times for the Steinke Hood were 9.93 seconds and 9.91 seconds respectively. The British have reported egress times with the SEIS of less than 4 seconds (Elliott, 1966; Hamlyn and Tayler, 1967) for their top egress single man escape tower. Since escape trunk configuration appears to be an important factor in egress times and, since some existing United States Navy

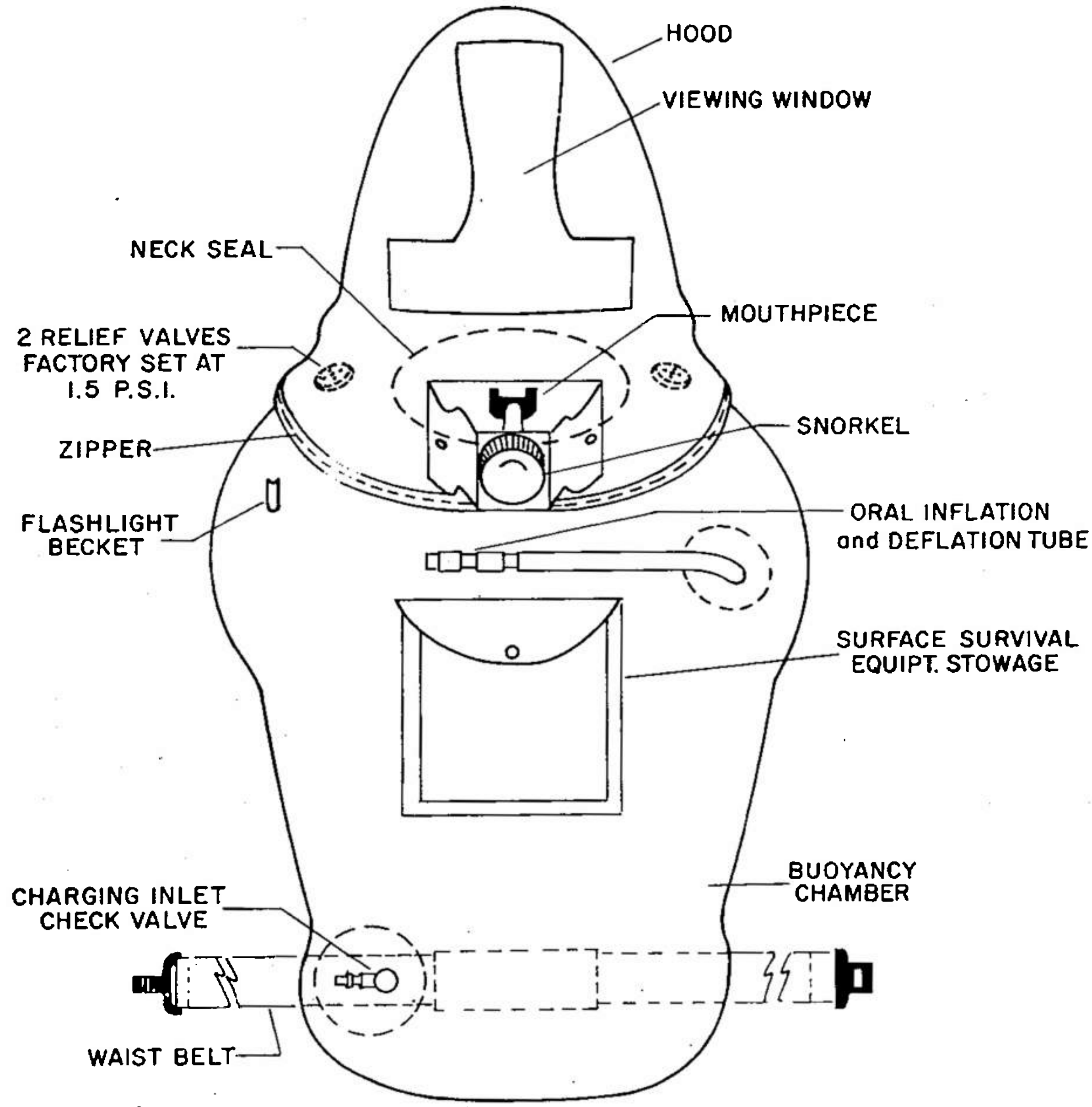

Fig. 2. Details of the Steinke Hood.

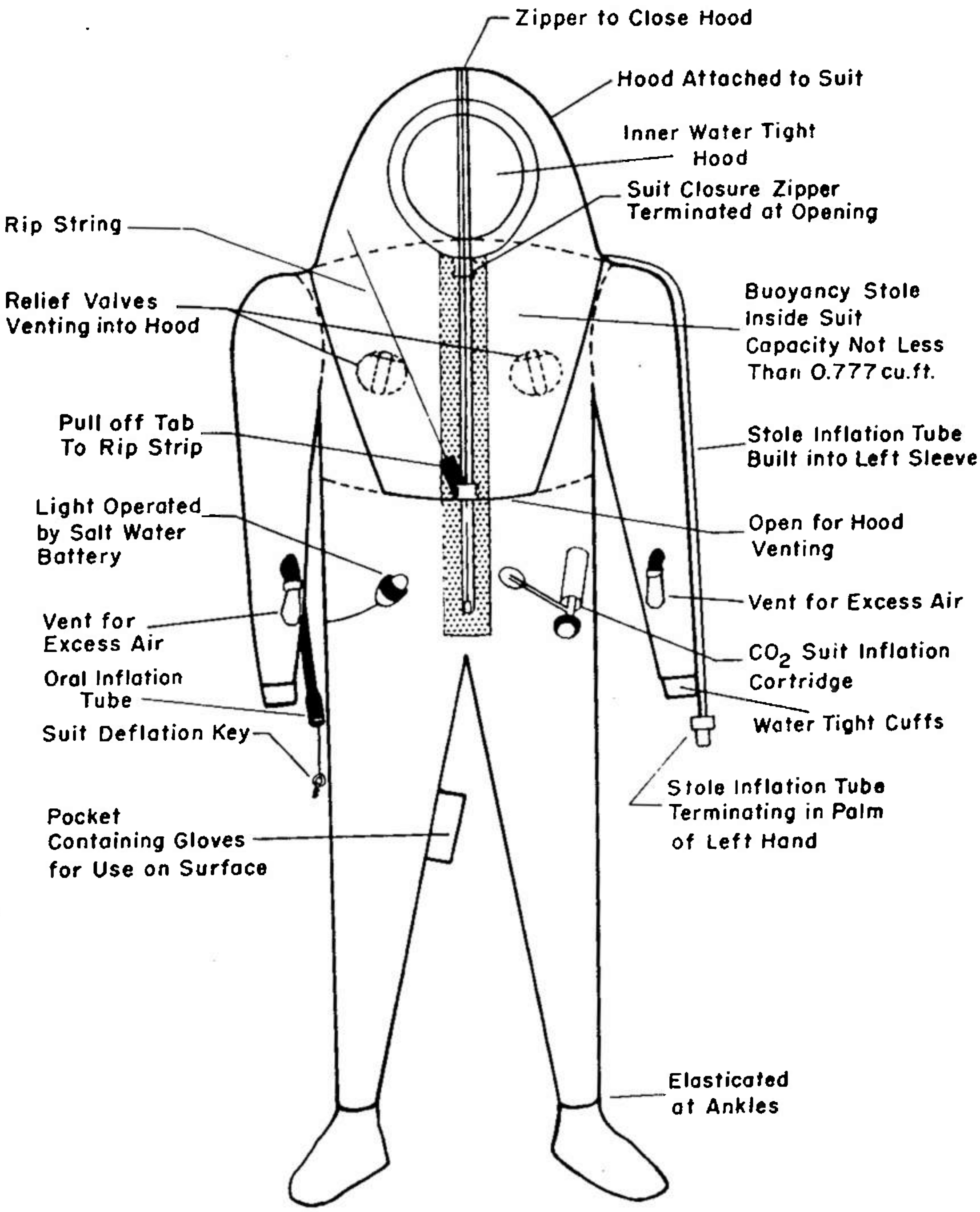

Fig. 3. Details of the British Mark VII Submarine Escape Immersion Suit.

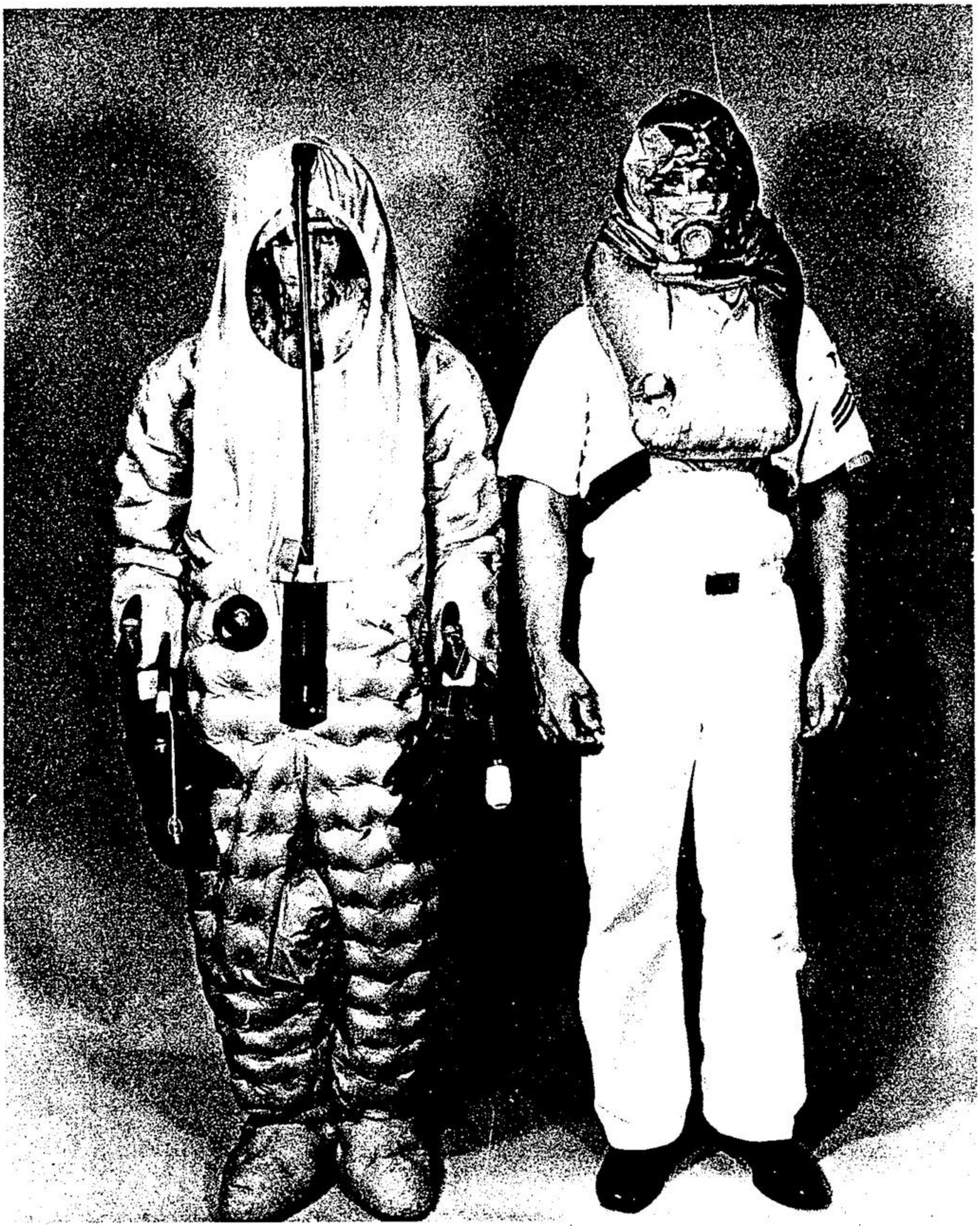

Fig. 4. Subjects wearing the British Mark VII Submarine Escape Immersion Suit (left) and the Steinke Hood (right). The exposure component of the suit is inflated.

submarines employ top egress (563-class), further evaluation of escape capabilities with the SEIS and the Steinke Hood from the top egress configuration is desirable.

The purpose of the present study was therefore: (a) the measurement of egress time for escapes by single men and groups (2, 3, and 4 men) from a top egress escape trunk configuration; and (b) the comparison of escape times of subjects wearing the SEIS or the Steinke Hood.

METHOD

Subjects

Ss were 15 United States Navy Escape Training Instructors from the Submarine Escape Training Department of the Naval Submarine School, Naval Submarine Base New London, Groton, Connecticut. The divers were experienced in the use of the Steinke Hood and were trained in the use of the SEIS. Nine of the 15 divers had served as Ss in the previous study. They represent the whole population of Navy divers in the Escape Training Department familiar with the SEIS, but do not necessarily represent the general population of Navy divers or submarine crews. The instructors were formed into five teams of three Ss each.

Experimental Design

This study was concerned only with the top egress escape trunk configuration as represented by the 563-class of submarines. The escape trunk is designed to accommodate four men, however, the small diameter of the trunk, in combination with the protruding tubing, controls, gauges, and skirt, results in crowded and potentially hazardous conditions which made the authors doubtful of the feasibility of simulated escapes by groups of four men. The present study was therefore limited to groups of one, two, and three men. To evaluate the assumption regarding the feasibility of four-man escapes, several four-man runs were made subsequent to the main investigation.

Table 1 summarizes the three factor experimental design. The factors are: (1) Escape appliance; (2) Team size; (3) Team. Ss made two one-man escapes, four two-man escapes, and six three-man escapes with each escape appliance. The design was replicated five times with different teams. As indicated in Table 1 the position of the Ss was counterbalanced for two-man and three-man escapes.

Apparatus

The Naval Submarine Medical Research Laboratory Escape Trunk Simulator (Ryack, Rodensky, and Walters, 1970a) was modified to reproduce the dimensions and configuration of a 563-class submarine escape trunk. The modifications included: reduction of the trunk diameter, provision of a top hatch, a 20-inch skirt extending into the trunk from the top of the simulator, and reproduction of the internal hardware by means of wooden mock-ups of tubing, controls, gauges, knobs, etc. Since the hatch of the 563-class is designed to open with equalization of trunk and bottom pressure, the top hatch was mounted in an open position. A diagram of the simulator is given in Figure 5.

Table 1. Experimental Design

Group Size	Escape Appliance					
	SEIS			Steinke Hood		
1	A	B	C	A	B	C
2	b-A c-A	a-B c-B	a-C b-C	b-A c-A	a-B c-B	a-C b-C
3	bc-A cb-A	ac-B ca-B	ab-C ba-C	bc-A cb-A	ac-B ca-B	ab-C ba-C

[1] Letters represent escape positions of three different Ss, A, B, C. Capital letters indicate the last man to escape. Numerals indicate the number of Ss attempting a group escape.

The simulator was submerged in 11 feet of water in a pool at the New London Laboratory, Naval Underwater Systems Command. Monitoring of the escape procedure was accomplished by means of two underwater closed circuit television cameras. One camera was mounted within the simulator and other external to it. Internal and external lighting was provided by two LT-6 thallium oxide underwater lamps. Two closed circuit television monitors were used for recording data and for general observations.

A Brush Operations Monitor, Model RB 3303-10, a Hunter Decade Interval Timer, Model 111-C, a Scientific Prototype 301G Interval Timer, and a specially constructed keyboard which activated the operations monitor were used for data recording. The operations monitor provided a record of the time in seconds and the time sequence for each S. Two signal lights, one mounted inside the escape trunk and the other mounted above the escape hatch, served as a ten-second warning signal for the Ss. The offset of the signal light was synchronized with the onset of the time recorder.

The hood and buoyancy stole portions of the escape appliances were charged with external compressed air from supply lines in the simulator. The charging system was not the standard system used on operational submarines. The air supply also provided an 18-inch bubble within the escape trunk. Contact between the Ss in the trunk and the surface was maintained by means of a Y

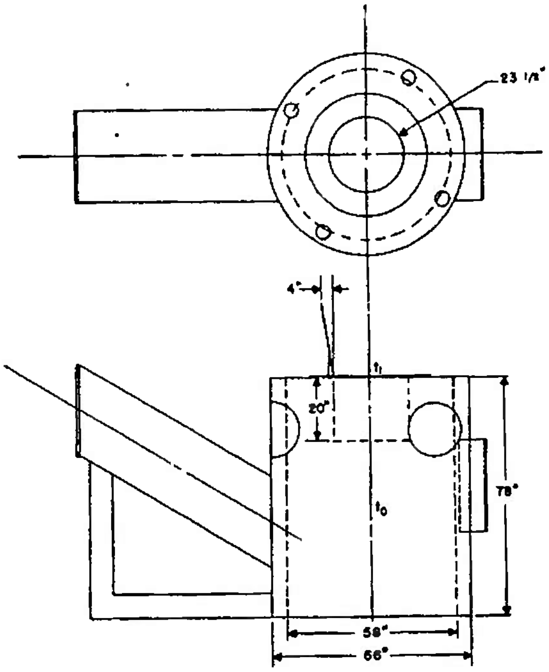

Fig. 5. Diagram of the Submarine Medical Research Laboratory Escape Trunk Simulator modified for top egress. Insert, hatch and skirt are shown. Interior details have been omitted. t indicates data collection point.

Square, Model 10-220 Yack/Yack underwater communications system.

Procedure

The order in which the individuals and two- or three-man teams were run was randomized for each group of Ss. For any given team, tests of the SEIS and the Steinke Hood were run successively and counterbalanced. Ss inflated their hoods immediately upon entering the trunk. The first S then positioned himself under the skirt and was ready for escape. At the offset of the signal light (t_0), the Ss began escape. As the first man left the escape trunk, the next man (in a two-man or three-man escape) ducked under the skirt and began his egress.

RESULTS

As indicated in Figure 5, the measure of escape efficiency was taken as the time from the offset of the ready signal (t_0) to the completion of escape (t_1). t_1 was defined as the time at which the escapee's chest cleared the hatch opening. The data appears in the Appendix, Table 1.

Mean total escape time for team size and escape appliance is summarized in Table 2 and Figure 6. Differences between the means were tested with a three factor repeated measurements analysis of variance (Table 3). The interaction between team size and escape appliance was statistically significant ($p < .05$), as were the linear component of the interaction, and the differences between the means for escape appliances ($p < .01$). Differences between the means for team size and the linear trend for team size were also significant ($p < .01$). Thus for both escape appliances there was a significant linear increase in egress time as team size increased.

Tests of the differences between the means for escape appliances were significant for three-man teams ($t = 6.01$, $df = 20$, $p < .01$) and two-man teams ($t = 4.72$, $df = 20$, $p < .01$) but were not significant for one-man ($t = 0.96$, $df = 20$, $p > .05$). Significantly shorter egress times were obtained with the SEIS than with the Steinke Hood.

To assess the effect of team size and egress position upon the escape time of any S within a team, additional two factor analyses of variance were performed. The mean time for the first

Table 2. Means and Standard Deviations of Escape Time[1] by Team Size and Position for the Steinke Hood and the SEIS

Team Size	Escape Appliance	Position 1 $\bar{X}$	Position 1 σ	Position 2 $\bar{X}$	Position 2 σ	Position 3 $\bar{X}$	Position 3 σ
1	SEIS	1.75	0.34				
	Steinke Hood	1.89	0.65				
2	SEIS	1.76	0.23	4.57	0.70		
	Steinke Hood	1.91	0.56	5.26	1.08		
3	SEIS	1.80	0.32	4.63	0.59	7.39	0.91
	Steinke Hood	1.73	0.23	5.25	0.93	8.27	1.28

[1] All escape times are in seconds.

man to egress was evaluated across all three team sizes for both escape appliances (Table 4). A similar analysis was made across two- and three-man teams for the second man (Table 5). Only the difference for escape appliance for the second man was significant ($\underline{p} < .01$). Egress time for the first and second man to escape was not affected by team size. The escape time for the second man was, however, significantly longer for the Steinke Hood. Since there were no teams with more than three-men, it was not possible to evaluate the third position.

DISCUSSION

This study was concerned with the evaluation of the speed of top egress by Ss wearing either the Steinke Hood or the SEIS and with the effects of collective escape upon egress time. For both escape appliances, one-man escapes were made significantly faster than

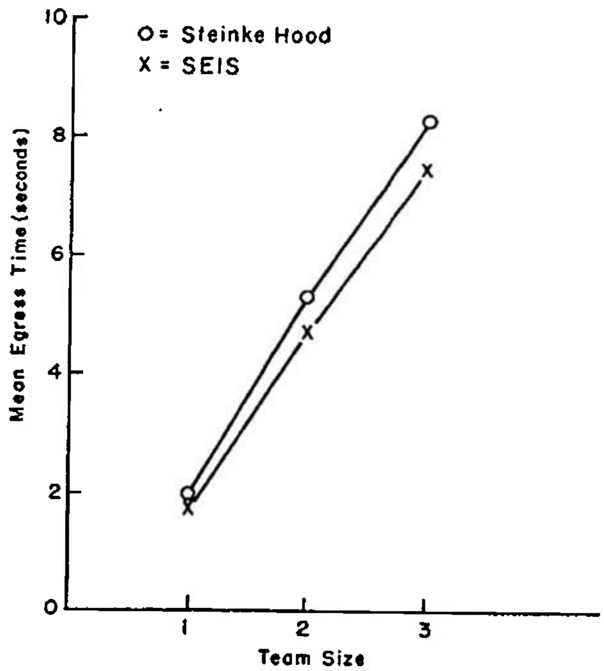

Fig. 6. Mean top egress times for one-, two- and three-man escapes with the SEIS and the Steinke Hood.

two-man escapes and two-man escapes were made significantly faster than three-man escapes. Trend analysis yielded a significant linear trend for team size as well as a significant team size linear trend and appliance interaction indicating that although the increase in mean escape time as team size increased was linear, the rate of increase differed for the two escape appliances. Additional analyses were performed to determine whether escape time for an S in a given position was dependent upon team size, i.e., did a single man escape faster than the first man in a two- or three-man escape; did the second man in a two-man team escape faster than the second man in a three-man team. For both appliances no significant differences were found for either the first position or the second position. The significant differences in escape time between one-man, two-man, and three-man teams can be attributed only to the number of men present in the escape trunk and not to escape position.

Significantly shorter egress times were obtained with the SEIS for two- and three-man teams than with the Steinke Hood. The significant interaction of team size and appliance reflects the fact that the magnitude of the difference increases with team size. Examining the data in terms of position within a team, significant differences between the escape appliances were obtained for the second man to escape but not the first man. The second man made a more rapid egress with the SEIS than with the Steinke Hood. Thus, although escape position had no significant effect for a particular escape appliance, it did have differential effects between escape appliances. These relationships are summarized in Figure 6.

By computing the linear least square regression lines fitted to the data for one-man, two-man, and three-man groups, it is possible to predict to a four-man escape. These regression lines are plotted in Figure 7. Preliminary evaluation of the 563-class escape trunk, however, indicated that the small diameter of the escape trunk and the presence of the skirt might make escape by four men impossible. To test this hypothesis, subsequent to the main experiment, two teams made four-man escapes. The first team of Ss made three escapes with the SEIS and then refused to re-enter the simulator because of the crowded conditions which they felt made egress hazardous. One S on the second team, composed of the most experienced divers, completed 24 four-man escapes with the SEIS but asked to be replaced after the 10th run

Table 3. Analysis of Variance for Team Size and Escape Appliance

Source	df	MS	F
Between Subjects	14		
Teams (T)	4	0.74	1.39
Subjects/T	10	0.53	
Within Subjects	79		20.01**
Appliance (A)	1	7.48	0.79
T X A	4	0.30	
Error	10	0.37	
Team Size (S)	2	270.67	581.58**
Linear	1	1082.40	2325.74**
Quadratic	1	0.28	0.60
T X S	8	0.32	0.70
Error	20	0.46	
S X A	2	1.12	3.50*
S Linear X A	1	4.11	12.73**
S Quadratic X A	1	0.36	1.12
S X A X T	8	0.51	1.57
Error	20	0.32	

** Probability of occurrence less than 1%.
* Probability of occurrence less than 5%.

with the Steinke Hood* because of fatigue. In post-escape interviews it was determined that all Ss had experienced exceptionally high levels of anxiety in the four-man escapes. All Ss felt that the size and configuration of the escape trunk made those escapes dangerous. The obtained mean egress times for the completed four-man escapes for the SEIS ($\overline{X}$ = 9.94) and for the Steinke Hood ($\overline{X}$ = 11.03) approximate the values predicted by the regression function (SEIS: $\overline{X}$ = 10.10; Steinke Hood: $\overline{X}$ = 11.52).

These results differ from those of the previous study of tube egress and side egress (Ryack, Rodensky, and Walters, 1970a) in which the Steinke Hood was found to give more rapid egress times than the SEIS. Since the Ss

* *SEIS and Steinke Hood escapes were made on successive days.*

Table 4. Analysis of Variance for the First Man To Escape and Escape Appliance

Source	df	MS	F
Team Size (T)	2	0.16	0.44
Escape Appliance (A)	1	0.24	1.36
T X A	2	0.24	1.36
Error	174	0.18	

Table 5. Analysis of Variance for the Second Man to Escape and Escape Appliance

Source	df	MS	F
Team Size (T)	1	0.03	0.04
Escape Appliance (A)	1	13.07	18.13**
T X A	1	0.06	
Error	116		

** Probability of occurrence less than 1%.

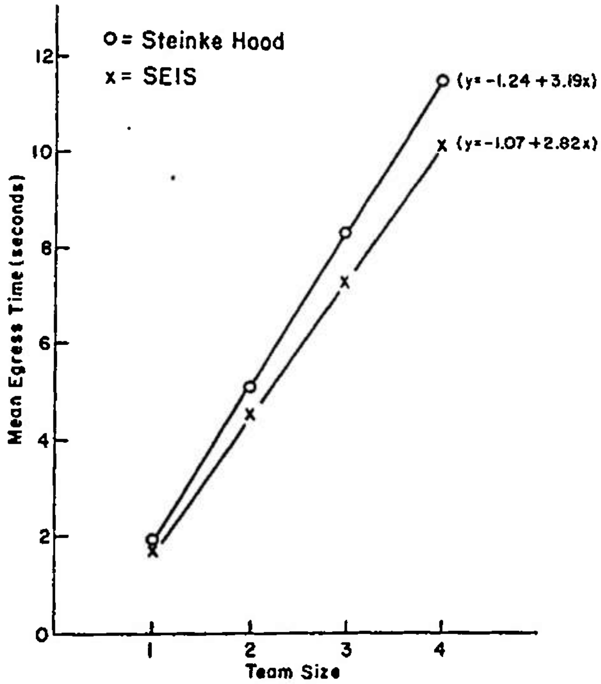

Fig. 7. Top egress regression curves for one-, two- and three-man escapes with the SEIS and the Steinke Hood.

in the two studies were drawn from the same pool of highly trained and experienced divers, it is believed that comparisons of the findings of the present study with those of the first study is legitimate. The data from the two studies is summarized in Table 6 and is plotted separately for each escape appliance in Figure 8. For both appliances, egress time from the top hatch was considerably more rapid than from either the tube or side egress configuration. For one man, top egress while wearing the SEIS, resulted in a reduction of time by 10.19 seconds when compared to tube egress, and of 9.83 seconds when compared to side egress. For a three-man escape, the reduction was 16.61 seconds for a tube egress and 23.52 seconds for a side egress. The comparable data for the Steinke Hood for one-man were reductions of 8.02 seconds for a tube egress and of 8.04 seconds for a side egress. For a three-man escape, the reduction for a tube egress was 11.71 seconds and for a side egress 21.01 seconds. The mean one-man top egress times of 1.75 (SEIS) and 1.89 (Steinke Hood) seconds obtained in the present study are comparable to the mean egress time of 2.2 seconds reported by the British Royal Navy for experienced divers (Hamlyn and Tayler, 1967). The comparable figure reported by Hamlyn and Tayler for submarine crews was 3.5 seconds.

The relative superiority of the SEIS to the Steinke Hood in top hatch egress would appear to be attributable to the differences in buoyancy between the two escape appliances and to differences in their configurations. The SEIS is 70 lbs. buoyant and the Steinke Hood 45 lbs. In contrast to side and tube egress, with top egress the Ss did not have to hold themselves down before entering the escape hatch. The greater buoyancy of the SEIS could therefore have been an asset to the Ss during a top egress and a hinderance during a side or tube egress. Additionally the inflated stole of the Steinke Hood protrudes further from the escapee then does the inflated stole of the SEIS (Figure 9). Ss wearing the Steinke Hood were observed to get caught on the skirt. The monitoring system did not provide for documentation of these incidents. That this factor could contribute to differences in escape time between the appliances was indicated by spontaneous verbal reports by some Ss. The Ss indicated that they had more difficulty entering the skirt with the Steinke Hood than with the SEIS. This difficulty was not reported for tube or side egress. Since the first man was required to

Table 6. Comparison of Mean Escape Time for Top Egress, Tube Egress, and Side Egress Trunk Configurations[1]

Team Size	Escape Appliance	Trunk Configuration: Top Egress $\bar{X}$	Top Egress σ	Tube Egress[2] $\bar{X}$	Tube Egress[2] σ	Side Egress[2] $\bar{X}$	Side Egress[2] σ
1	SEIS	1.75	0.34	11.94	3.70	11.63	4.51
	Steinke Hood	1.89	0.65	9.91	2.49	9.93	2.65
2	SEIS	4.57	0.70	19.61	8.30	21.31	5.64
	Steinke Hood	5.26	1.08	13.82	3.25	21.42	3.87
3	SEIS	7.39	0.91	24.00	7.14	30.91	5.96
	Steinke Hood	8.27	1.28	19.98	4.19	29.28	3.45

[1] All times are in seconds.
[2] From Ryack, Rodenksy, and Walters, 1970a.

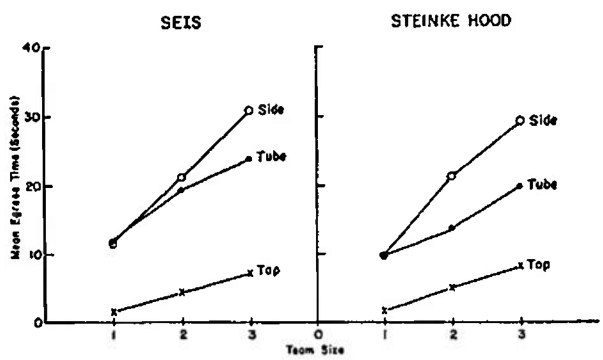

Fig. 8. Relative top, tube and side egress times for the SEIS and the Steinke Hood.

enter the skirt before the beginning of escape, the difference in escape time between appliances could have been reduced for a one-man escape.

Table 7 illustrates how allowable bottom time decreases as depth increases. Bottom time includes egress time and is defined as the time elapsed from leaving the surface until the commencement of ascent. The values given in Table 7 are conservative and minimize the possibility of decompression sickness, nitrogen narcosis,

Fig. 9. Difference in protrusion at the chest of the inflated Mark VII Submarine Escape Immersion Suit (left) and the Steinke Hood (right).

Table 7. No Decompression Limits as a Function of Depth[1]

Depth (Keel)	Time
50 feet	100 minutes
100 feet	25 minutes
150 feet	7 minutes
200 feet	3 minutes, 45 seconds
300 feet	2 minutes
400 feet	1 minute, 15 seconds
450 feet	1 minute
500 feet	45 seconds
600 feet	30 seconds

[1] The exposure values were computed by D. A. Hall, LT, MSC, USN, using a modified Haldane model with "M" values from Table N, Appendix C in Workman (1965). Recomputation using the method described by Robertson and Moeller and Workman's "M" values indicates that the time estimates may be conservative.

and carbon dioxide toxicity. When compared to side and tube egress, top egress provides a substantial reduction in escape time and therefore in total bottom time. The shorter the total bottom time the greater the margin of safety in making an escape from a given depth and the greater the potential depth from which a safe escape can be made.

Table 8 summarizes the maximum possible depth from which safe no decompression ascents can be made from the three escape trunk configurations. The Corrected Total Bottom Times were derived by adjusting the obtained Mean Egress Time for its variance ($\bar{x} + 2.33\sigma$) and adding an assumed compression time of 20 seconds (Barnard & Eaton, 1965; Bennett, Dossett & Ray, 1964; Hall et al., 1970). The corrected values may be expected to be exceeded in only one percent of the escapes. Taking bottom time into consideration, safe ascents from depths in excess of 450 feet by two or more men are feasible from a top egress configuration but are not possible with either escape appliance from a tube or side egress configuration. Top egress is clearly superior to both side and tube egress.

In summary, top egress provides much shorter escape times and therefore shorter bottom times than either side

Table 8. Maximum Possible Ascent Depths Based Upon Egress Time And No Decompression Time Limits [1]

Trunk Type	Escape Appliance	Team Size	Mean Egress Time	Corrected Total Bottom Time [2]	No Decompression Time Limits	Maximum No Decompression Ascent Depth
Top Egress	SEIS	1	1.75	22.54	30	600
		2	4.57	26.38	30	600
		3	7.39	29.51	30	600
		4	10.21 [3]	31.79	45	500
	Steinke Hood	1	1.89	23.40	30	600
		2	5.26	27.77	30	600
		3	8.27	31.25	45	500
		4	11.52 [3]	33.90	45	500
Tube Egress	SEIS	1	11.94	40.56	45	500
		2	19.61	58.95	60	450
		3	24.00	57.63	60	450
		4	30.58 [3]	66.07	75	400
	Steinke Hood	1	9.91	35.71	45	500
		2	13.82	41.37	45	500
		3	19.98	49.74	60	450
		4	24.64 [3]	52.28	60	450
Side Egress	SEIS	1	11.63	42.14	45	500
		2	21.31	54.45	60	450
		3	30.91	64.80	75	400
		4	40.56 [3]	72.93	75	400
	Steinke Hood	1	9.93	36.10	45	500
		2	21.42	50.44	60	450
		3	29.28	57.32	60	450
		4	39.56 [3]	67.64	75	400

1 All times are in seconds.
2 Obtained egress time corrected for variance and compression time.
3 Computed from regression equation.

egress or tube egress. For top egress the SEIS results in more rapid egress times than the Steinke Hood and provides exposure protection. Consideration should be given to modifying existing United States Navy side egress and tube egress escape trunks to conform to the top egress configuration. The top egress configuration should be employed in the construction of future submarine escape trunks.

FUTURE PLANS

Subsequent research will be concerned with a series of variables which may affect either the speed or the ease of egress from an escape trunk. These variables, which were controlled but not investigated in the present study, include: ease of disconnect from the system used to charge the escape appliance with air; the position of the escapee with respect to the escape hatch; the diameter of the escape trunk; the attitude which the submarine, and consequently the escape trunk, assumes when disabled. The results of these studies will have important implications for the design of a safer submarine escape system.

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APPENDIX

Table 1. Raw Data: Table of Obtained Egress Times[1]

SEIS - Top Egress									
	One Man Escapes		Two Man Escapes			Three Man Escapes			
Group	Cell	$t_2 - t_0$	Cell	$t_2 - t_0$ First Man	$t_2 - t_0$ Second Man	Cell	$t_2 - t_0$ First Man	$t_2 - t_0$ Second Man	$t_2 - t_0$ Third Man
1	B	1.8	b-A	2.0	5.1	ab-C	1.5	4.1	6.9
	B	1.3	c-A	2.0	4.5	ca-B	1.7	3.9	6.8
	C	1.3	b-C	1.8	3.7	cb-A	1.3	3.8	6.2
	A	1.4	c-B	1.3	5.1	ac-B	1.2	4.0	7.0
	A	1.2	a-B	1.4	4.8	ba-C	1.7	3.9	7.3
	C	1.6	a-C	1.5	3.9	bc-A	1.3	4.1	6.2
2	C	1.9	c-B	1.6	5.0	cb-A	1.9	5.3	8.4
	C	1.7	b-C	2.0	6.4	bc-A	1.6	5.0	6.8
	B	1.7	a-C	1.8	5.6	ba-C	1.5	4.2	6.9
	A	2.0	b-A	1.5	4.2	ab-C	2.0	5.5	8.0
	A	1.8	c-A	1.8	4.3	ac-B	2.0	5.0	7.5
	B	1.5	a-B	1.6	5.2	ca-B	2.4	4.9	7.0
3	B	2.3	b-A	2.0	4.4	ab-C	2.2	5.8	10.1
	A	1.6	c-A	2.0	4.6	ca-B	1.9	4.8	8.3
	A	1.6	a-B	1.8	5.3	cb-A	1.9	4.8	7.0
	C	2.0	a-C	1.8	5.1	ba-C	1.8	4.2	7.2
	B	2.0	c-B	1.7	4.8	ac-B	1.7	4.8	8.2
	C	1.8	b-C	2.1	5.8	bc-A	1.8	4.8	8.0
4	C	1.5	b-C	1.3	4.0	ba-C	1.5	4.0	6.7
	B	1.7	a-C	1.4	3.8	cb-A	1.5	5.8	9.8
	A	1.8	c-B	1.7	4.5	ab-C	1.6	4.1	6.3
	A	1.8	b-A	2.0	4.7	bc-A	1.7	4.0	7.0
	C	1.3	a-B	1.8	4.1	ca-B	2.4	5.2	7.8
	B	1.6	c-A	1.5	4.1	ac-B	1.7	4.2	6.9
5	A	2.7	b-A	1.8	4.3	ab-C	1.8	5.1	7.0
	A	2.5	a-C	2.0	3.6	bc-A	2.5	4.9	7.4
	C	2.0	c-A	1.9	4.6	ac-B	2.1	4.1	6.7
	C	1.6	c-B	1.7	3.3	ca-B	1.9	4.8	7.6
	B	1.8	b-C	2.0	3.8	ba-C	2.0	5.4	7.4
	B	1.7	a-B	2.0	4.1	cb-A	2.0	4.4	7.2

[1] All times are in seconds.

Table 1. (cont.)

Steinke Hood - Top Egress										
	One Man Escapes		Two Man Escapes			Three Man Escapes				
Group	Cell	$t_2 - t_0$	Cell	$t_2 - t_0$ First Man	$t_2 - t_0$ Second Man	Cell	$t_2 - t_0$ First Man	$t_2 - t_0$ Second Man	$t_2 - t_0$ Third Man	
1	A	1.5	a-B	1.9	5.0	cb-A	1.3	4.8	7.2	
	C	1.6	a-C	1.4	4.0	ba-C	1.9	6.8	9.2	
	A	1.7	c-A	1.3	4.8	ca-B	1.5	5.4	8.8	
	C	1.2	b-C	1.9	4.1	ac-B	1.8	4.8	8.4	
	B	2.0	c-B	1.2	4.4	bc-A	1.4	4.7	6.9	
	B	2.0	b-A	1.9	6.1	ab-C	1.8	8.3	11.1	
2	B	4.7	c-B	2.3	5.0	ca-B	1.7	4.2	6.8	
	C	2.2	b-C	2.1	6.3	bc-A	2.0	4.2	6.5	
	A	1.5	c-A	1.5	5.0	cb-A	1.6	4.2	7.2	
	C	1.8	a-C	1.8	4.0	ac-B	1.7	5.7	8.7	
	A	1.8	a-B	3.2	6.8	ba-C	1.9	4.9	9.0	
	B	2.0	b-A	2.1	4.9	ab-C	1.8	5.0	7.9	
3	A	1.7	b-C	2.0	5.7	cb-A	1.9	5.4	8.8	
	A	1.8	b-A	2.0	6.2	ab-C	1.7	5.8	8.2	
	C	1.8	c-A	3.7	6.0	bc-A	1.8	5.0	7.7	
	B	2.0	a-C	1.4	4.6	ca-B	2.0	4.4	9.1	
	C	1.8	c-B	1.9	5.2	ac-B	1.9	4.8	8.4	
	B	1.3	a-B	1.6	4.9	ba-C	1.7	5.8	9.8	
4	C	1.4	a-B	2.0	4.1	bc-A	2.0	5.4	8.3	
	A	1.8	c-A	1.9	6.9	cb-A	1.9	4.8	7.3	
	B	1.7	b-A	1.7	5.0	ab-C	1.8	5.0	7.2	
	C	3.3	c-B	3.1	5.5	ca-B	2.1	6.4	8.8	
	A	1.2	a-C	1.5	4.9	ba-C	1.3	4.7	7.4	
	B	1.8	b-C	1.8	4.8	ac-B	1.3	5.7	9.6	
5	A	1.8	c-A	1.9	6.5	ac-B	1.8	4.2	7.4	
	C	1.9	c-B	1.8	4.8	ca-B	2.0	4.7	7.2	
	C	1.7	a-C	1.4	8.9	ba-C	1.8	4.3	6.1	
	B	2.0	a-B	1.2	4.2	bc-A	1.7	5.4	8.7	
	A	1.9	b-A	2.0	4.5	ab-C	1.4	7.0	11.8	
	B	1.9	b-C	1.8	4.7	cb-A	1.4	5.6	8.6	

Table 1. (cont.)

SEIS - Top Egress					
Four Man Escapes					
Run	Order	First Man $t_2 - t_0$	Second Man $t_2 - t_0$	Third Man $t_2 - t_0$	Fourth Man $t_2 - t_0$
1	bca-D	1.7	5.4	8.2	11.3
2	bac-D	1.8	4.5	10.7	14.2
3	dcd-A	1.8	4.2	6.6	9.0
4	adc-B	1.9	4.2	6.3	11.3
5	cdb-A	1.7	4.7	6.8	9.2
6	cad-B	1.8	3.9	6.6	9.7
7	dab-C	2.0	4.2	6.9	9.1
8	dba-C	1.8	4.0	6.3	8.5
9	bcd-A	2.0	4.1	7.3	9.5
10	bad-C	1.7	3.7	6.5	9.0
11	dca-B	1.9	4.2	6.7	10.1
12	acb-D	2.0	4.8	6.7	8.9
13	abd-C	1.7	3.3	6.7	10.0
14	cda-B	1.3	3.9	6.3	8.8
15	cab-D	1.5	4.2	6.4	9.7
16	acd-B	1.8	4.0	6.9	9.1
17	bdc-A	1.7	4.0	7.0	10.1
18	cbd-A	1.7	3.6	5.6	7.8
19	bda-C	1.8	4.4	6.2	9.0
20	adb-C	1.6	3.3	5.8	8.8
21	dbc-A	2.2	3.8	6.1	8.8
22	dac-B	2.0	4.3	6.3	8.3
23	abc-D	1.7	3.2	5.8	8.3
24	cba-D	1.7	3.9	5.9	8.1

Table 1. (cont.)

Steinke Hood - Top Egress					
Four Man Escapes					
Run	Order	First Man $t_2 - t_0$	Second Man $t_2 - t_0$	Third Man $t_2 - t_0$	Fourth Man $t_2 - t_0$
1	dca-B	2.0	4.8	7.8	11.3
2	cba-D	2.0	4.9	7.7	10.8
3	bca-D	2.1	7.1	10.0	12.8
4	dac-B	2.2	6.2	8.3	10.9
5	acd-B	1.8	5.4	8.0	11.1
6	bdc-A	1.8	3.8	7.7	10.4
7	bcd-A	2.0	5.0	7.8	10.8
8	cbd-A	1.9	4.3	7.0	10.4
9	bad-C	1.6	3.7	6.2	10.4
10	adb-C	1.8	9.6	12.4	16.4
11	dac-B	2.0	4.7	7.2	10.2
12	dab-C	2.0	4.7	8.4	11.3
13	dba-C	2.0	6.3	9.4	12.0
14	bda-C	2.0	4.8	7.2	11.3
15	cdb-A	2.0	4.8	7.3	14.9
16	cda-B	2.0	4.2	7.0	10.0
17	cab-D	1.9	6.0	8.4	11.0
18	acb-D	1.8	4.1	7.0	10.0
19	dcb-A	2.0	5.2	7.8	10.5
20	abc-D	2.0	4.1	6.7	9.3
21	cad-B	1.7	3.9	6.2	8.8
22	bac-D	1.4	4.0	6.7	9.3
23	dbc-A	2.0	5.8	8.7	11.0
24	abd-C	2.1	4.3	7.4	9.8

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13. ABSTRACT

The British Mark VII Submarine Escape Immersion Suit (SEIS) which provides thermal protection and the Steinke Hood which does not were evaluated for single-man and group escape (2- and 3-man teams) from a simulated top egress United States Navy escape trunk. For both escape appliances, egress time increased linearly as a function of team size. Three-man teams and two-man teams escaped faster with the SEIS than with the Steinke Hood; there was no difference for one-man escapes. Single-man escape times with the SEIS were comparable to those obtained by the British. When compared with side and tube egress, top egress offers a substantial reduction in escape time and therefore in total bottom time. Safe escapes from depths in excess of 450 feet by teams of more than two men are feasible from a top hatch configuration but are not possible from a side or tube egress configuration. A submarine escape system employing top egress and the exposure protection of the SEIS is recommended.

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Steinke Hood						