OPEN SEA, SURFACE EVALUATION OF SUBMARINE ESCAPE AND IMMERSION EQUIPMENT

by

James W. Parker, M.S.
David A. Hall, LT MSC USN
Naval Submarine Medical Center

and

John J. Mellon
Naval Air Development Center

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Transmitted by:

Thomas N. Markham, CDR, MC, USN
Head, Military Operations Branch

Reviewed and Approved by:

Charles F. Gell, M.D., D.Sci.(Med)
Scientific Director
SubMedResLab

Reviewed and Approved by:

J. D. Bloom, CDR, MC USN
Director
SubMedResLab

Approved and Released by:

J. E. Stark
Captain, MC, U.S. Navy
Commanding Officer, NSMC

SUMMARY PAGE

THE PROBLEM

To assess the sea-worthiness of the Mark VII Submarine Escape and Immersion Equipment and the ACED Hooded Immersion Suit/Raft (HISR), in the open sea under varying sea state and weather conditions.

FINDINGS

Both the Mark VII SEIE and the ACED HISR performed satisfactorily and afforded the escapee with suitable protection under sea conditions such as were experienced during the trials. The Mark VII, due to the supine attitude imposed upon the escapee, is somewhat better in providing the man with conditions less favorable to the onset of the symptoms of motion sickness.

APPLICATIONS

This study provides information applicable to the design, testing and evaluation of submarine escape and survival equipment.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Unit MF12.524.006-9025B - Assessment of Factors Related to Submarine Habitability, Escape and Rescue. The present report is No. 34. The manuscript was approved for publication on 20 February 1970, and designated as Submarine Medical Research Report No. 614.

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ABSTRACT

The Mark VII Submarine Escape and Immersion Suit and the ACED Hooded Immersion Suit, Raft, were subjected to open sea evaluation using five inexperienced subjects and eight experienced Submarine Escape Tank Instructors/Divers as subjects. The sea states experienced varied from sea state 1 (smooth) to sea state 4 (rough) with the water temperature constant at 78° F, and the air temperature ranging from 74° F to 84° F. Over a four-hour test drift rates from 0.212 kt to 1.522 kts were noted. From the air the Mark VII was visible for one mile from 1000 foot altitude with the ACED suit being visible from slightly greater distances. Upon being exposed to the rotor wash from a hovering helicopter no difficulty was noted. It was concluded that both the Mark VII Submarine Escape Immersion Equipment and the ACED suit performed satisfactorily and afforded the escapee with suitable protection under the sea conditions which were experienced during the trials. The Mark VII suit, due to the supine attitude imposed upon the subject, was somewhat better in providing conditions less favorable to the onset of symptoms of motion sickness.

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INTRODUCTION

The United Kingdom Royal Navy has developed a submarine escape suit affording reasonable exposure protection when consideration is given to storage requirements, cost, simplicity of operation and capability for ascent from deep depths. This escape suit embodies the concepts of individual escape as compared with present U.S. Navy group escape philosophy. The evaluations conducted by the Royal Navy are described by Elliott, 1966. When it was decided to look at this equipment with possible view of adapting it for use in USN submarines, the Deep Submergence Systems Project Office (PM-11) tasked the Naval Submarine Medical Center (NSMC) to look into the thermal protective properties of this equipment. An extensive study was conducted by NSMC personnel with the assistance of the Naval Air Development Center, Aerospace Crew Equipment Department (ACED) and reported by Hall et al, 1968. The results of this study showed that the Mark VII suit provided 24-hour survival in 44° F air and 20 MPH wind. No studies had been made of the survival properties on the surface of the open sea, nor had any work been done on the visibility for search and rescue purposes or on the buoyancy and stability properties of the suit under varying sea conditions.

At the same time that the evaluation work was being carried on with the Mark VII Submarine Escape and Immersion Equipment (SEIE), the ACED was conducting developmental work on a submarine escape suit which would resemble the Mark VII as far as its ascent properties, but would rely on a one-man raft, similar to that used in Naval Aviation, for the surface survival mode. Comparison of the two suits is presented elsewhere as far as the egress and ascent modes are concerned.

This paper, presents a comparative evaluation of the Mark VII SEIE and the ACED suit/raft concept. The objective of this open sea evaluation of the two submarine escape suits was to assess the sea-worthiness of both the escapee and the equipment in the open sea under varying sea state and weather conditions.

DESCRIPTION OF EQUIPMENT

The Mark VII SEIE is a yellow, two layer coated fabric, CO_2 inflatable, immersion suit, with hooded type breathing/ascent system. Figure 1 shows the suit with the hood closed and the escapee wearing the gloves which are donned once the man has reached the surface after ascending from the submarine. For escape purposes the breathing/ascent chamber of the suit is inflated with compressed air in the submarine escape trunk, while the immersion protective chamber of the suit is inflated by a CO_2 cylinder upon reaching the water surface. Figure 2 shows a surfacing Mark VII suit after a simulated submarine escape. Figure 3 shows an escapee adrift in the sea

Fig. 1: The Mark VII SEIE suit.

in the Mark VII suit after inflation of the immersion protective chamber of the suit.

The hooded, immersion suit, raft (HISR) is shown in Figure 4. This suit is very similar to the Mark VII, except that it is a single-layered suit providing only the flotation characteristics by the breathing ascent chamber nearly identical to that in the Mark VII suit. No thermal protection is provided by the

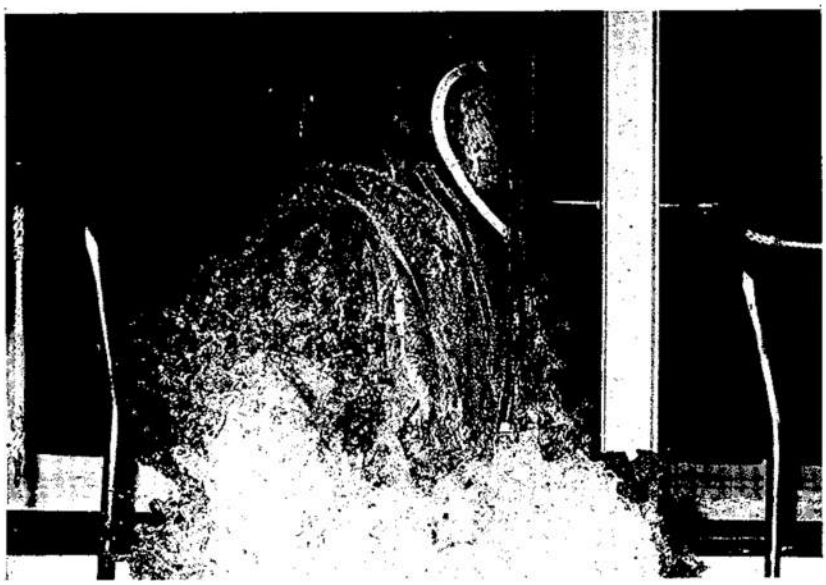

Fig. 2: The Mark VII suit surfacing from a simulated escape.

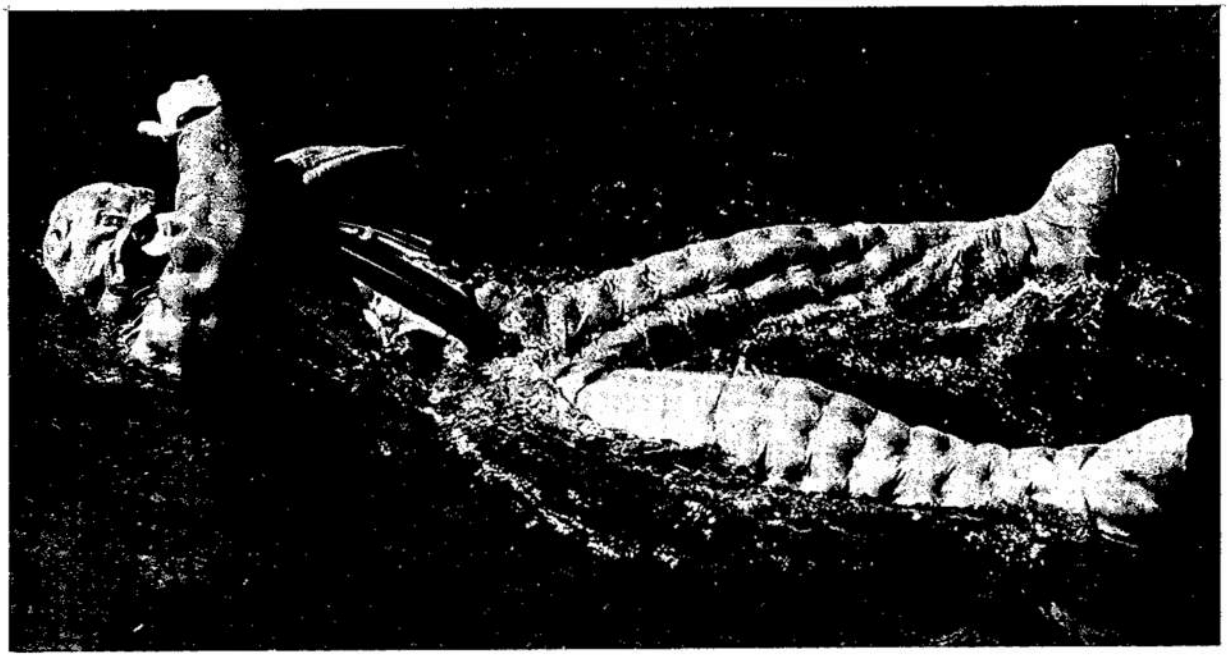

Fig. 3: Subject floating in a completely inflated Mark VII suit.

Fig. 4: The ACED hooded, immersion suit, raft (HISR).

suit itself. The surface thermal protection and flotation characteristics are provided by a one-man, aircraft type, life raft which is worn as a low-back pack by the escapee. On reaching the surface the raft is inflated by a CO_2 cartridge and is boarded by the man. Figure 5 shows the raft being boarded by a man during training. After the raft is boarded the man erects and orally inflates the canopy and bails out the accumulated water from inside the raft. The man is then completely enclosed inside the raft in a semi-sitting position as is shown in figure 6.

METHOD AND PROCEDURE

Two groups of subjects were used for the study. The first group consisted of eight Submarine Escape Training Tank instructors who also were trained divers; the second group was made up of five men who were non-divers and relatively inexperienced in and around the water except for swimming ability. The men all were attached to the Pearl Harbor Submarine Base First Lieutenant's Department and usually were assigned to general duty. No other qualifications were used in the selection of the subjects.

Since one of the factors to be evaluated with respect to the surface capabilities of the submarine escape suits was the susceptibility of the escapee to motion sickness, it was necessary to collect some background data on each which might be relevant. Personal communication with Captain L. M. Davey, MC, USNR, consultant to the Submarine Medical Research Laboratory in Otolaryngology and Neurosurgery, established that certain relevant items such as head and neck injury, participation in contact sports and ear injuries might be predictors of susceptibility to motion sickness. Therefore, it was decided to use the background form used in an earlier study having to do with motion sickness, Davey, 1963. A copy of this form is included as Appendix A. A complete profile on the subjects used can be found in Table 1, which presents a summary of the information assembled from this form. Each subject was interviewed by the senior author prior to the commencement of the study and the form completed.

Once each subject had been interviewed, the subjects and project personnel assembled at the Pearl Harbor Submarine Base swimming pool where a complete briefing was held. Both suits were shown and explained to the subjects. Each subject was given the opportunity to don each suit, enter the pool and go through the various maneuvers possible. For example, with the Mark VII SEIE the subject was shown how to inflate and deflate orally both the stole and suit proper, as well as how to roll over from a face down position to a face up position and vice versa. All other pertinent aspects of the suit were explained. Each subject then was given the opportunity to wear the ACED Hooded Immersion Suit, Raft (HISR), in the pool, and since it is similar to the Mark VII, inflate and deflate the stole portion. He was then given instruction and practice in inflating, boarding and bailing the raft as well as instruction on inflating the canopy. At the conclusion of the pool training the subjects were informed of the daily schedule and the safety precautions which would be taken at sea during the trials.

On a typical trial day the subjects and project personnel assembled at the Escape Training Tank where they were met by the project support craft (a modified LCM). All personnel then departed the base for the open sea test area which was approximately three miles seaward from the entrance to Pearl Harbor. At the test area the LCM rendezvoused with the Coast Guard Cutter CAPE CORWIN (WPB-95326). The cutter would collect the required

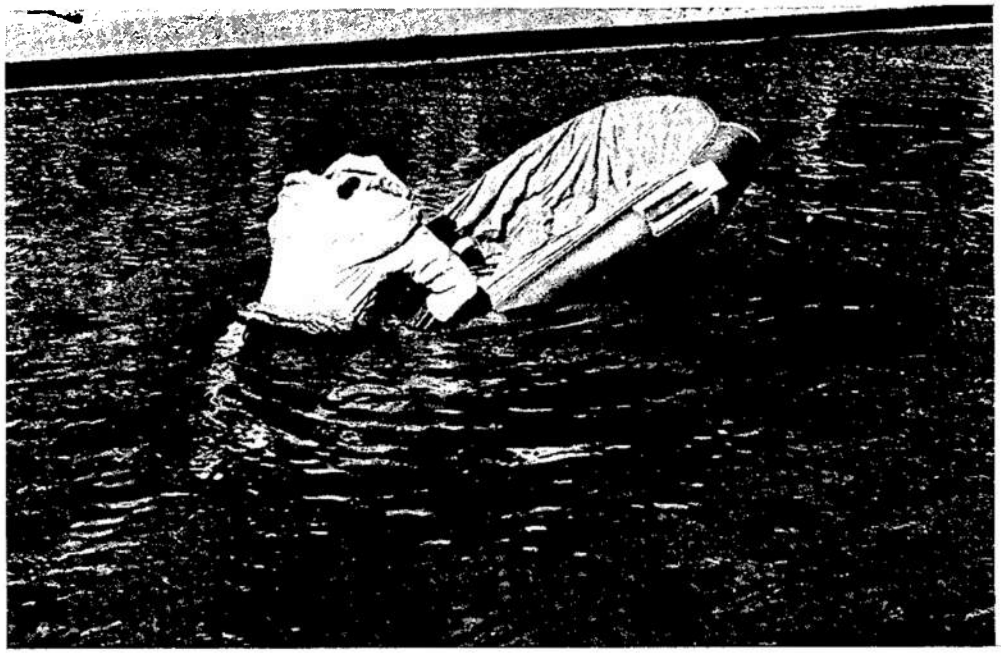

Fig. 5: One-man life raft being boarded by a man wearing the ACED HISR suit.

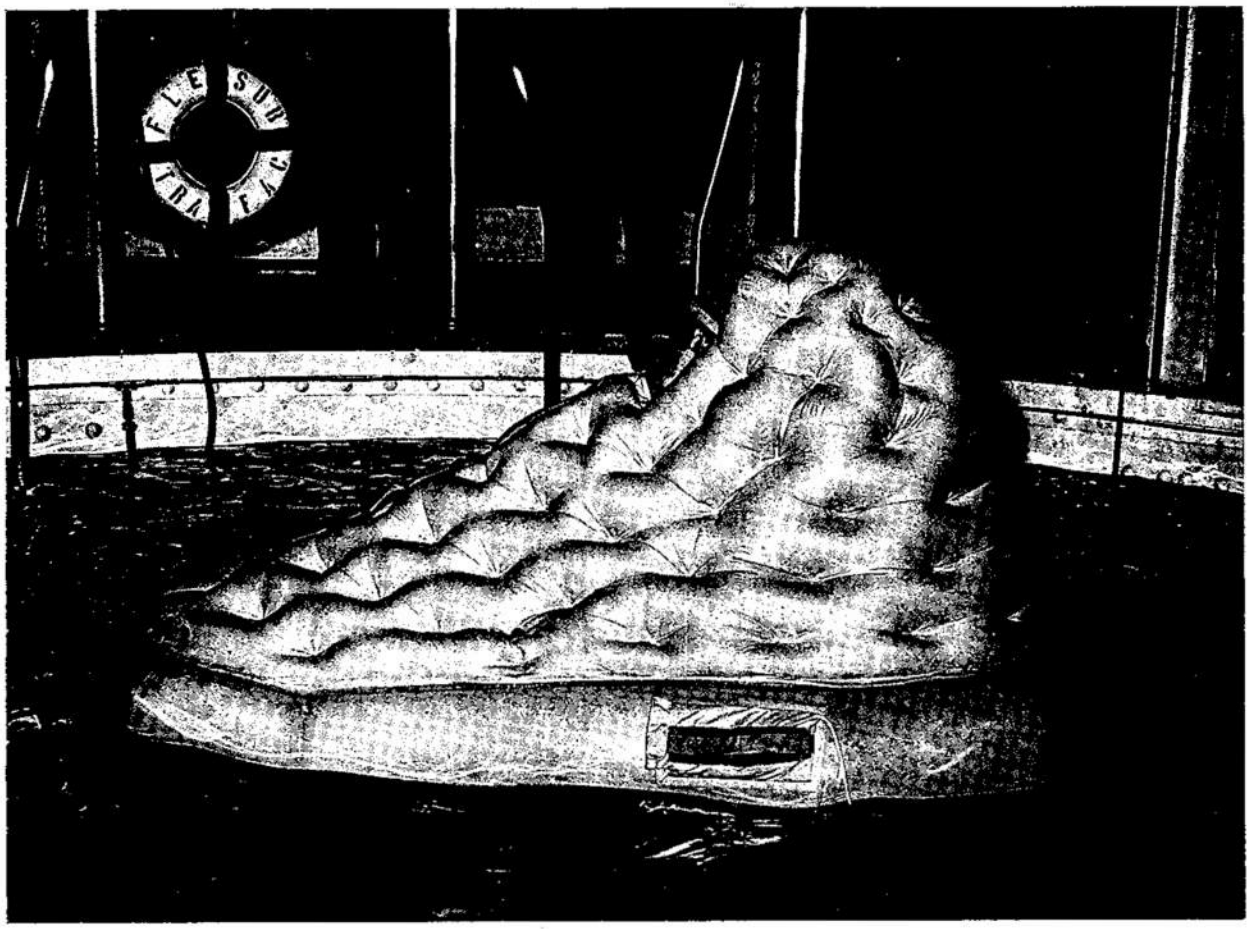

Fig. 6: The one-man life raft with inflated canopy.

Table 1. Summary of background information on seaworthiness trial subjects

Initials	Rate	Age	Contact Sports	Head Injury	Sea Sickness	Sea Duty
Instructor/Diver Subjects						
JA	EM1	34	No	No	Occasional*	10 years
MB	GMGSN	23	Yes	No	No	2 years
RB	BM2	25	No	No	No	8 years
BC	BM1	28	Yes	No	No	10 years
GG	BM1	27	No	No	Occasional*	4 years
RH	HMC	32	Some football	Yes	No	8 years
GJ	SM2	35	No	Yes	No	17 years
DK	BMC	38	Yes	No	Occasional*	18 years
Non-SS/DV Subjects						
JC	SK3	21	No	Yes#	Yes	7 months
RL	SA	18	Yes	Slight	No	none
MN	SA	19	Yes	No	No	none
LS	ETN3	21	Yes	No	Once	3 months
FY	SA	18	Some	No	No	none

Notes: * Occasional sea sickness in diver subjects was reported as being on first time out when returning to sea duty after time on shore duty.

Severe cut on forehead necessitating the wearing of glasses ever since; gets severe headaches without glasses.

Fig. 7: Rendezvousing with CAPE CORWIN (WPB-95326) and preparation of ten-man life raft.

environmental data, plot the drift course of the floating suits and provide additional safety support. While proceeding to the test area each subject was interviewed by the senior author and asked to complete the pre-trial adjective check list. This adjective check list (Appendix B) was designed to elicit systematically the inner feelings of the subject as well as any physical symptomatology which might have implications for motion sickness. Once the interview had been completed the subjects donned the suit and prepared for the four hour trial. It was the plan to have each subject participate in two trials -- one in each suit. It also was intended to have one inexperienced man paired with one instructor/diver for the trials. The former was to insure that each suit was given evaluation with both types of subjects and the latter to provide some additional safety to the trial.

Upon arriving on station a careful search of the area was made by both the Coast Guard Cutter and the LCM to insure that the area was shark free. Then the two, ten-man life rafts equipped with outboard motors were put over the side and manned by two instructor/diver safety men. The communications equipment consisting of FM walkie-talkies were checked and the subjects entered the rafts. Upon signal from the LCM the subjects entered the water with the stole portion of the suits inflated. After one minute in the water the subjects were instructed to inflate either the suit or the raft depending on which was being used. Each man was checked by the safety crew in the rubber raft and the results reported back to the LCM by radio. The safety raft then took station close to the subject so as to maintain a constant watch on the safety and well-being of the subjects as they drifted free. On the first two days at sea only two subjects were in the water, one in the Mark VII and one in the HISR. After this, four subjects were tested simultaneously for the remainder of the trials --- two men in each suit, one experienced and one inexperienced.

After one hour in the water each subject was administered an abbreviated adjective check list (Appendix C) by the senior author. This was accomplished over the walkie-talkie radios by having the rubber raft move close to the subject where the words were read to him and his response, "affirmative" or "negative" radioed back to the LCM. This abbreviated check list contained many of the adjectives

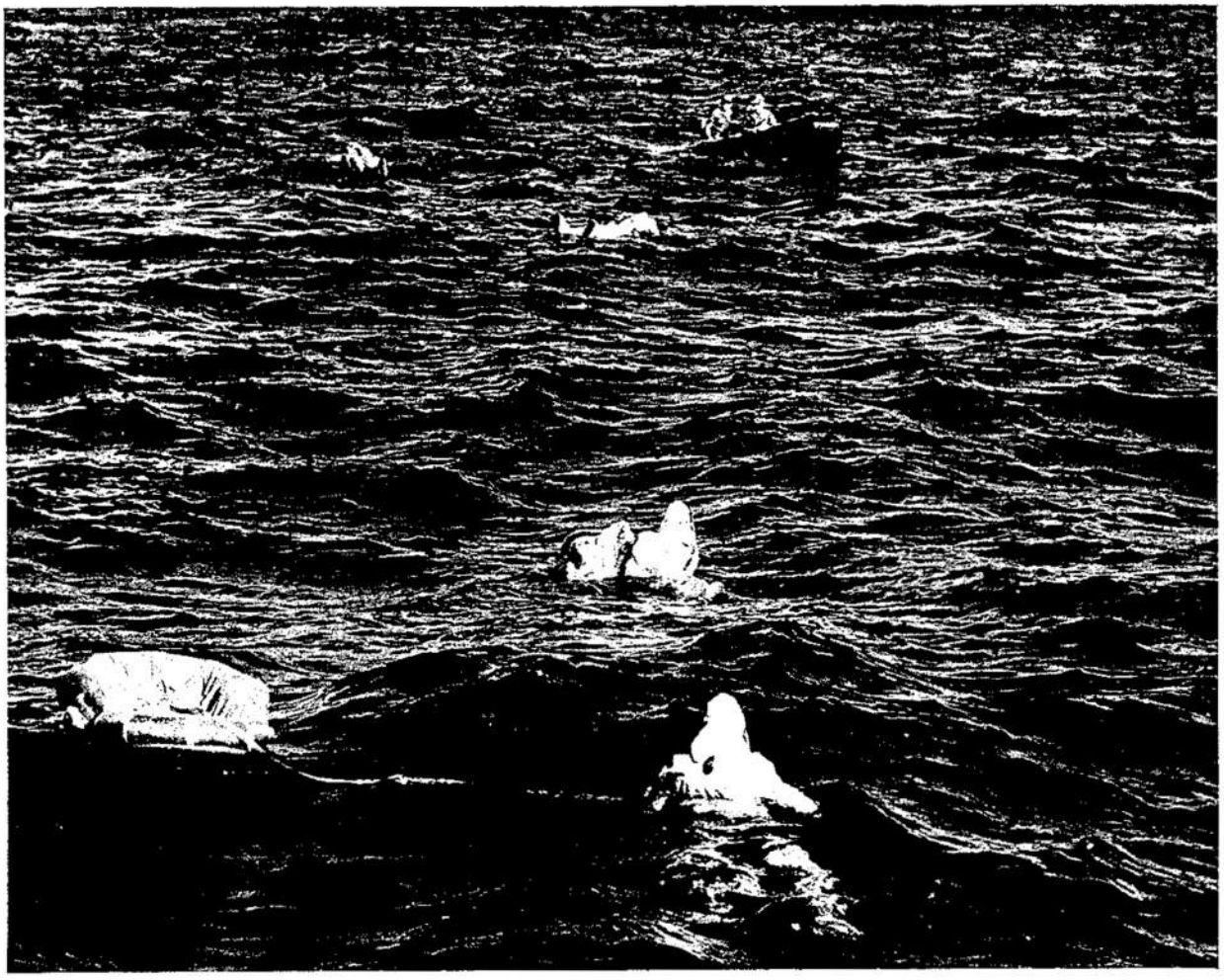

Fig. 8: Subjects floating with HISR subjects boarding life rafts; safety crew standing by.

found on the pre-trial list and was shortened for time-saving purposes. The retained words were those felt to be most pertinent to the situation and would be those which would give the investigators the best indication of the condition of the subject. This same procedure of completing the abbreviated check list for each subject was repeated as each subject completed two hours in the water and again at the three hour time. The only time this was not done was for those runs which were aborted as will be explained in a later section of this report. The subjects were to report any unusual feelings or change in between briefings and also could abort at any time. At the completion of four hours in the water the rubber boats were instructed to pull the subjects from the water and return to the LCM. It should be pointed out at this time that during the four hour exposures in the water the subjects were left alone and were not permitted to smoke, drink or eat. Their only contact with support personnel was during the short periods when the check lists were being administered. Once the subjects had been brought aboard the LCM, they were permitted to remove the suits. During this time they were interviewed by the senior author and asked to again complete the same check list as they had prior to entering the water. They also were interviewed by ACED personnel with respect to the suits and/or rafts and any problems connected therewith.

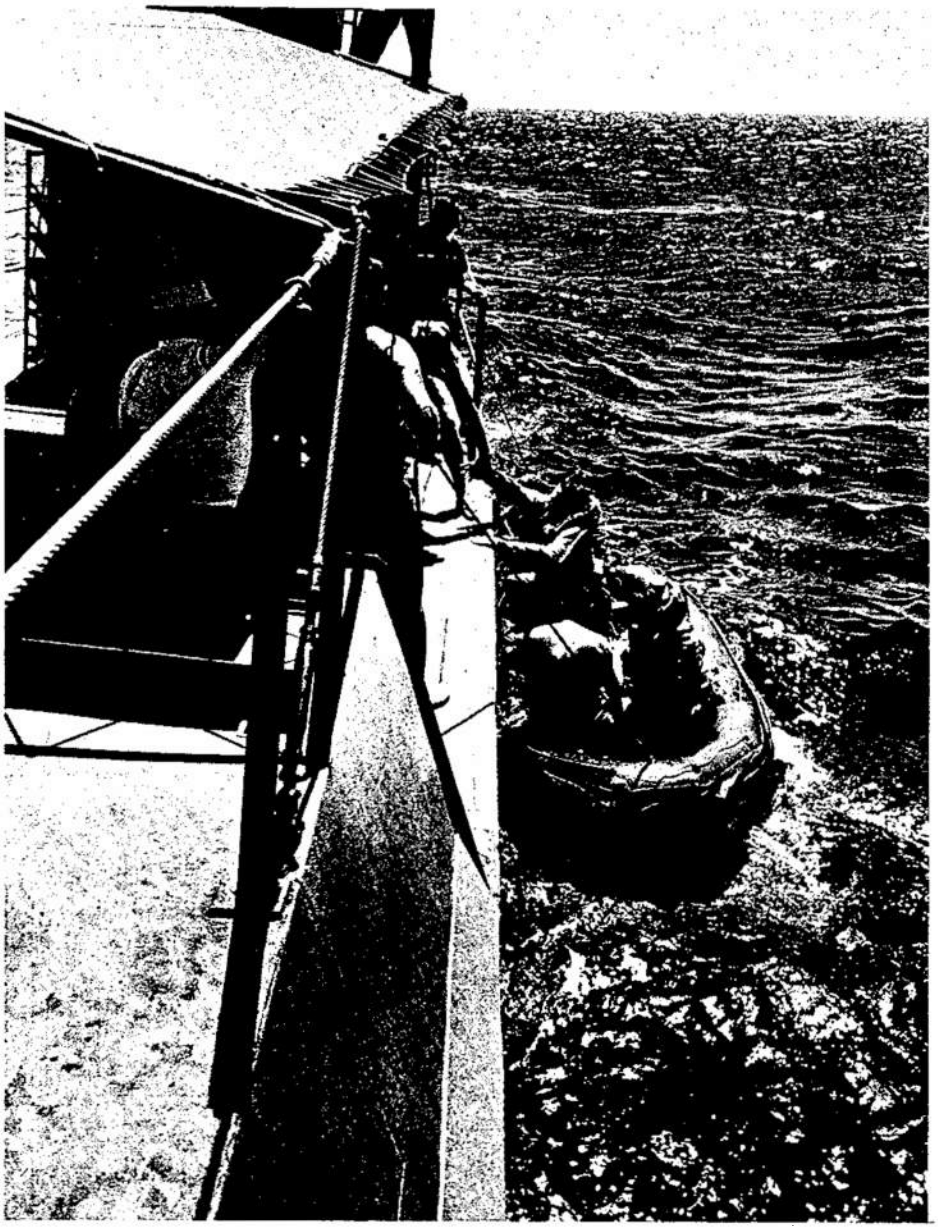

Fig. 9: Subjects being brought back aboard support craft.

As soon as all the subjects and equipment had been brought aboard the LCM the craft proceeded back to Pearl Harbor. During this time the subjects were permitted to eat, put on dry clothing, and essentially make themselves comfortable. Project personnel then held the final debriefing on the day's trial. Plans for the following day also were discussed at this time.

RESULTS

This section of the report will present the results of the surface, at-sea trials. Since conditions under which each of the six trials took place were different, no attempt will be made to lump the results together; instead each trial will be presented and discussed separately. Table 2 summarizes the six trials and presents the overall plan which was ultimately followed. It will be noted that the five, inexperienced subjects did participate in all trials, once in the Mark VII suit and once in the ACED HISR suit. For varying reasons the instructor/diver subjects did not all complete the planned two trials each. Nevertheless, it is not believed that this design change affected the results significantly. It also can be seen in Table 2, that the sea varied from sea state 1 (smooth) in trials 5 and 6, to rough in trial 2, giving a fair spread of varying conditions which will enhance the value of the study.

Each trial will now be presented in detail including a summary of the responses to the check lists made by the subjects. The presentation of each trial will conclude with a summary of the observations made by project personnel and comments by the subject:

Trial No. 1:

Two subjects: Sea State: 3 (moderate)

FY: non-SS/DV Mark VII suit
GJ: DV HISR suit

Pre-trial check list:

FY: felt good, but somewhat nervous, no other complaints.
GJ: a very outgoing subject; checked 47 of the 123 adjectives, none indicating any nervousness or other complaint.

After 1 hour:

FY: no complaints except "a little wet" and sleepy.
GJ: no complaints.

After 2 hours:

FY: wet, drowsy, tired.
GJ: warm and happy.

After 3 hours:

FY: warm, wet, drowsy, tired.
GJ: cool, calm, contented.

Post-trial check list:

FY: happy, safe, secure, tired, drowsy, wet.
GJ: no adverse comments.

Table 2. Summary of trials, including sea state and subjects

Trial	Sea State	Subjects	
		Mark VII	HISR
1	3 (moderate)	FY	GJ (DV)
2	2 increasing to 4 (slight to rough)	MN (notes 1, 2)	RB (DV) (notes 1, 4)
3	3 (moderate)	JA (DV) RL	MB (DV) FY
4	2 increasing to 3 (slight to moderate)	JC (note 3) GG (DV)	MN BC (DV)
5	1 (smooth)	LS GJ (DV)	RL DK (DV)
6	1 (smooth)	RH (DV) BC (DV)	JC LS

Notes: DV = Instructor/Diver subject
1. Subject vomitted
2. Run aborted after 2.75 hours
3. Run aborted after 2.00 hours
4. Run aborted after 3.00 hours

Summary:

Subjects reported no adverse reactions to drift. Suits functioned as designed. Successful trial.

Trial No. 2:

Two subjects: Sea state: 2-4 (slight increasing to rough)

MN:	non-SS/DV	Mark VII suit
RB:	DV	HISR suit

Pre-trial check list:

MN: felt good except for being nervous and tense.
RB: thirsty; had banana pie for breakfast.

After 1 hour:

MN: impatient, unhappy, mouth salty.
RB: disgusted, irritated, miserable, nauseous, had vomitted.

After 2 hours:

MN: somewhat nauseous, cold, wet, mouth salty, had vomitted.
RB: suffering, wet, tired, chilly, wanted to be left alone.

After 2.75 hours:

MN: taken from water - run aborted - man very cold and shaking.

After 3 hours:

RB: wet, drowsy, tired, grouchy - run aborted.

Post-trial check list:

MN: cold, impatient, miserable, nauseous, panicky, shaky, tense, upset, wet, chilly.
RB: safe, drowsy, sleepy - felt better after throwing up and falling asleep.

Summary:

MN became ill and vomitted after being brought aboard LCM; recovered after one hour on way back to port. RB reported no further symptoms. Sea was rough, wave height 5 to 8 feet, and both subjects showed all signs of true motion sickness. No problems encountered with the suits. Subject complaining of being cold is believed to be due to effects of motion sickness rather than from the thermal properties of the suit. Water temperature was 78°F.

Trial No. 3:

Four subjects: Sea state: 3 (moderate)

MB:	DV	HISR suit
FY:	non-SS/DV	HISR suit
JA:	DV	Mark VII suit
RL:	non-SS/DV	Mark VII suit

Pre-trial check list:

MB: no complaints, had breakfast consisting of six eggs, potatoes, and juice; had duty night before.
FY: no complaints, second trial for subject; had toast and coffee for breakfast; no drinking night before.
JA: no complaints; no breakfast; no drinking night before.
RL: felt tired, sleepy and sullen; no breakfast; several beers night before.

After 1 hour:

MB: nauseous, impatient, drowsy.
FY: a little nauseous, a little wet, liked Mark VII suit better.
JA: bored, impatient, miserable, wet, headache, fingers numb off and on, has to urinate.
RL: lonely, a little wet, drowsy, tired.

After 2 hours:

MB: contented, drowsy, right arm numb.
FY: a little wet.
JA: miserable, urinated OK, wet, tired, chilly, headache.
RL: a little damp, lonely, drowsy.

After 3 hours:

MB: warm, sleepy.
FY: a little wet, drowsy.
JA: impatient, miserable, wet, tired, chilly, headache.
RL: lonely, getting wet, sleepy.

Post-trial check list:

MB: no complaints.
FY: wet, hungry, drowsy.
JA: nauseous, hungry, tired, chilly, headache, sun-burned face.
RL: wet, no other complaints.

Summary:

Subjects reported no adverse reactions to drift; however, subject JA did have moderately severe facial sunburn requiring medication. Suits functioned as designed.

Trial No. 4:

Four subjects: Sea state: 2-3 (slight increasing to moderate)

JC:	non-SS/DV	Mark VII
GG:	DV	Mark VII
MN:	non-SS/DV	HISR suit
BC:	DV	HISR suit

Pre-trial check list:

JC: enthusiastic, interested, nervous, hungry (never eats breakfast); attended movie night before.
GG: nothing adverse.
MN: no complaints, nervous (second time out).
BC: nothing adverse.

After 1 hour:

JC: impatient, somewhat miserable and nauseous, tense, back wet, a little chilly, having trouble keeping suit inflated.
GG: a little wet, toes numb, "suit feet too small".
MN: drowsy, real comfortable.
BC: drowsy.

After 2 hours:

JC: discouraged, miserable, nauseous, nervous, wet, fingers, legs, feet and toes numb.

Subject taken from water; cold and shivering; reports he had dry heaves half hour after entering water, but OK after that. Subject reported his suit kept losing air in small of back; he stayed flat with head back in full supine position. When questioned about having no breakfast, he reported that he gets sick if he tries to eat.
GG: a little wet.
MN: lonely, drowsy, mouth dry.
BC: warm and happy.

After 3 hours:

GG: warm, toes numb, suit feet too tight.
MN: lonely, warm, mouth dry.
BC: contented.

Post-trial check list:

GG: no complaints, but found hands slightly numb from cuffs being tight; also feet; deflating suit slightly helped.
MN: no complaints; liked HISR better than Mark VII, "easier to relax".
BC: no complaints.

Summary:

When brought aboard the LCM subject JC was observed to be pale and shivering. It was noted that his body was wet as were his swim trunks. However, no quantity of water was found inside the suit. This would indicate that the wetness and subsequent cold sensation probably was due to the motion sickness and not to the leaking of the suit. Subject also reported that sea water was washing over his face during the trial. Subject completely recovered during trip back to Pearl Harbor. Subject GG reported no difficulty, however he experienced difficulty in keeping the suit inflated. This difficulty was due to several minor rips and tears in the outer suit from the handling during many trials. This suit was removed from further use in the trials. Aside from that just mentioned no other problems with either the Mark VII suit or the HISR suit was noted. Subjects inside the canopy of the one man raft reported it being quite warm, but this could be eliminated by opening the closure.

Trial No. 5:

Four subjects: Sea state: 1 (smooth)

LS:	non-SS/DV	Mark VII suit
GJ:	DV	Mark VII suit
RL:	non-SS/DV	HISR suit
DK:	DV	HISR suit

Pre-trial check list:

LS: cooperative, drowsy.
GJ: enthusiastic, talkative; very outgoing as in previous trial (second time out).
RL: cheerful, cooperative (second time out).
DK: enthusiastic, interested.

After 1 hour:

LS: irritated, wet, chilly, complaining about suit leaking air - is topping off orally.
GJ: contented, lonely, suit leaking air - topping off orally.
RL: lonely, contented, drowsy, a little tired.
DK: happy, warm.

After 2 hours:

LS: irritated, unhappy, wet, chilly, back is cold; topping off suit every 4-5 minutes.
GJ: warm, complaining; topping off suit every half hour.
RL: contented, secure, a little sleepy.
DK: no complaints, wants a cigarette (not granted).

After 3 hours:

LS: irritated, wet, same complaints as before regarding suit.
GJ: warm, feels good.
RL: happy, tired, sleepy.
DK: warm, sleepy.

Post-trial check list:

LS: feels good, warm, thirsty.
GJ: usual outgoing, talkative self.
RL: cheerful, pleasant, secure, hungry.
DK: enthusiastic, warm, hungry.

Summary:

Suit leaks are due to small rips and tears resulting from their continued use in these trials. Temporary patches were made in an attempt to minimize this problem. All subjects reported no other discomforts other than those already noted. Those

subjects in the one-man rafts wearing the HISR suit reported being somewhat warm. They alleviated the condition by opening the canopy closure. During this trial all subjects were subjected to the downwash from a helicopter conducting a simulated search and rescue mission as well as a photographic mission. Even with the helicopter hovering at 12 to 15 feet over the subjects, none reported any problem with water spray or ducking; they did report feeling the wind blast with no discomfort. The helicopter reported being successful in moving the subjects in both the Mark VII and HISR suits with the wind blast. As before both suits performed as designed.

Trial No. 6:

Four subjects: Sea state: 1 (smooth)

RH:	DV	Mark VII suit
BC:	DV	Mark VII suit
JC:	non-SS/DV	HISR suit
LS:	non-SS/DV	HISR suit

Pre-trial check list:

RH: cooperative, enthusiastic, interested.
BC: cooperative, happy (second time out).
JC: calm, cheerful, enthusiastic, interested, nervous, tense (second time out).
LS: calm, cooperative, discontented, impatient, understanding (second time out).

After 1 hour:

RH: calm, contented, safe, warm.
BC: contented, secure, warm.
JC: contented, safe, warm, wet
LS: happy, secure, tired, sleepy.

After 2 hours:

RH: calm, happy, safe, warm.
BC: calm, happy, safe, warm.
JC: contented, safe, warm, wet.
LS: calm, happy, tired, sleepy.

After 3 hours:

RH: bored, impatient, secure, warm.
BC: bored, happy, warm, a little wet.
JC: calm, happy, warm, wet.
LS. calm, safe, warm, tired.

Post-trial check list:

RH: amused, bored, enthusiastic, warm, wet, thirsty, hungry.
BC: bored, cheerful, happy, warm, wet, hungry
JC: calm, cheerful, safe, wet, hungry.
LS: cheerful, happy, safe, tired.

Summary:

All subjects reported no adverse reactions to the four hour drift. Those subjects who had just completed their second runs all reported that they preferred the Mark VII suit to the HISR. All suits performed as designed.

DISCUSSION

The results of the six trials just presented most adequately can be summarized by stating that they were a complete success. The sea state on the six days varied from smooth to rough with the water temperature remaining constant at 78°F, and the air temperature ranging from 74°F to 84°F. All subjects cooperated well and no problems were encountered.

When the Mark VII suit was inflated by the CO_2 system to design shape, the subject was automatically floated on his back in the manner shown in Figure 3. In a smooth sea with less than one foot wave height and light winds (1-3 knots), the Mark VII appeared to float the subject in an almost completely horizontal, supine position. This attitude generally persisted through wave heights up to the four to five foot range with wind velocities up to 20 knots. The amount of buoyancy present in the CO_2 inflated suit appeared adequate in that there was no observed tendency for the suit to get "out of phase" with the waves in choppy seas. If the amount of buoyancy in the suit was not adequate, then in choppy seas it could be anticipated that the subject would fail to rise to the top of each wave, and consequently would be repeatedly "ducked". No such tendency in the Mark VII was noted in the sea conditions encountered during the trials. The suited subject appeared to drift on the sea surface as a relatively rigid unit rather than as a sectional, undulating unit.

The large surface area of the suit, the freeboard created by the excess buoyancy of the suit and a slight rise from the supine position evident in the hooded area of the suit all apparently combine to create a "sail" effect so that the subject drifts or "sails" down wind. Aside from the normal motion effects of the sea, no distinctively rotating, twisting or turning moments that could be attributed to the design of the Mark VII suit were observed in the trials. However, some tendencies of the outstretched legs to rotate back and forth were noted in moderate and choppy sea conditions. From the data and visual observations it is considered that the Mark VII suit exhibited good sea-worthiness in the sea states encountered during the trials. Further, from the excellent behavior of the suit during the choppy seas encountered in one of the trials, it can be considered that the suit would continue to exhibit sea-worthiness in much higher sea states than those encountered in these particular trials.

With respect to the HISR suit and raft, it can be said that some difficulty was experienced by the subjects in boarding the one-man life raft once it was inflated. The degree of difficulty seemed to increase as the sea state increased. The subjects also experienced some difficulty in erecting the collapsed canopy. This probably was due to the manner in which it had been folded for packing. Once erected no difficulty was experienced in the inflation of the canopy. The next part of the evolution involved the bailing of the water from the raft. The usual depth of water in the rafts was approximately eight inches. With the small collapsible cup provided with the raft, and having to pour the water out through a tube in the

side of the canopy, it was not unusual for the time necessary for the bailing to exceed 20 to 25 minutes. The deploying of the sea anchor attached to the raft presented no problem; however, once deployed the line attaching the sea anchor to the raft twisted due to the nearly constant rotation of the sea anchor itself, and, thereby, shortening the length of the tether line. The canopied raft with the subject enclosed appeared to ride high on the sea and was able to ride the tops of the waves. Comfort-wise the subjects reported that the most comfortable position was to slouch down with the back of the neck resting on the after gun-whale of the raft. Also, in sunny, warm weather the interior of the canopied raft became somewhat uncomfortably hot; the subjects countered this by opening the canopy and riding with the head exposed. As with the Mark VII suit it is considered that the raft/suit combination exhibited good sea-worthiness in the sea states encountered and that it would continue to exhibit sea-worthiness in much higher sea states.

From a search and rescue viewpoint it was the opinion of the Coast Guard Project Officer that the effect of tidal currents on the drift rate of both the Mark VII and HISR suits was negligible with the wind velocity and direction being the major factors in surface drift. It was noted that the drift rate varied from a low of 0.212 knots to a high of 1.522 knots. The environmental data indicates some relationship probably exists between drift rate and wind velocity, wave/wind directions and wave height. It is evident, in retrospect, that some additional sea state factors such as wave length, wave period and wave velocity should also be considered for inclusion in any future drift trials. It is quite possible that some of the reasons for the variations in drift rate would be more evident if such additional data were to be collected. It should also be noted that the Mark VII suits tended to drift a greater distance than did the HISR -- a fact attributable to the presence of the sea anchor on the one-man raft portion of the HISR.

Visibility checks also were made by the Coast Guard. From CAPE CORWIN the Mark VII was visible from a distance up to a one mile maximum (surface visibility, 10 miles; 15 knot wind; two to three foot sea). Additional checks were made from a helicopter from the Barber's Point Coast Guard Air Station. From the air the Mark VII was visible for one mile from an altitude of 1000 feet (weather, clear to hazy; surface visibility, 7 miles). The one-man raft was visible from slightly longer distances. Neither the Mark VII nor the HISR one-man raft could be detected by radar from CAPE CORWIN. Both the Mark VII suit and the HISR life raft were yellow in color. Visibility perhaps would have been better had they been made from a red material since previous work, Malone 1953, has demonstrated that a red between 2.5 and 7.5 is more easily detected at search distances than the standard lifeboat yellow.

During one of the trials two drifting subjects in the Mark VII and two in the one-man raft were exposed to downwash from a helicopter hovering near the subjects at an altitude of 12 to 15 feet while performing a photographic support mission and simulated pick up. The subjects reported feeling the rotor wash in the Mark VII, but indicated no water or spray passed under the suit hood. The subjects in the raft also reported no water or spray problem. Because of the lack of mobility and the bulk of the subjects in the Mark VII suit it should be anticipated that helicopter-type rescues may be difficult with either the rescue sling (horse collar) or the Boyd (three pronged) seat currently in use. However, the newly adopted Billy Pugh Rescue Net would appear to offer the best possibility for rapid helicopter recovery. It would appear that the HISR suit would be only slightly more adaptible to helicopter rescue as compared with the Mark VII suit. Regardless of the system adopted, a formal development and documentation of helicopter rescue procedures for recovery of suited survivors should be completed and made available for use by all air rescue services.

It was anticipated that the signs and symptoms of motion sickness would be seen during these sea-worthiness trials. It is well known that the primary cause of motion sickness is motion, although many stimuli (visual, psychic, visceral) may contribute to its incidence. A rotary component of motion (rolling and pitching of the Mark VII or the one-man life raft) is necessary to produce motion sickness. This motion was, in fact, experienced by the subjects in both the Mark VII suit and the HISR. It was expected that the supine position of the subject in the Mark VII suit together with the lack of head movement would favor this equipment in terms of sea-sickness when compared with the raft where the subject was in a semi-sitting position with the head free to move. It also was expected that many hours would be needed for the onset of the symptoms of motion sickness, and a gradual increase in these symptoms was anticipated beginning with pallor, cold perspiration, dizziness, vertigo, and leading to nausea and vomiting. No attempt was made to study the motion sickness itself in the subjects. Only the occurrence of or lack thereof was recorded.

Analysis of the results found with the check lists and interviews indicates that any motion sickness problems which did arise during the trials were detected in the check lists. The personal history data collected before the trials, while not conclusive, did indicate that one subject (JC) probably would be susceptible to motion sickness during the trials. The sea state during the trial increased from slight to moderate (wave heights increasing from two to five feet) and probably added to the problem. Both subjects in trial 2 were pulled from the water before completion of the planned four hour duration. In this trial the sea state rapidly increased from slight to rough (wave heights increasing from two to eight feet). Examination of the personal history data of the inexperienced subject (MN) showed nothing which might have predicted his susceptibility. The experienced subject (RB) had eight years of sea duty and had not been sea sick. However, upon questioning by the senior author it was learned that this man had been drinking the night before and had eaten a breakfast consisting of banana pie. While subject MN did not vomit, he exhibited the classic signs of motion sickness and was removed from the water. Subject RB was in the one-man raft wearing the HISR suit. The raft was observed to be experiencing all the rotary

components of motion which are known to enhance the onset of motion sickness. The balance of the subjects did not, for the most part, experience any serious difficulties, only discomforts.

One artifact in the trials is worthy of mention and discussion. During the later trials many subjects wearing the Mark VII suit complained about being wet and the suit's leaking air. It should be pointed out that, at no time, did the stole or "life jacket" portion of the suit leak air and thus endanger the safety of the subject. All the leaks reported were in the suit proper - that which provides the additional surface buoyancy and thermal protection of the suit. These leaks were all due to the fact that these suits, while designed for one time use, had been used for previous trials in this study as well as for ascent work in the escape training tank. The rubberized, Egyptian cotton, from which they are constructed just cannot take the mechanical punishment of donning and doffing, walking around on steel deck plates, jumping in and out of rubber rafts, and being subjected to numerous other abrasions, through handling and storage. These facts must be kept in mind when evaluating the performance of the Mark VII suit. On the other hand, these problems were not encountered with the ACED HISR suit and one-man life raft. The HISR suit was constructed of a heavier, much stronger synthetic material which was much more resistant to mechanical damage. No leakage was noted with this suit in the water. Once the man had entered the life raft he was isolated from the sea. Any leakage problems with the life rafts was minimum and could be handled on a day to day basis.

At the conclusion of the trials the subjects and project personnel attended a debriefing session. The subjects were given the opportunity to express preference for one suit or the other. These informal comments, while not conclusive, seem to lean towards the Mark VII suit as the preferred one. The primary objection to the HISR suit and one-man raft was to the problem with boarding the inflated raft and the subsequent problems with erecting the canopy, inflating the canopy, bailing the water from the raft and inflating the floor of the raft. In rough seas the subjects felt they would have a better chance of survival in the Mark VII, due to the simplicity of the evolution once on the surface. Certain subjects did prefer the one-man raft since it affords them the opportunity to assume a more natural, semi-sitting position, once it has been completely erected and inflated.

CONCLUSIONS

It can be concluded from these sea-worthiness trials that:

1. The Mark VII Submarine Escape and Immersion Equipment, when inflated to design shape and in an intact condition, satisfactorily performed as a sea worthy device in the sea state and weather conditions encountered during these trials.

2. The ACED Hooded Immersion Suit/Raft equipment affords the escapee with suitable protection in the open sea under conditions such as were experienced during these trials.

3. The Mark VII suit, due to the supine attitude imposed upon the escapee, is somewhat better in providing the man with conditions less favorable to the onset of the symptoms of motion sickness.

4. The techniques used in these trials provides sufficient information for the evaluation of the well-being of the subject during the periods of drift on the open sea.

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APPENDIX A

Pre-Trial Personal History Form

APPENDIX A

NAME_____ DATE_____

RATE_____ SERIAL NUMBER _____ AGE_____

1. PERSONAL HISTORY

   A. Contact sports:
      indicate which

   B. Head injuries:
      unconsciousness

   C. Neck injuries:
      nature

   D. Ear diseases:
      nature

   E. Exposure to pressure:
      failed

      passed
        what depth

   F. Motion sickness:
      nature

   G. Sea duty:

APPENDIX B

Pre- and Post-Trial Check List

APPENDIX B

PRE- AND POST-TRIAL CHECK LIST

1	( )	active	42	( )	friendly	83	( )	satisfied
2	( )	adventurous	43	( )	frightened	84	( )	secure
3	( )	afraid	44	( )	furious	85	( )	shaky
4	( )	agitated	45	( )	glad	86	( )	shy
5	( )	agreeable	46	( )	gloomy	87	( )	steady
6	( )	agressive	47	( )	good-natured	88	( )	stubborn
7	( )	amiable	48	( )	grim	89	( )	stormy
8	( )	amused	49	( )	happy	90	( )	strong
9	( )	angry	50	( )	healthy	91	( )	suffering
10	( )	annoyed	51	( )	hostile	92	( )	sullen
11	( )	awful	52	( )	impatient	93	( )	sympathetic
12	( )	bitter	53	( )	indignant	94	( )	tense
13	( )	blue	54	( )	inspired	95	( )	terrible
14	( )	bored	55	( )	interested	96	( )	terrified
15	( )	calm	56	( )	irritated	97	( )	thoughtful
16	( )	cautious	57	( )	joyful	98	( )	timid
17	( )	cheerful	58	( )	lonely	99	( )	tormented
18	( )	cold	59	( )	lost	100	( )	understanding
19	( )	complaining	60	( )	low	101	( )	unhappy
20	( )	contented	61	( )	lucky	102	( )	upset
21	( )	contrary	62	( )	mad	103	( )	warm
22	( )	cool	63	( )	mean	104	( )	wet
23	( )	cooperative	64	( )	mild	105	( )	wild
24	( )	critical	65	( )	miserable	106	( )	willful
25	( )	cross	66	( )	nauseous	107	( )	wilted
26	( )	daring	67	( )	nervous	108	( )	worying
27	( )	desperate	68	( )	obliging	109	( )	vigorous
28	( )	devoted	69	( )	offended	110	( )	sluggish
29	( )	disagreeable	70	( )	outraged	111	( )	drowsy
30	( )	discontented	71	( )	panicky	112	( )	thirsty
31	( )	discouraged	72	( )	patient	113	( )	hungry
32	( )	disgusted	73	( )	peaceful	114	( )	tired
33	( )	displeased	74	( )	pleased	115	( )	fed up
34	( )	dizzy	75	( )	pleasant	116	( )	angry
35	( )	energetic	76	( )	powerful	117	( )	talkative
36	( )	enraged	77	( )	quiet	118	( )	mouth dry
37	( )	enthusiastic	78	( )	reckless	119	( )	chilly
38	( )	fearful	79	( )	rejected	120	( )	headache
39	( )	fine	80	( )	rough	121	( )	eyes blurred
40	( )	fit	81	( )	sad	122	( )	sleepy
41	( )	free	82	( )	safe	123	( )	fingers numb

NAME_____ DATE/TIME_____

APPENDIX C

Abbreviated Adjective Check List

APPENDIX C

ABBREVIATED ADJECTIVE CHECK LIST

1	( )	angry	18	( )	nauseous	33	( )	drowsy
2	( )	annoyed	18	( )	nervous	34	( )	tired
3	( )	bored	19	( )	panicky	35	( )	fed up
4	( )	calm	20	( )	safe	36	( )	angry
5	( )	complaining	21	( )	satisfied	37	( )	grouchy
6	( )	contented	22	( )	secure	38	( )	refreshed
7	( )	cool	23	( )	shaky	39	( )	mouth dry
8	( )	discouraged	24	( )	suffering	40	( )	chilly
9	( )	disgusted	25	( )	tense	41	( )	headache
10	( )	fearful	26	( )	terrified	42	( )	eyes blurred
11	( )	frightened	27	( )	unhappy	43	( )	sleepy
12	( )	happy	28	( )	upset	44	( )	heart palpitates
13	( )	impatient	29	( )	warm	45	( )	fingers numb
14	( )	irritated	30	( )	wet	46	( )	legs numb
15	( )	lonely	31	( )	worrying	47	( )	feet numb
16	( )	mad	32	( )	sluggish	48	( )	toes numb
17	( )	miserable						

NAME_____ DATE/TIME_____

1	( )	angry	18	( )	nauseous	33	( )	drowsy
2	( )	annoyed	18	( )	nervous	34	( )	tired
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NAME_____ DATE/TIME_____

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13. ABSTRACT

The Mark VII Submarine Escape and Immersion Suit and the ACED Hooded Immersion Suit, Raft, were subjected to open sea evaluation using five inexperienced subjects and eight experienced Submarine Escape Tank Instructors/Divers as subjects. The sea states experienced varied from sea state 1 (smooth) to sea state 4 (rough) with the water temperature constant at 78°F, and the air temperature ranging from 74°F to 84°F. Over a four-hour test drift rates from 0.212 kt to 1.522 kts were noted. From the air the Mark VII was visible for one mile from 1000 foot altitude with the ACED suit being visible from slightly greater distances. Upon being exposed to the rotor wash from a hovering helicopter no difficulty was noted. It was concluded that both the Mark VII Submarine Escape Immersion Equipment and the ACED suit performed satisfactorily and afforded the escapee with suitable protection under the sea conditions which were experienced during the trials. The Mark VII suit, due to the supine attitude imposed upon the subject, was somewhat better in providing conditions less favorable to the onset of symptoms of motion sickness.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Escape appliance						
Sea worthiness						
Air/Sea rescue						