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HUMAN FACTORS EVALUATION OF SUBMARINE ESCAPE:
III. The Effects of Three Types of
Charging Connectors on Disconnect Time

by

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Bureau of Medicine and Surgery, Navy Department
Research Work Unit MF12.524.006-9025BA9K.40

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NAVAL SUBMARINE MEDICAL CENTER REPORT 688

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SUMMARY PAGE

THE PROBLEM

To evaluate speed of disconnect with three types of connectors utilized in charging submarine escape appliances in studies of simulated escape.

FINDINGS

Although statistically significant differences were found between the various types of connectors, the magnitude of the differences in disconnect time is so small as to be of no practical significance in the choice of connector used.

APPLICATION

The research described in this report should contribute to the development of improved connectors to be used in charging submarine escape appliances.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MF12.524.006-9025BA9K Human Factors in Submarine Escape, Survival, and Rescue. The present report is No. 40 on Work Unit MF12.524.006-9025BA9K. It was approved for publication on 24 November 1971 and designated as Submarine Medical Research Laboratory Report No. 688.

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ABSTRACT

Three types of connectors utilized in charging submarine escape appliances in simulated submarine escapes were evaluated with respect to speed of disconnect in a dry environment. Statistically significant differences in disconnect time were found between the various types of connectors, however, the magnitude of these differences is so small that they are of no practical significance in the submarine escape evolution. It is recommended that the study be repeated in a wet environment, more closely simulating actual submarine escape conditions.

HUMAN FACTORS EVALUATION OF SUBMARINE ESCAPE:

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INTRODUCTION

The submarine escape evolution can be conceived to have several parts: Pre-escape, escape, and post-escape. The pre-escape part of the evolution is the period from the initial emergency in the submarine until an escapee enters the escape trunk, the means of egress from the submarine. Compression to ambient water pressure, egress from the escape trunk, and transit to the surface occur in the escape portion of the evolution. Post-escape includes surface survival and rescue. During escape and post-escape, an escape appliance provides air for the escapee to breathe on the way to the surface and positive buoyancy. High positive buoyancy is required to get the escapee to the surface rapidly and to keep him afloat once he gets there. A charging connector allows the appliance to be charged with air from supply lines in the escape trunk during compression; breaking this connection allows the escapee to leave the submarine.

In escape, the time elapsed from the beginning of compression until egress is completed must be minimized if one is to avoid serious physiological consequences such as decompression sickness and nitrogen narcosis. Certain other physiological considerations (lung squeeze, ear squeeze, etc.) fix the maximum rate of compression, so that the only variable in this phase of the evolution which can be changed to meet the requirements of the various escape conditions is speed of egress. Speed of egress may be affected by factors such as: the escape trunk configuration; the type of escape appliance; the size of the escaping team; the type of charging connector; stress and anxiety. The first three factors were evaluated in a recently completed series of studies at the Naval Submarine Medical Research Laboratory (Ryack, Rodensky, and Walters,[1,2] ; Ryack and Walters,[3,4] ; other studies in preparation). In these studies three representative United States Navy submarine escape trunks, side, tube and top egress were evaluated using one, two and three man teams, with escapees wearing one of three escape appliances, the Steinke Hood, the British Mark VII, Submarine Escape Immersion Suit (SEIS), or the prototype United States Navy Escape and Survival Equipment, Mark 1, Mod 0 (EASE) (Fig. 1). Stress and anxiety are known to be present in actual submarine escapes and were observed in the studies of simulated submarine escape cited above. Type of charging connection has not been satisfactorily evaluated and may be a factor influencing speed of egress, i.e., the faster an escapee can disconnect from his air supply in the escape trunk, the faster he can escape.

In the studies mentioned above, several different methods of charging were employed. A gun-type charging device which has a simple lever operated valve to inject air and a tube with a tapered end for easy insertion, was utilized with the EASE and the Steinke Hood. Both of those escape appliances are equipped with a standard male Schrader quick-disconnect air fitting. This connector (Fig. 2), hereafter called Type I, is a friction type held in place solely by pressure supplied by the escapee. A standard female Schrader quick-disconnect air fitting, like those found in the escape trunk of an operational submarine, was also used with the aforementioned escape appliances, and the configuration thus obtained is designated Type II (Fig. 2). This connector locks together; the escapee must pull back a collar on the female part of the connector to release it. Charging of the British SEIS, which has a plastic air fitting (Fig. 2), was accomplished by placing a one-hole rubber stopper over the tube of the gun-type connector. This again is a friction type fitting, similar to a Type I connector, and will be called a Type III connector.

The present study examined the effect of these various methods of charging on the speed of egress in a non-stressful environment. It was hypothesized that the Type I and Type III connectors would take less time to disconnect than the Type II, and that Types I and III would be equivalent in that respect.

METHOD

Subjects

Subjects (Ss) were ten enlisted personnel waiting to start the Naval Basic Enlisted Submarine Course, at the Naval Submarine School, Naval Submarine Base New London, Groton, Connecticut.

Experimental Design

The two major independent variables were Type of Connector and Trials (to examine learning effects). These variables were manipulated within a Treatments X Treatments X Subjects experimental design. Ss were given two blocks of five trials with each method of charging, in a single test session. A different random order of presentation of the various blocks was employed for each S to avoid any possible ordering effects.

Apparatus

Coveralls were used to simulate the escape appliances. To simulate EASE, an air hose with a male Schrader fitting, was attached to the left arm of one set of coveralls; to simulate the SEIS, a British-type connector and air hose were attached to the left arm of another set of coveralls (Fig. 3). The simulated EASE was employed with Type I and II connectors, and the simulated SEIS was employed with the Type III connector. Air hoses were of such a length that they could be held easily in S's left hand.

Fig. 1. Ss wearing the Steinke Hood (left), the British Submarine Escape Immersion Suit (center), and the United States Navy Escape and Survival Equipment, Mark 1, Mod 0.

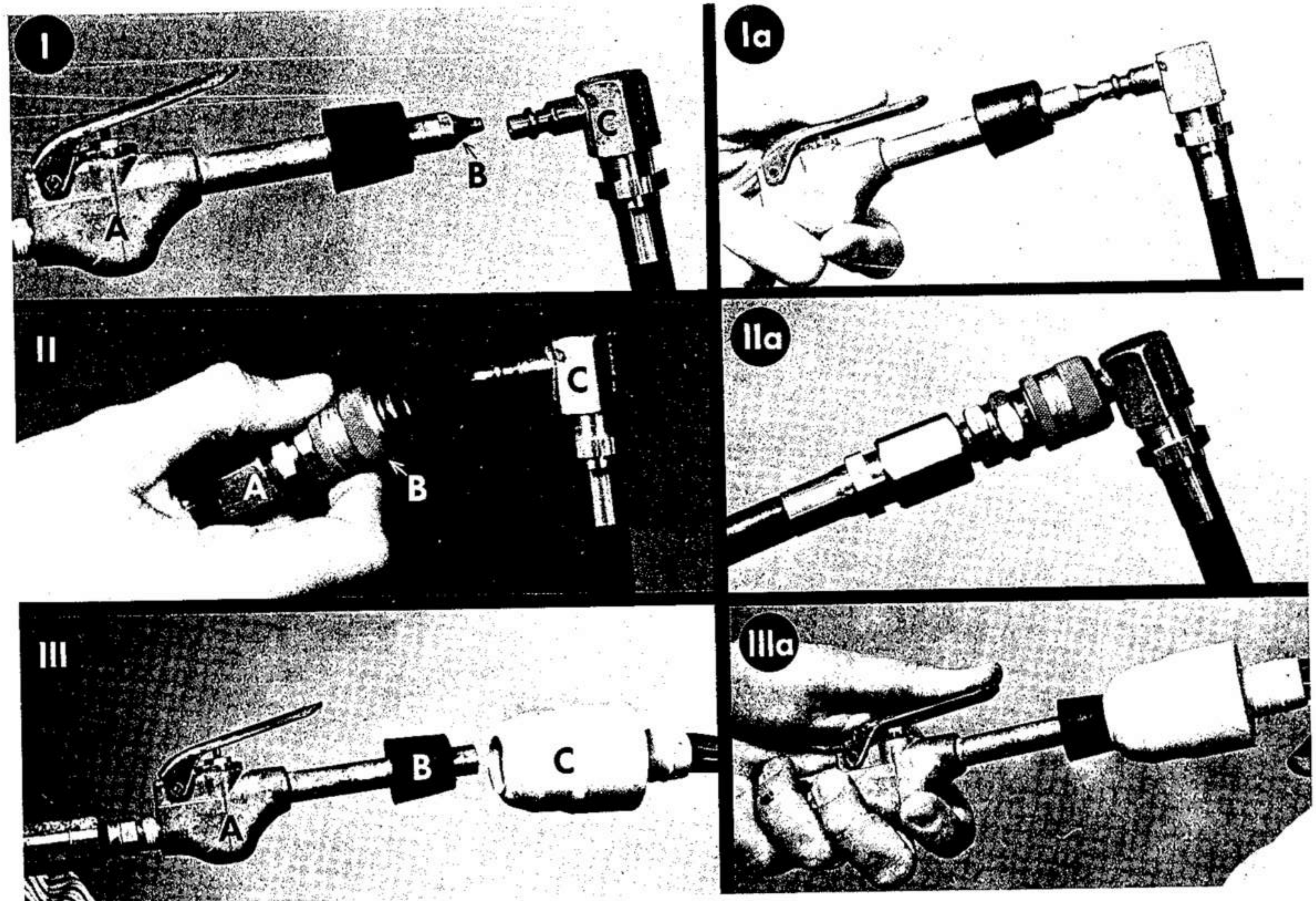

Fig. 2. *I. The Type I connector, showing the gun-type charging device (A), with nozzle (B), attached for easy insertion into the male Schrader fitting (C). IA. The Type I connector in use. II. The Type II connector showing the female Schrader fitting (A), with collar (B), pulled back to allow joining with the male Schrader fitting (C). IIA. The Type II connector in use. III. The Type III connector, showing the gun-type charging device (A), with rubber stopper (B), about to be inserted into the British air fitting (C). IIIA. The Type II connector in use.*

Fig. 3. Ss wearing the simulated escape appliances, SEIS (left) and EASE.

Simulated charging was accomplished using either the gun-type or the female Schrader quick-disconnect air fitting and attached hoses. The Schrader fitting was supplied with compressed air at 100 psi to simulate actual escape conditions of continuous charging. Compressed air was not used with the gun-type fitting, because continuous charging was not performed in those studies of submarine escape where it was employed.

A Hunter Decade Interval Timer, Model 111-C, Series D, a Standard Electric Timer, Type S-1, and a Control Unit were employed in data collection. The Hunter Timer actuated a signal light for five seconds. Offset of the signal light was synchronized with onset of the Standard Electric timer, which gave readings in hundredths of a second.

A six-volt battery supplied current which established a circuit, through the charging devices utilized with EASE, thus separating the parts of the connector, broke the circuit and stopped the timer. With the SEIS, when the parts of the connector were separated, a circuit was established, which stopped the timer.

Procedure

S was given a brief explanation of the purpose of the experiment and a demonstration of the operation of all three types of connectors. S was then asked to try each of the connectors, to assure experimenter that he was able to operate them.

At the beginning of a trial S connected his appliance and the signal light was then turned on for five seconds. At the offset of the signal light, S disconnected as fast as possible. The time of disconnect, defined as the time from the offset of the signal light, until the circuit was broken for the Type I and II connectors, and as the time to establish the circuit for the Type III connector, was recorded.

RESULTS

The means and standard deviations of the disconnect times are given in Table 1. The raw data appear in the Appendix. Analysis of variance, Table 2, resulted in a statistically significant connector effect ($p < .01$). Duncan Multiple Range Tests of the differences between the means revealed significantly shorter disconnect times for Type I than for Type II ($p < .01$) and Type III ($p < .05$) connectors; times for Type II and III connectors were not significantly different from each other. The main effect for trials was significant ($p < .05$), as was the linear trend for trials ($p < .01$). There were no significant nonlinear effects, nor were there any significant interactions. Disconnect time decreased linearly over trials (Fig. 4).

DISCUSSION

The results indicate significant differences exist in speed of disconnect for various types of connectors. As predicted, the Type I connector resulted in the most rapid disconnect times. Although performance with the Type II connector was better than expected, it took significantly longer to disconnect than the Type I connector. Performance with the Type III connector was not as fast as expected, and disconnect time with this connector was not significantly different from that with the Type II connector.

Observations in previous experiments in which the Type II connector had been utilized, were that in most instances the Type II connector would provide for rapid disconnect, but that on a fair number of trials it would jam. Although this difficulty had been observed about once in every twenty trials in previous experiments, it only appeared once in this study. The failure of the Type II connector to jam may have been the result of the dry environment in which this study was performed. Previous observations were made while the Ss were submerged in 12 feet of water.

The rubber stopper, which is employed on the Type III connector to prevent air leaks, tended to stick in this study and this factor may have

Table 1. Means and Standard Deviations of Disconnect Time[1] by Type of Connector and Trial

Trial	Type Connector					
	I		II		III	
	$\overline{X}$	σ	$\overline{X}$	σ	$\overline{X}$	σ
1	0.248	0.0380	0.312	0.0695	0.302	0.0482
2	0.277	0.0421	0.325	0.0884	0.303	0.0865
3	0.243	0.0361	0.313	0.0618	0.288	0.0652
4	0.237	0.0434	0.301	0.0685	0.285	0.0723
5	0.236	0.0336	0.284	0.0414	0.274	0.0321
6	0.234	0.0266	0.293	0.0574	0.264	0.0296
7	0.258	0.0457	0.296	0.0992	0.267	0.0415
8	0.247	0.0498	0.282	0.0495	0.255	0.0243
9	0.252	0.0629	0.272	0.0408	0.263	0.0305
10	0.226	0.0324	0.268	0.0515	0.256	0.0521

[1]All disconnect times are in seconds.

Table 2. Analysis of Variance for the Various Types of Connectors and Trials

Source	df	MS	F
Trials (T)	9	0.0067	2.25*
Linear	1	0.0463	15.44**
Non-Linear	8	0.0018	0.59
Type Connector (C)	2	0.0395	6.95**
Subjects (S)	9	0.0242	
T X C	18	0.0012	0.27
Linear T X C	1	0.0081	1.84
Non-Linear T X C	17	0.0008	0.18
T X S	81	0.0030	
C X S	18	0.0057	
T X C X S	162	0.0044	

*Significant at beyond the .05 level.
**Significant at beyond the .01 level.

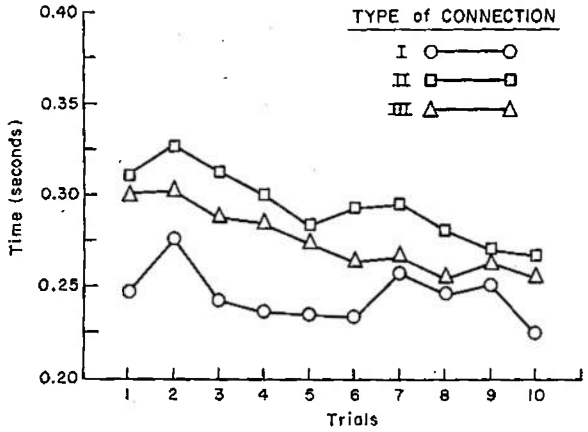

Fig. 4. Mean egress times over trials for Type I, II, and III connectors.

increased disconnect time. During normal escapes, water would act as a lubricant for the stopper and a decrease in disconnect time should be obtained. Thus the Type III disconnect time would more closely approximate that for the Type I connector, as had been predicted.

The significant main effects for Trials and Trials Linear Trend reflects a linear decrease in mean disconnect time over trials. The lack of an interaction between Trials and Type of Connector indicates that the curves are parallel (Fig. 4), and that the learning effects for all three types of connectors are similar. The exceptionally small magnitude of the variances resulted in a statistically significant learning effect, however, the absolute differences in mean speed of disconnect over trials for each type of connector is less than one tenth of a second, and is of no practical significance.

Although the Type I connector provides the fastest disconnect time, the largest difference in mean disconnect time obtained between the various connector in this study was only 0.04 seconds. The effect of a difference in disconnect time of 0.04 seconds on speed of egress is of no practical significance in terms of the time limitations (Table 3) placed on speed of egress in the escape evolution. It would appear that the connectors considered in this study are interchangeable, as far as their practical effect on speed of egress is concerned.

Table 3. Maximum Allowable Egress Times at Various Depths[1]

Depth (feet)	Time
50	99 minutes, 40 seconds
100	24 minutes, 40 seconds
150	6 minutes, 40 seconds
200	3 minutes, 40 seconds
300	1 minute, 40 seconds
400	55 seconds
450	40 seconds
500	25 seconds
600	10 seconds

[1]These values were obtained by subtracting an assumed compression time of 20 seconds from the values given by Ryack and Walters (1970a) for No Decompression Limits as a Function of Depth.

The gun-type charging device used in Type I and III connectors, is not used by the Navy to charge submarine escape appliances, as is the Type II connector. This gun-type connector was employed in the initial studies of submarine escape (Ryack and Walters, 1970a, 1970b; Ryack, Rodensky, and Walters, 1970a, 1970b) because the female Schrader fitting was not available. Its satisfactory performance should not be inferred as a recommendation for its use in place of the Type II connector. The protruding lever could be caught in the tubing, gauges, and controls of an escape trunk or be easily damaged in use. A better type of connector, would employ a friction type release similar to the Types I and III, connected to the escape suit in the vicinity of the waist, thus freeing the escapee's arms. The connection could be broken either directly by the escapee or by the buoyancy of his escape appliance as he began ascent.

In interpreting the results of this study, it should be realized that compared to previous studies or to actual submarine escapes, the conditions of this study were ideal. This study was conducted in a dry well-lighted environment. Real or simulated escapes are conducted under water, in a small dimly-lighted trunk. The anxiety associated with actual escape, that was noted in previous studies, was absent in this study. The Ss in this study could concentrate on the disconnect and were not concerned with other aspects of the escape evolution. Thus the conditions of this study may have contributed to a decrease in disconnect times as compared to those which might be obtained in an actual escape.

Given the conditions of this study and the small amount of learning associated with this task, there would be no difference in disconnect time expected from the fact that the Ss used in this study were not experienced divers as were the Ss in previous studies.

In conclusion, although there are statistically significant differences between the types of charging connectors employed in this study, these differences are of no practical importance. Before final conclusions about the effect of different charging connectors on speed of egress are drawn, it is felt that the present study should be repeated in a wet environment, which more closely resembles actual submarine escape conditions.

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APPENDIX A

Raw Data: Table of Obtained Disconnect Times[1]

S	1			2			3			4			5		
Type of Connection	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Trial															
1	.258	.238	.290	.322	.290	.220	.190	.240	.232	.178	.238	.280	.175	.242	.320
2	.266	.370	.270	.278	.270	.298	.262	.318	.262	.258	.270	.280	.302	.220	.290
3	.246	.200	.262	.205	.272	.240	.205	.302	.218	.210	.290	.229	.240	.263	.232
4	.320	.400	.380	.225	.258	.258	.236	.322	.270	.202	.260	.250	.220	.298	.250
5	.242	.292	.272	.326	.500	.240	.252	.300	.272	.240	.280	.268	.220	.313	.300
6	.288	.350	.276	.315	.440	.488	.240	.435	.449	.303	.435	.470	.230	.288	.272
7	.250	.323	.258	.263	.398	.288	.303	.390	.340	.235	.418	.340	.251	.366	.300
8	.203	.280	.348	.262	.243	.257	.250	.230	.282	.200	.295	.242	.240	.280	.242
9	.200	.275	.282	.316	.296	.420	.208	.314	.282	.230	.252	.250	.215	.260	.298
10	.210	.350	.380	.260	.280	.320	.289	.282	.270	.310	.270	.240	.265	.312	.234
S	6			7			8			9			10		
1	.212	.238	.242	.200	.232	.205	.162	.270	.198	.125	.210	.200	.190	.215	.212
2	.262	.230	.256	.352	.270	.338	.292	.212	.285	.242	.311	.282	.238	.210	.278
3	.190	.270	.217	.220	.249	.220	.205	.272	.241	.222	.212	.258	.202	.243	.219
4	.256	.374	.307	.280	.368	.280	.250	.262	.240	.248	.322	.272	.242	.330	.195
5	.232	.240	.310	.238	.235	.282	.310	.390	.265	.300	.280	.269	.190	.260	.224
6	.232	.346	.280	.274	.260	.250	.220	.310	.265	.238	.274	.262	.215	.280	.316
7	.280	.328	.260	.302	.550	.312	.316	.300	.260	.375	.288	.302	.230	.295	.347
8	.226	.230	.235	.260	.240	.235	.232	.250	.272	.270	.252	.302	.210	.195	.232
9	.212	.360	.270	.222	.240	.254	.212	.242	.252	.268	.249	.245	.298	.333	.232
10	.240	.310	.262	.230	.320	.290	.267	.315	.270	.236	.320	.240	.243	.320	.310

[1]All times are in seconds.

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13. ABSTRACT

Three types of connectors utilized in charging submarine escape appliances in simulated submarine escapes were evaluated with respect to speed of disconnect in a dry environment. Statistically significant differences in disconnect time were found between the various types of connectors, however, the magnitude of these differences is so small that they are of no practical significance in the submarine escape evolution. It is recommended that the study be repeated in a wet environment, more closely simulating actual submarine escape conditions.

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Escape and Survival Equipment, Mark I, Mod 0 (EASE)						
British Submarine Escape Immersion Suit, Mark VII (SEIS)						