What is the Survival Suit Designed to Do, and Will it Work for Me in the Event of a Ditching or Ship Abandonment?

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SUMMARY
Three hundred and fifty seven people attended a series of practical survival courses at Survival Systems Ltd., Dartmouth, Nova Scotia between January and June, 2001. Each of the attendees earns their living either working on, or flying over water. During the courses, they wore a variety of survival suits: a helicopter passenger suit; a marine, one-size-fits-all ship abandonment suit; or a military constant wear survival suit. At the beginning and the end of the course, a questionnaire was administered to enquire about (a) the reasons for wearing such a suit, (b) the ergonomics of the suit, and (c) how much confidence they had that the suit would do its job in the case of ship abandonment or helicopter ditching. Pre-course, little was known about the four stages of immersion, but the anecdotal evidence that there was general dissatisfaction with the suits was not generally borne out by the results. Water integrity was better than expected; this can be attributed to better manufacturing procedures, fabrics and standards. An interesting finding was that those people with small wrists or wearing a suit with slack fit of the wrist seal, benefited from tightening the seal with duct tape. The opinions on the ergonomics of the suits followed a normal distribution curve, with the majority of people expressing a relatively good opinion. Most people had confidence that they would survive in them. Post course, the degree of knowledge of the dangers of sudden cold water immersion had improved, but will require re-testing at a later date to investigate the retention factor.

INTRODUCTION

From Biblical times until the middle of the 20th Century, loss of life from cold water immersion was generally ignored. Finally, in 1943, the British Medical Research Committee (Reference 12) published a pamphlet on "The Guide to the Preservation of Life at Sea After Shipwreck". This was based on the observations of naval medical officers who had treated survivors, and on 279 survivor interviews. This document was the basis from which all the modern physiological research has been conducted on cold water immersion.

After the Second World War, two other reports were to follow that revealed the shocking loss of life at sea which could have been prevented. The first was the Talbot Report (1946) (Reference 13). This study showed

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the inadequacy of the RN lifebelt and the Carley type floats. Over 30 000 men died after escaping from their ships, in other words, during the survival phase. The second study was the Medical Research Committee report by McCance et al (1956) which investigated "The Hazards to Men in Ships Lost at Sea 1940 – 1944". This examined in greater detail the cause of death at sea (Reference 10).

The pioneering post-war work was conducted under the auspices of the Royal Navy Personnel Research Committee and subsequently the Royal Navy Institute of Naval Medicine. This was summarized in Professor Keatinge's monograph (1969) (Reference 9). As a result of all the aforementioned information, it had become clear that the human body cannot maintain its internal body temperature when immersed in water below 25°C when conscious and shivering. The body temperature must progressively fall until death occurs. However, there was much more to the problem than a drop in the body core temperature.

Golden and Hervey (1981) (Reference 7) identified four distinct stages in which a human immersed in cold water may become incapacitated and die. The four stages are: 1) Initial Immersion (cold shock); 2) Short-Term Immersion (swimming failure); 3) Long-Term Immersion (hypothermia); and 4) Post-Rescue Collapse. What is important to note is that stages 1, 2 and 4 were largely regarded as of academic interest only; and did not have a large effect on survival policy, international regulations, or survival equipment.

All efforts of the Navies, Merchant Services, and the International Maritime Organizations concentrated on predicting the onset of hypothermia. There is still no consideration given to the physiological impact resulting from the first two stages of immersion in the design of emergency equipment. For instance, flares are still vacuum packed in polythene bags and, as in the Estonia accident were not usable simply because no one had the grip strength or the tactility to open the bags. For instance, the bailer in the Estonia life raft was wrapped in polythene and after attempting to open it with his teeth; the survivor finally gave up after he had lost several teeth!

So, in spite of very good regulations, very good survival suits, good training programs for such agencies as the Coast Guard, the Red Cross, and the National Life Saving Association, there are still over 140,000 open water deaths each year (Reference 5).

It became apparent that the first two stages of the immersion incident; i.e., cold shock and swimming failure were much more important causes of death than originally interpreted. This has been supported by a number of recent papers by Giesbreicht (1995) (Reference 5), Tipton et al (1992, 1994, 1999), (References 14, 15, 16) and Wallingford (2000) (Reference 17).

Therefore, in order to increase the knowledge of the dangers of the first two stages of immersion, Brooks, in 1997, in conjunction with the Canadian Search and Rescue Secretariat produced a new video titled: "The Cold Facts" to explain the physiological effects and preventative measures to be taken. For three years now, international survival training establishments have used this video.[1]

PURPOSE OF THE STUDY

The first part of this study was designed to enquire of all trainees who attended various survival courses at Survival Systems, Dartmouth, Nova Scotia, how much they were now aware of cold shock, swimming failure, and why they needed to wear survival suits to protect themselves. This was done by administering one questionnaire before and one questionnaire after the course. The second part of the study was related to the work done on the development of a Canadian General Standards Board standard for the improvement of helicopter passenger survival suits. This initial standard was established in 1989 (Reference 3). In 1999, it was revised to include new technology and scientific advancement in clothing technology (Reference 4). However, during the recent revision, the question of fit and sizes of the suit was not addressed. There was no scientific data to suggest that there should be more than the traditional manufactured sizes of small, medium,

[1] The Cold Facts – Surviving Sudden Cold Water Immersion. Canadian Department of National Defense. Catalogue No. 22-1535C. Available from: Intercom Films. Suite 303, 1650 Younge St., Toronto, Ontario, M4T 2A2.

large, and extra large generally established for the male population. So, after each course, included in the second questionnaire, there were questions asking specifically about fit, comfort, wear, and an overall opinion about their confidence that the suit would do its job properly in the event of abandonment into cold water.

METHOD

Survival Systems delivers regular weekly safety survival courses throughout the year. Class sizes range from 6 to 30 trainees depending on the demand of the military organizations, the offshore oil community, and the Coast Guard. From 1 January 2001 to 30 June 2001, it was decided to canvass the opinion of as many trainees as possible who attended the Basic Survival Training (BST) course (5 days); the Basic Survival Training Refresher (BSTR) course (3 days); the military Aircraft Ditching (ADC) course (2 days); or the Offshore Survival Introduction (OSI) course (1 day).

Two questionnaires were administered. The first one was handed out on the morning of the first day of each course. Apart from basic personal information, the objective was to enquire about the knowledge of the dangers of cold water immersion. It asked:

(a) Basic personal data – name, age, sex, height, weight

(b) If this was the first attendance on a safety survival training course. If not, then date and type of previous course.

(c) What critical temperature of water would you decide to don a survival suit before abandoning ship, rig, or helicopter. [Answer: 15°C]

(d) When suddenly immersed in water, how many stages are there in which you may die. [Answer: 4]

(e) If possible, name the stages identified in question (d). [Answer: cold shock, swimming failure, hypothermia, and post rescue collapse]

(f) Water transfers heat away from the body how many times more rapidly than air. [Answer: 25-27xs]

The objective of this questionnaire was to discover if the trainees knew about the four stages of the immersion incident; that immersion in water below 15°C was particularly dangerous; that a survival suit must always be worn when operating in water at or below this temperature; and the fact that water transfers heat away from the body 25-27 times more rapidly than air, hence the requirement for a dry suit versus a wet suit.

During the week, each trainee was shown the new video in the classroom. Then, depending on which course they attended, they wore one of the following:

- An orange-coloured, commercially available helicopter passenger suit (Figure 1)
- A yellow-coloured, commercially available marine abandonment suit (Figure 2)
- A green-coloured Canadian Forces military helicopter constant wear immersion suit (Figure 3)
- Or, for the offshore oil industry, a combination of both commercially available suits

The orange suit was constructed from 5 mm neoprene foam and a quilted liner bonded to the inside. Closure was achieved with a front zip that finished on the lower edge of the face shield. This had neoprene foam for the wrist seals and the neck as sealed by the hood that made a continuous seal around the face. There were rubber Wellington boots glued onto the trouser legs and it is manufactured in five sizes; extra small, small, medium, large, and extra large. Pockets in the sleeves were provided for gloves.

The yellow survival suit was constructed from urethane-coated nylon and had a 3 mm foam rubber detachable lining. A front zip that ended in the neck seal achieved closure. The neck and wrists were sealed

by 3 mm foam and the soft rubber boots were welded onto the trouser legs. Pockets in the sleeves were provided for gloves. It was a one-size-fits-all, the idea being that it could be stowed on the upper deck and be available for use by anyone who required it.

Finally, the green military aircrew survival suit was constructed from Gortex / Nomex. This relied on neoprene rubber seals for the neck and the wrists. The feet were sealed by a fabric sock. A horseshoe zip that started at the front of one shoulder, ran around the back of the shoulders, and ended up at the front of the other shoulder achieved closure of the suit. This suit is manufactured in 9 sizes.

Figure 1: The orange helicopter passenger suit made in three sizes.

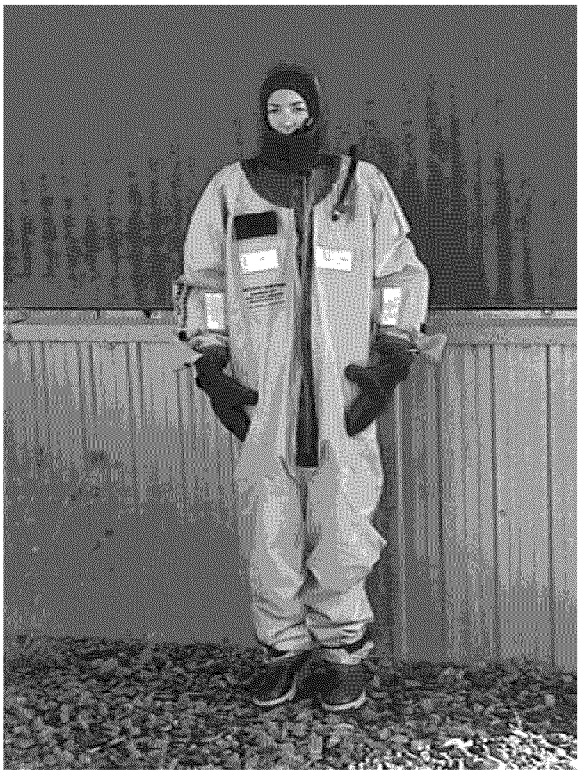

Figure 2: The yellow one-size-fits-all marine abandonment suit.

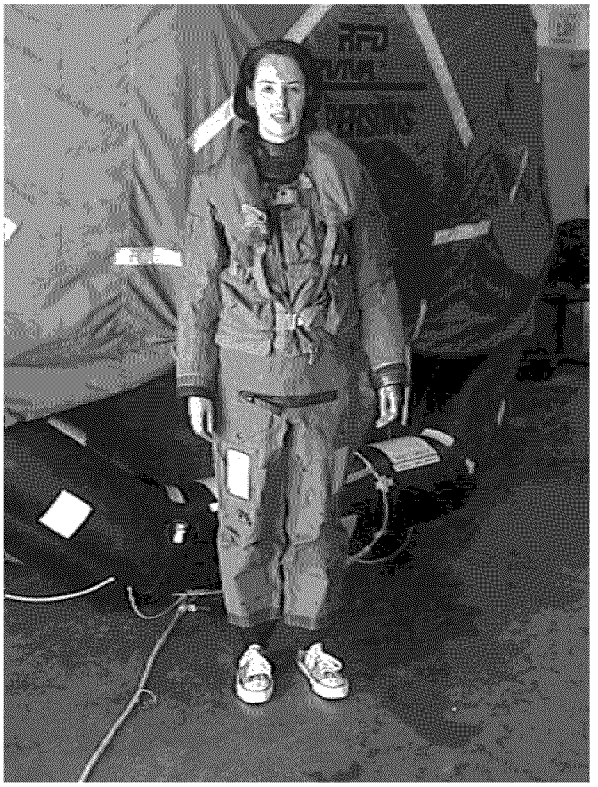

Figure 3: The green military aircrew immersion suit made in nine sizes.

Wearing one or more of the suits, depending on the course, each trainee was required to do (a) the standard marine exercises such as jumping off the 3 metre tower into the pool, climbing a Jacobs ladder, and launching and entering the standard marine life raft in the pool; (b) all the helicopter underwater training exercises such as strapping into the helicopter underwater escape trainer, assuming the crash position, locating the emergency escape exit underwater, jettisoning the window or door, undoing the seat harness, and escaping; and (c) all the survival activities at sea such as abandoning ship from the Fast Rescue Craft (FRC) into the Atlantic Ocean off Halifax Harbor in whatever weather conditions occurred that day, entering into a life raft and then being recovered by the FRC.

In other words, each trainee wore the suits under a variety of different physical conditions and weather conditions. The coldest sea day in January was -20°C and the sea water was +2°C and the warmest sea day in June was +24°C and the sea water was +11°C.

Following the completion of the course, a second questionnaire was administered.

This was divided into two parts. The first part was basically a repeat of the first questionnaire to ascertain how much knowledge the trainees had gained from the video, the classroom and pool instruction. It asked only three questions:

a) At what critical water temperature would you decide to don a survival suit?

b) List in chronological order the sequences in which post rescue collapse, swimming failure, hypothermia, and cold shock occur.

c) Water transfers heat away from the body how many more times rapidly than air?

The second series of questions was related to the ergonomics of the survival suit, interface of the lifejacket, and ease or difficulty of strapping in and escaping from the helicopter underwater escape trainer. It asked about:

a) Fit of the suit
b) Ease of donning and doffing
c) Ease of operating the zip
d) Comfort and fit of the neck seal
e) Comfort and fit of the wrist seal
f) Comfort and fit of the gloves
g) Comfort and fit of the boots
h) Opinion of the general feel and ergonomics of the suit
i) Mobility
j) Interface with the lifejacket
k) Ease of strapping into the helicopter seat
l) Ease of escape from the helicopter underwater escape trainer
m) Ease of climbing into the life raft
n) Dryness of the suit
o) Confidence that the person could survive in the suit

The trainees were asked to rank all these factors on a scale of 1 to 5, where one was very good and 5 was very poor.

The answers from the questions were entered into an Excel spread sheet and statistically analyzed by Minitab (Minitab Inc.).

RESULTS

A total of 357 people completed the questionnaire between 1 January 2001 and 30 June 2001. There were 342 males and 15 females. Their ages ranged from 19 to 63 years old. When split into the four categories of training courses that they attended, there were 173 people who attended the Basic Survival Training (BST) course; 123 people who attended the Basic Survival Training Refresher (BSTR) course; 47 military people who attended the Aircraft Ditching (ADC) course; and there was just one group of 14 people who attended the Offshore Survival Introduction (OSI) course.

EXAMINATION OF THE RESULTS OF THE FIRST (KNOWLEDGE) QUESTIONAIRE

Male Trainees' Data

Course	Attendees	Age Range	Height Range	Weight Range
BST	164	19-63	62"-79"	115-300 lbs
BSTR	119	21-60	63"-79"	140-265 lbs
ADC	46	24-52	65"-75"	150-260 lbs
OSI	13	29-49	65"-74"	150-250 lbs

Female Trainees' Data

Course	Attendees	Age Range	Height Range	Weight Range
BST	9	22-41	60"-69"	120-220 lbs
BSTR	4	21-38	61"-70"	120-205 lbs
ADC	1	39	61"	150 lbs
OSI	1	Not provided	60"	108 lbs

Basic Survival Training Course (BST)

Water Temperature

From the possible temperatures of 25°C, 20°C, 15°C, 10°C, 5°C, 0°C, or Don't Know at what temperature to decide to don a survival suit if one had to abandon ship, rig, or helicopter, 37 people (21.4%) identified the correct water temperature (15°C); 79 people (45.7%) gave an incorrect temperature; and 57 people (33%) admitted they did not know. The most common incorrect temperature chosen was 25°C chosen by 37 people (21.4%) and 20°C chosen by 18 people (10.4%).

Number of Stages of Immersion

From possible answers of 1, 2, 3, 4, 5, 6 or Don't Know how many physiological phases there are during which one may die when suddenly immersed in cold water, 10 people (5.8%) identified correctly that there were 4 phases; 38 people (22.5%) gave an incorrect number; and 125 people (72.3%) admitted they did not know. (Figure 4)

Naming the Stages of Cold Water Immersion

When asked to name the 4 physiological phases, no one (0%) named all 4 phases correctly; 41 people (23.7%) identified at least one of the phases correctly; and 132 people (76.3%) admitted they did not know. The most common correct answer was hypothermia. (Figure 5)

Water Heat Transfer

From possible answers of 3xs, 10xs, 17xs, 25xs, 33xs, or Don't Know how many times more rapidly (than air) water transfers heat away from the body, 14 people (8.1%) identified 25-27 times as the correct answer; 59 people (34.1%) gave an incorrect answer; and 100 people (57.8%) admitted they did not know.

Basic Survival Training Refresher Course (BSTR)

Water Temperature
From the possible temperatures of 25°C, 20°C, 15°C, 10°C, 5°C, 0°C, or Don't Know at what temperature to decide to don a survival suit if one had to abandon ship, rig, or helicopter, 18 people (14.6%) identified the correct water temperature (15°C); 82 people (66.6%) gave an incorrect temperature; and 23 people (18.7%) admitted they did not know. The most common incorrect temperature chosen was 25°C chosen by 34 people (27.6%) and 20°C chosen by 31 people (25.2%).

Number of Stages of Immersion
From possible answers of 1, 2, 3, 4, 5, 6 or Don't Know how many physiological phases there are during which one may die when suddenly immersed in cold water, 21 people (17.0%) identified correctly that there were 4 phases; 38 people (31.0%) gave an incorrect number; and 64 people (52.0%) admitted they did not know. (Figure 4)

Naming the Stages of Cold Water Immersion
When asked to name the 4 physiological phases, one (0.8%) named all 4 phases correctly; 35 people (28.5%) identified at least one of the phases correctly; and 87people (70.7%) admitted they did not know. The most common correct answer was hypothermia. (Figure 5)

Water Heat Transfer
From possible answers of 3xs, 10xs, 17xs, 25xs, 33xs, or Don't Know how many times more rapidly (than air) water transfers heat away from the body, 11 people (8.9%) identified 25-27 times as the correct answer; 49 people (39.9%) gave an incorrect answer; and 63 people (51.2%) admitted they did not know.

Aircraft Ditching Course (ADC)

Water Temperature
From the possible temperatures of 25°C, 20°C, 15°C, 10°C, 5°C, 0°C, or Don't Know at what temperature to decide to don a survival suit if one had to abandon ship, rig, or helicopter, 16 people (34.0%) identified the correct water temperature (15°C); 23 people (48.9%) gave an incorrect temperature; and 8 people (17.0%) admitted they did not know. The most common incorrect temperature chosen was 25°C chosen by 8 people (17.0%) and 20°C chosen by 11 people (23.4%).

Number of Stages of Immersion
From possible answers of 1, 2, 3, 4, 5, 6 or Don't Know how many physiological phases there are during which one may die when suddenly immersed in cold water, 4 people (8.5%) identified correctly that there were 4 phases; 10 people (21.3%) gave an incorrect number; and 33 people (70.2%) admitted they did not know. (Figure 4)

Naming the Stages of Cold Water Immersion
When asked to name the 4 physiological phases, no one (0.0%) named all 4 phases correctly; 8 people (17.0%) identified at least one of the phases correctly; and 39 people (83.0%) admitted they did not know. The most common correct answer was hypothermia. (Figure 5)

Water Heat Transfer
From possible answers of 3xs, 10xs, 17xs, 25xs, 33xs, or Don't Know how many times more rapidly (than air) water transfers heat away from the body, 13 people (27.7%) identified 25-27 times as the correct answer; 16 people (34.1%) gave an incorrect answer; and 18 people (38.3%) admitted they did not know.

Offshore Survival Introduction (OSI)

Water Temperature

From the possible temperatures of 25°C, 20°C, 15°C, 10°C, 5°C, 0°C, or Don't Know at what temperature to decide to don a survival suit if one had to abandon ship, rig, or helicopter, 1 person (7.0%) identified the correct water temperature (15°C); 4 people (28.5%) gave an incorrect temperature; and 9 people (64%) admitted they did not know. The most common incorrect temperature chosen was 25°C chosen by 1 person

Number of Stages of Immersion

From possible answers of 1, 2, 3, 4, 5, 6 or Don't Know how many physiological phases there are during which one may die when suddenly immersed in cold water, 3 people (21.4%) identified correctly that there were 4 phases; 1 person (7.1%) gave an incorrect number; and 10 people (71.4%) admitted they did not know. (Figure 4)

Naming the Stages of Cold Water Immersion

When asked to name the 4 physiological phases, no one (0%) named all 4 phases correctly; 5 people (35.7%) identified at least one of the phases correctly; and 9 people (64.3%) admitted they did not know. The most common correct answer was hypothermia. (Figure 5)

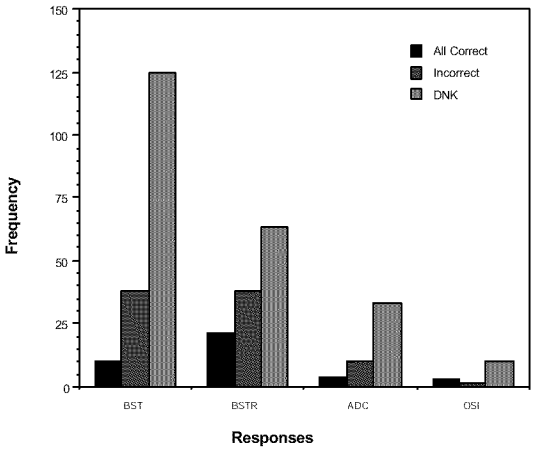

Figure 4: Number of physiological stages of immersion.

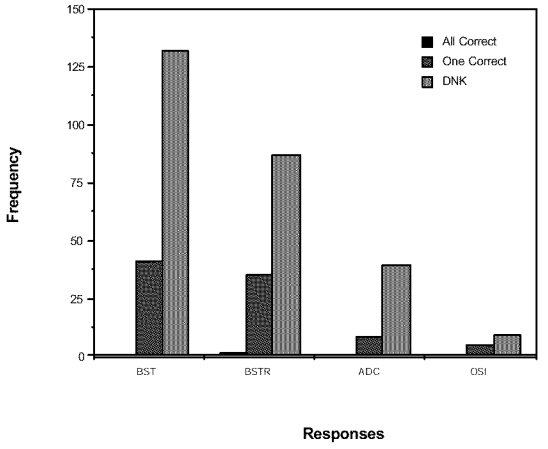

Figure 5: Naming the physiological stages of immersion.

EXAMINATION OF THE RESULTS OF THE SECOND (KNOWLEDGE & ERGONOMICS) QUESTIONAIRE

On completion of the course, the following responses were elucidated from the trainees answering the second questionnaire. These are listed in Tables 1-15 below.

Table One: Fit of the Suit

Course	Suit	Scale				
		1 (Best)	2	3	4	5 (Worst)
BST	Orange	17(11%)	53(34.4%)	49(31.8%)	20(13%)	15(9.7%)
	Yellow	44(25%)	69(40.4%)	38(22.2%)	14(8.2%)	6(3.5%)
BSTR	Orange	14(14.3%)	42(42.7%)	27(27.6%)	13(13.3%)	2(2.0%)
	Yellow	25(20.3%)	46(37.4%)	37(30.1%)	12(9.8%)	3(2.4%)
ADC	Green	6 (12.8%)	26(55.3%)	11(23.4%)	2(4.3%)	2(4.3%)
OSI	Yellow	5 (38.5%)	4(30.8%)	1(7.7%)	2(15.4%)	1(7.7%)

Table Two: Donning of the Suit

Course	Suit	Scale				
		1 (Very Easy)	2	3	4	5 (Very Difficult)
BST	Orange	25(16.2%)	79(51.3%)	33(21.4%)	14(9.1%)	3(2.0%)
	Yellow	42(24.7%)	83(48.8%)	32(18.8%)	9(5.3%)	4(2.4%)
BSTR	Orange	22(22.5%)	51(52.0%)	22(22.5%)	3(31.1%)	0(0.0%)
	Yellow	31(25.8%)	60(50.0%)	22(18.3%)	7(5.8%)	0(0.0%)
ADC	Green	2(4.3%)	17(36.2%)	15(31.9%)	9(19.2%)	4(8.3%)
OSI	Yellow	5(38.5%)	3(23.1%)	5(38.5%)	0(0.0%)	0(0.0%)

Table Three: Operating the Zip

Course	Suit	Scale				
		1 (Very Easy)	2	3	4	5 (Very Difficult)
BST	Orange	20(12.9%)	68(43.9%)	44(28.4%)	19(12.3%)	4(2.6%)
	Yellow	42(24.6%)	74(43.3%)	31(18.1%)	20(11.7%)	4(2.3%)
BSTR	Orange	33(33.7%)	39(39.8%)	21(21.4%)	5(5.1%)	0(0.0%)
	Yellow	38(31.4%)	60(49.6%)	15(12.4%)	8(6.6%)	0(0.0%)
ADC	Green	0(0.0%)	3(6.4%)	6(12.8%)	20(42.6%)	18(38.3%)
OSI	Yellow	3(21.4%)	6(42.9%)	2(14.3%)	1(7.1%)	5(14.3%)

Table Four: Comfort of the Neck Seal

Course	Suit	Scale				
		1 (Very Comfortable)	2	3	4	5 (Very Uncomfortable)
BST	Orange	12(7.8%)	33(21.6%)	58(37.9%)	34(22.2%)	16(10.5%)
	Yellow	19(11.1%)	45(26.3%)	37(21.6%)	51(29.8%)	19(11.1%)
BSTR	Orange	13(13.3%)	32(32.7%)	36(36.7%)	12(12.2%)	5(5.1%)
	Yellow	21(17.4%)	35(28.9%)	33(27.3%)	22(18.2%)	10(8.3%)
ADC	Green	4(8.5%)	10(21.3%)	17(36.2%)	12(25.5%)	4(8.5%)
OSI	Yellow	2(14.3%)	3(21.4%)	4(28.6%)	4(28.6%)	1(7.1%)

Table Five: Comfort of the Wrist Seal

Course	Suit	Scale				
		1 (Very Comfortable)	2	3	4	5 (Very Uncomfortable)
BST	Orange	33(21.9%)	64(42.4%)	32(21.2%)	16(10.6%)	6(4.0%)
	Yellow	63(36.8%)	63(36.8%)	28(16.4%)	12(7.0%)	5(2.9%)
BSTR	Orange	28(29.5%)	33(34.7%)	22(23.2%)	7(7.4%)	5(5.3%)
	Yellow	43(35.8%)	43(35.8%)	23(19.2%)	8(6.7%)	3(2.5%)
ADC	Green	6(12.8%)	24(51.1%)	10(21.3%)	5(10.6%)	2(4.3%)
OSI	Yellow	3(21.4%)	7(50.0%)	0(0.0%)	1(7.1%)	3(21.4%)

Table Six: Comfort and Fit of the Gloves

Course	Suit	Scale				
		1 (Very Comfortable)	2	3	4	5 (Very Uncomfortable)
BST	Yellow	9(5.3%)	33(19.4%)	44(25.4%)	47(27.7%)	5(21.8%)
BSTR	Yellow	10(8.7%)	19(16.5%)	26(22.6%)	33(28.7%)	27(23.5%)
OSI	Yellow	3(33.3%)	3(33.3%)	1(11.1%)	2(22.2%)	0(0.0%)

Table Seven: Fit of the Boots

Course	Suit	Scale				
		1 (Very Comfortable)	2	3	4	5 (Very Uncomfortable)
BST	Orange	30(19.9%)	56(37.1%)	28(18.5%)	15(9.9%)	22(14.5%)
	Yellow	22(12.9%)	59(34.5%)	49(28.7%)	23(13.5%)	18(10.5%)
BSTR	Orange	21(22.8%)	31(33.7%)	21(22.8%)	11(12.0%)	8(8.7%)
	Yellow	16(13.1%)	30(24.6%)	24(23.8%)	29(23.8%)	18(14.8%)
OSI	Yellow	5(35.7%)	1(7.1%)	6(42.9%)	1(7.1%)	1(7.1%)

Table Eight: Overall Opinion of the Survival Suit

Course	Suit	Scale				
		1 (Very Comfortable)	2	3	4	5 (Very Uncomfortable)
BST	Orange	19(13.6%)	55(39.3%)	41(29.3%)	16(11.4%)	9(6.4%)
	Yellow	46(26.9%)	82(48.0%)	30(17.5%)	10(5.0%)	3(1.8%)
BSTR	Orange	12(12.2%)	49(50.0%)	27(27.6%)	10(10.2%)	0(0.0%)
	Yellow	27(22.3%)	58(47.9%)	26(21.5%)	8(6.6%)	2(1.7%)
ADC	Green	2(4.3%)	17(36.2%)	20(42.6%)	8(17.0%)	0(0.0%)
OSI	Yellow	7(50.0%)	3(21.4%)	2(14.3%)	2(14.3%)	0(0.0%)

Table Nine: Mobility in the Survival Suit

Course	Suit	Scale				
		1 (Very Easy)	2	3	4	5 (Very Difficult)
BST	Orange	23(14.9%)	69(44.8%)	39(25.3%)	15(9.7%)	8(5.2%)
	Yellow	46(27.0%)	85(49.7%)	27(15.8%)	12(7.0%)	1(0.6%)
	Green	5(10.6%)	32(68.1%)	7(14.9%)	3(6.4%)	0(0.0%)
BSTR	Orange	17(17.4%)	49(50.0%)	23(23.5%)	6(6.1%)	3(3.1%)
	Yellow	33(26.8%)	63(51.2%)	21(17.1%)	6(4.9%)	0(0.0%)
ADC	Green	2(4.3%)	17(36.2%)	20(42.6%)	8(17.0%)	0(0.0%)
OSI	Yellow	6(42.9%)	4(28.6%)	2(14.3%)	2(14.3%)	0(0.0%)

Table Ten: Ease of Strapping into the Helicopter Underwater Escape Trainer

Course	Suit	Scale				
		1 (Very Easy)	2	3	4	5 (Very Difficult)
BST	Orange	33(19.9%)	66(39.8%)	48(28.9%)	17(10.2%)	2(1.2%)
BSTR	Orange	19(17.8%)	42(39.3%)	31(29.0%)	13(12.2%)	2(1.9%)
ADC	Green	4(16.7%)	12(50.0%)	8(33.3%)	0(0.0%)	0(0.0%)

Table Eleven: Interface with the Lifejacket

Course	Suit	Scale				
		1 (Very Easy)	2	3	4	5 (Very Difficult)
BST	Orange	19(11.5%)	78(47.0%)	40(24.1%)	44(14.5%)	5(3.0%)
BSTR	Orange	26(24.8%)	44(41.9%)	27(25.7%)	5(4.8%)	3(2.9%)
ADC	Green	6(25.0%)	10(41.7%)	6(25.0%)	2(8.2%)	0(0.0%)

Table Twelve: Ease of Escape from the Helicopter Underwater Escape Trainer

Course	Suit	Scale				
		1 (Very Easy)	2	3	4	5 (Very Difficult)
BST	Orange	53(32.1%)	79(47.9%)	24(14.6%)	9(5.5%)	0(0.0%)
BSTR	Orange	33(30.6%)	53(49.1%)	16(14.8%)	6(5.6%)	0(0.0%)
ADC	Green	3(12.5%)	16(66.7%)	5(20.8%)	0(0.0%)	0(0.0%)

Table Thirteen: Ease of Life Raft Entry

Course	Suit	Scale				
		1 (Very Easy)	2	3	4	5 (Very Difficult)
BST	Yellow	57(34.3%)	85(51.2%)	19(11.5%)	5(3.0%)	0(0.0%)
BSTR	Yellow	39(35.1%)	52(45.1%)	15(13.5%)	3(2.7%)	2(1.8%)

Table Fourteen: Dryness of the Survival Suit

Course	Suit	Scale				
		1 (Very Dry)	2	3	4	5 (Very Wet)
BST	Orange	6(8.8%)	19(27.4%)	19(27.9%)	10(14.7%)	14(20.6%)
	Yellow	84(49.4%)	70(41.2%)	9(5.3%)	5(2.9%)	2(1.2%)
BSTR	Orange	6(13.6%)	7(15.9%)	11(25.0%)	8(18.2%)	12(27.3%)
	Yellow	71(59.2%)	35(29.2%)	10(8.3%)	1(0.8%)	3(2.5%)
ADC	Green	1(2.3%)	7(15.9%)	4(9.1%)	11(25.0%)	21(47.7%)
OSI	Yellow	6(42.9%)	5(35.7%)	1(7.1%)	1(7.1%)	1(7.1%)

Table Fifteen: Confidence in the Survival Suits

Course	Suit	Scale				
		1 (Very Confident)	2	3	4	5 (No Confidence)
BST	**Orange**	27(25.0%)	39(36.1%)	27(25.0%)	13(12.0%)	2(1.9%)
	Yellow	76(44.4%)	65(38.0%)	17(9.9%)	8(4.7%)	5(2.9%)
BSTR	**Orange**	24(33.8%)	21(29.6%)	10(14.1%)	14(19.7%)	2(2.8%)
	Yellow	42(35.3%)	36(30.3%)	23(19.3%)	9(7.6%)	9(7.6%)
ADC	**Green**	3(6.5%)	13(28.3%)	23(50.0%)	7(15.2%)	0(0.0%)
OSI	**Yellow**	6(46.2%)	1(7.7%)	2(15.4%)	2(15.4%)	2(15.4%)

Specific answers to the identification of the correct water temperature, identification of the correct water heat transfer question pre and post-course, and the correct listing of the four stages of immersion are illustrated in Figures 6 to 10. Specific illustrations of opinions on ergonomic factors such as fit, interface with the lifejacket, ease of escape from the helicopter underwater escape trainer, overall opinion of the suit, confidence in the suit, and the water integrity are depicted in Figures 11 to 16.

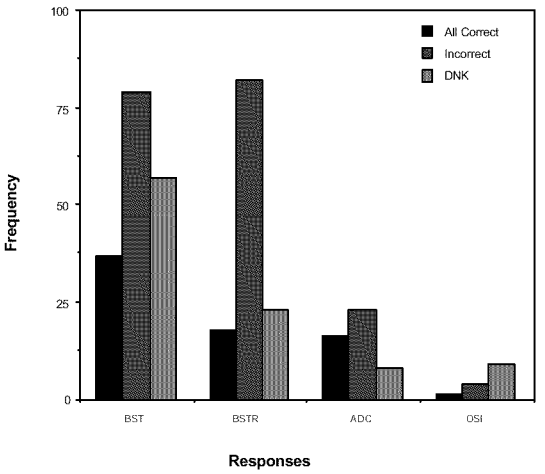

Figure 6: Identifying the correct water temperature (15ºC) for survival suit donning, pre course.

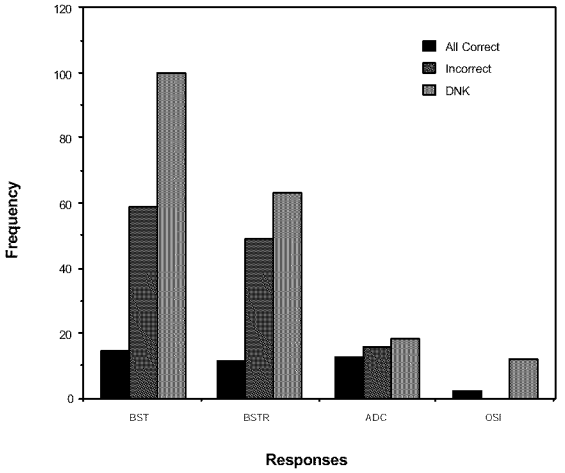

Figure 7: Identifying the water heat transfer factor, pre course.

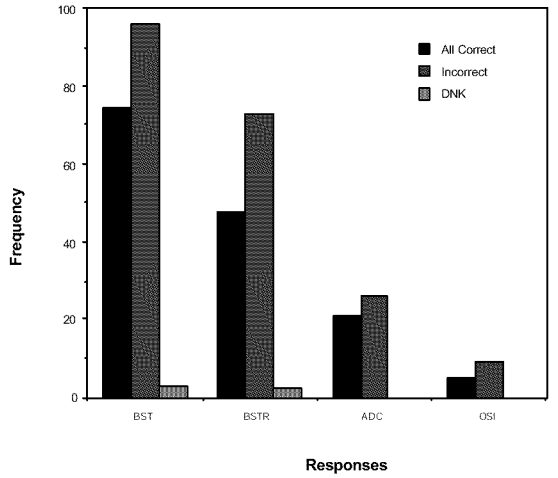

Figure 8: Identifying the correct water temperature (15ºC) for survival suit donning, post course.

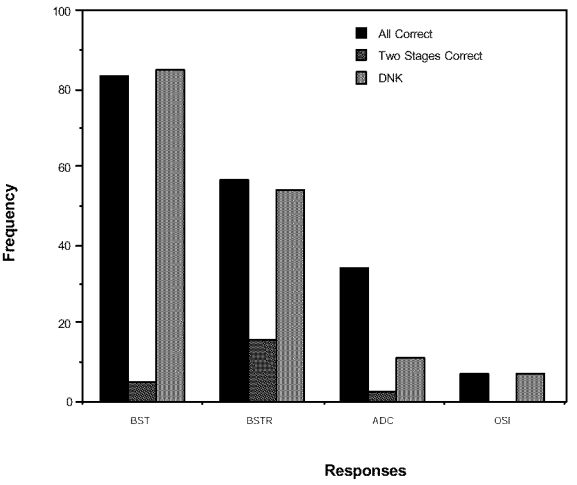

Figure 9: Listing the physiological stages of immersion in chronological order, post course.

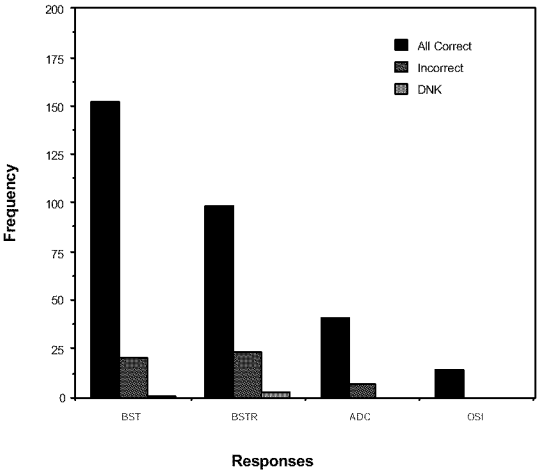

Figure 10: Identifying the correct water heat transfer factor, post course.

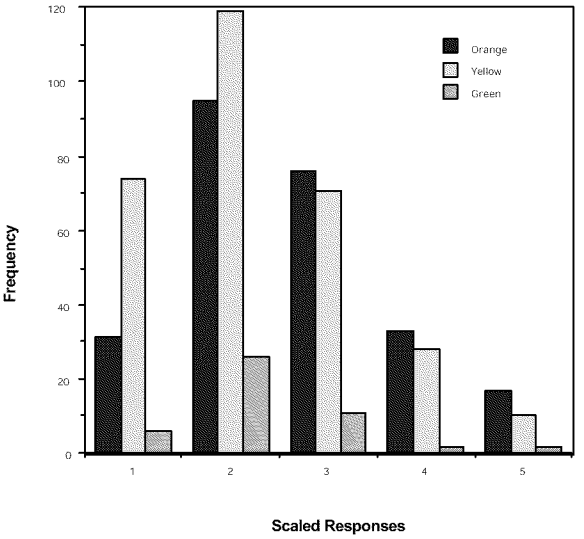

Figure 11: Assessment of the suit fit. (1=very good, 5=very poor)

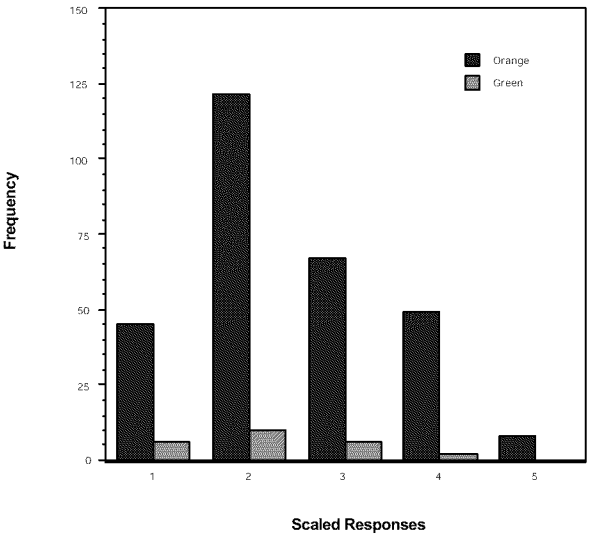

Figure 12: Assessment of the interface with the life jacket. (1=very easy, 5=very difficult)

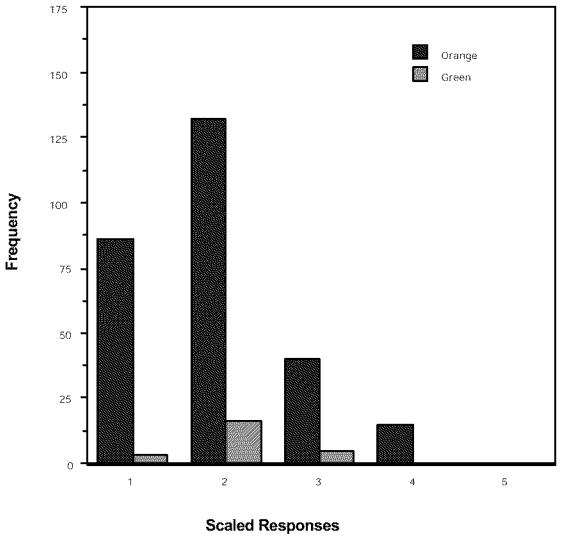

Figure 13: Assessment of the ease of escape from the helicopter underwater escape trainer. (1=very easy, 5=very difficult)

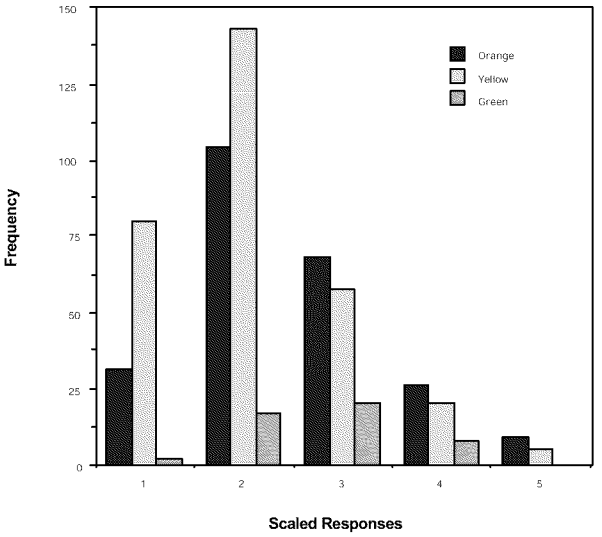

Figure 14: Overall ergonomic opinion of the survival suit. (1=very good, 5=very poor)

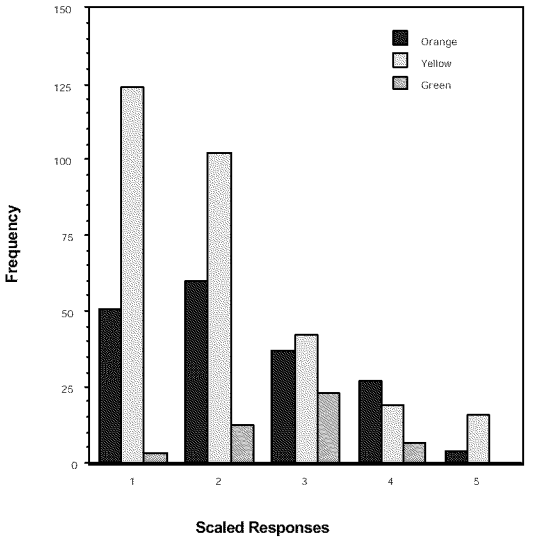

Figure 15: Confidence in the survival suit. (1=absolutely confident, 5=zero confidence)

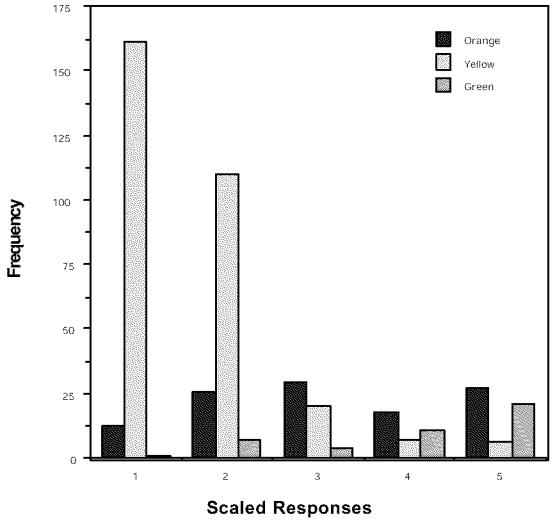

Figure 16: Assessment of the dryness of the suit. (1=completely dry, 5=completely soaked)

DISCUSSION

To the best of our knowledge, this is the first, although preliminary study, to survey a large group of people who all earn their living either in the military, in the offshore oil industry flying over water, or operating small vessels such as Fast Rescue Crafts on the water. Three hundred and fifty-seven people were asked about their basic knowledge of the reasons for wearing a dry type survival suit, their opinions concerning its fit and comfort, the interface with the lifejacket, the ergonomics of strapping into and escape from the helicopter underwater escape trainer, ability to conduct general sea survival duties, and how much confidence they had in the suits. Depending on which of the investigators was available, the questionnaire was administered to as many courses as possible over a six-month period and a very good cross section of ages and physical sizes has been achieved.

Because of the very tight timing schedules in each of the classes to complete the course content, we had to be as fast as possible. The first questionnaire was given on the first day of the course after the basic administration was completed; and the second questionnaire was given after the trainees had showered and changed from their day at sea. This was the principle reason that the questionnaires were short. The second reason was that having worked with this group of people for many years we knew that a longer more detailed questionnaire would result in poorer compliance in answering the questions with enthusiasm and conscientiousness. Their ages ranged from 19 to 63 years old. The range of educational backgrounds was very wide from people who left school at 16 with no educational qualifications to PhD engineers. Unfortunately, with the need to keep the questionnaire as short as possible, it was not possible to enquire in any detail about these factors and then examine whether there was any correlation with the results. As predicted, if the question required a lot of thought, then the response was inadequate. For instance, the enquiry as to whether the person had attended a previous survival course, what type of course and when and where it took place could not be analyzed because of the vague information in the responses. One immediate finding is that only 5% of the people who attended our courses were female. This at least provides some guidelines to suit manufacturers and training course directors of the current male / female ratio for training in Atlantic Canada.

The Knowledge of the Dangers of Sudden Cold Water Immersion and the Fundamental Criteria for Donning a Survival Suit

It did not surprise us that initially only 38 people (10.6%) knew that there were four distinct physiological phases to cold water immersion (Figure 4), and that only one person (0.28%) named all four stages of the immersion incident correctly (Figure 5). This person had been an undergraduate student on the principal author's survival course at Dalhousie the previous year and was attending the course in preparation for working offshore. Two people (0.6%) named three stages correctly; 36 people (10.1%) named two phases correctly; 51 (14.3%) named one stage correctly; and 267 people (74.8%) did not know. It also did not surprise us that hypothermia was the most common correct identification of immersion stages (75 people, 20%). Nor did it surprise us that only 72 people (20.2%) knew that 15ºC was the critical temperature below which all the physiological symptoms become rapidly worse (Figure 6). It also did not surprise us that only 40 people (11.2%) identified that water transferred heat away from the body 25-27 times more rapidly than air (Figure 7).

The encouraging part of this study is that on completion of the course, 148 people (41.5%) knew that the critical water temperature was 15°C (Figure 8). Prior to the course, approximately 60% assigned a temperature of 15°C or above; and following the course, this figure was increased to 92%. One hundred and eighty one people (51.0%) wrote down the correct chronological order in which the four stages occurred (Figure 9), and 17 people (5%) at least identified cold shock and swimming failure as the first two stages. Three hundred and four people (85.2%) correctly identified that 25-27 times was the correct transfer factor (Figure 10). The instructors and the video had a positive effect on increasing the pool of knowledge in this group of people. The results are encouraging especially considering the wide range of educational backgrounds. With a continuous emphasis on the dangers of sudden cold water immersion, it is hoped that the pool of general knowledge will slowly continue to rise. Recently, it has been recommended (Reference 2), that Transport Canada amend the Marine Emergency Duties curriculum to include the Canadian video on cold shock and swimming failure. However, unless people are retested on return for refresher training, it will not be possible to determine the retention factor for this information.

The Overall Fit, Comfort, Dryness, and General Ergonomics of the Survival Suits

Prior to the Ocean Ranger oil rig accident in 1984, the general design of survival suits in Canada was poor; they leaked badly, there were no regulations requiring mandatory use or standards for manufacture. One of the actions arising from the Board of Inquiry was to recommend the introduction of new regulations for helicopter passenger suit systems (Reference 11). The standard was completed in 1989 and revised in 1999. Supporting the Ocean Ranger findings from 15 years ago, there was considerable anecdotal evidence that the survival suits were poorly constructed and leaked badly and that there was a lot of customer dissatisfaction with fit, comfort, and general sartorial elegance. There have always been general complaints about the

comfort of the military immersion suit. This study was fortunate in being able to assess opinions about three fundamentally different types of suits: a military aircrew constant immersion wear suit (green), a commercial constant wear helicopter passenger suit (orange), and a one-size-fits-all marine abandonment suit (yellow). Each was designed for the same purpose, that is, to protect humans in the water from the four physiological phases of cold water immersion, which could cause death. All the suits provided 0.75 immersed CLO of insulation and were manufactured to the latest standard Canadian General Standards Board (Reference 4).

When all the ergonomic factors were examined, the results show a classic normal distribution curve with the trend of responses being between 1 and 3 (very good, good, average) with the remainder being in the 4-5 (poor, very poor) range (Figures 11 through 16). This comes as a surprise and does not bear out the anecdotal evidence. What is more interesting is that the opinions expressed as to the ergonomic appeal of the suits (Figure 14) and the confidence in the suits was much better than expected. The commercial orange and yellow suits were favourably assessed and the green military immersion suit had a fair assessment (Figure 14). It would be expected that the sized orange helicopter passenger suit would have been rated higher than the one-size-fits-all marine abandonment suit. It is postulated this was not the case because of the timing of the second questionnaire. It was administered immediately after the trainees had been in cold sea water in the yellow marine abandonment suit and had all fared well. Therefore, they were basically psychologically pre-disposed to rating the ergonomic facts such as fit, comfort, etc. higher than for the orange suit, which had only been worn in the warm pool, water the previous day (Figure 15). When the responses for the various ergonomic factors 4-5 were compared to the responses for height, weight, age, and sex, there was no correlation. We were particularly interested in peoples opinion as to (a) the interface of the lifejacket with the survival suit because there is no cross reference between lifejacket and survival suit standards, and (b) the ease or difficulty of escape from the helicopter underwater escape trainer with 146 Newtons of positive suit buoyancy. However, the opinions also followed a bell shaped curve with few extreme scores (Figures 12 &13).

Watertight integrity of the suits is a critical factor. It only takes a leakage of one litre of water into the suit to reduce the CLO insulation value by 50% (Reference 1 and 6). Our findings were that, overall, the orange suit was assigned a good or very good factor by 38 people (33.6%); the yellow suit was assigned a good or very good factor by 271 people (88.2%); and the green military suit was assigned a good or very good factor by 8 people (18.2%)(Figure 16).

Although we have no scientific data to compare the leakage results to any other previous large group of people, it is our impression that our new Canadian standard has improved the quality of the suit. Certainly, the crotch area, the zip area and the feet are notoriously difficult to keep watertight for the majority of people. In this study, they remained relatively dry. It is suggested that this is due to the fact that the new standard requires manikin testing with the manikin positioned at 45° in the water. This means there can be no cheating during the regulatory approval process by the manufacturers because zip closure, crotch, feet, neck and wrist seals, are partially, wholly, or most of the time, under water. These are the common areas where leakages occur if the suit is poorly or cheaply constructed.

Considering that the suits worn by each trainee were from our stock of suits; (i.e., not their personal suits), and receive considerable wear each week, it would appear that the manufacturers have taken the quality control message to heart and are making a good quality product. The relatively poorer assessment of the dryness of the orange suit compared to the yellow suit is due to the nearly impossible problem of keeping the suits waterproof from the effects of chlorinated water. The poor assessment of the military immersion suit is because these suits are manufactured from Nomex / Gortex, making them notoriously difficult to keep watertight especially when they are regularly and frequently used in the chlorinated pool water. Furthermore, each military trainee had to do at least twice the number of immersions (eight versus four) in the helicopter underwater escape trainer than the trainees in the civilian BST and BSTR courses. Hence, the greater chance of inducing leakage. Nevertheless, this does demonstrate that the military should be investigating the possibility of using other material than Nomex / Gortex for their suits.

It was a puzzle to us why the one-size-fits-all yellow ship abandonment suit should produce such a favourable response (88%), which is considerably higher than the other two suits on the leakage question. On further examination of the enigma, it was discovered that the instructors routinely take a roll of duct tape to sea with them. Anyone who is wearing a suit with a loose fitting wrist seal or a person with thin wrists is offered the option of tightening the seals with duct tape. This obviously works very well. In the event that there is some time available before abandonment into water, the availability of a roll of duct tape to tighten up any seals or excessive folds in a suit is a good idea. We would recommend that tape be available at ship abandonment stations to do just that.

CONCLUSIONS

1. Questionnaires were given to 357 trainees (342 males and 15 females) who attended one of four marine survival or helicopter ditching courses at Survival Systems Ltd. between January 2001 and June 2001.
2. The questionnaires asked about the knowledge of the dangers of immersion in cold water and the ergonomics of the survival suits that were worn during the course. The suits were fundamentally different: a commercially available sized helicopter passenger suit, a one-size-fits-all marine abandonment suit, and a sized military aircrew constant wear immersion suit.
3. Prior to the course, the answers in the questionnaire confirmed our suspicion that the general knowledge of the dangers of cold water immersion is poorly understood and hypothermia was the only stage of immersion identified.
4. On completion of the course, there was a general improvement in this knowledge with over 50% of students being able to list the chronological order of the four stages correctly.
5. Classroom instruction and videos have improved the knowledge of the dangers of sudden cold water immersion, but trainees will need retesting to assess the retention factor.
6. The general parameters related to the ergonomics of the suits followed a normal distribution curve. Generally, people were relatively satisfied. There was no correlation between extremes of sizes, ages and sex and satisfaction or dissatisfaction.
7. The water integrity of the suits was better than expected. This can be attributed to better standards, manikin testing, better quality control by manufacturers and duct tape used by the instructors.
8. The option of duct tape at ship abandonment stations is a good idea.
9. The overall confidence factor in the suit was higher than anecdotal evidence would suggest.

REFERENCES

1. Allan, J.R., Higenbottom, C., Redman, P.J. *The Effect of Leakage on the Insulation Provided by Immersion Protective Clothing.* RAF Institute of Aviation Medicine. Report No. AEG511, September, 1984.
2. Brooks, C.J. Survival in Cold Water. A Report Prepared for Transport Canada. August, 2001. T8275-010075.
3. Canadian General Standards Board. *Helicopter Passenger Transportation Suit Systems.* CAN/CSGB-65.17-M88.
4. Canadian General Standards Board. *Helicopter Passenger Transportation Suit Systems.* CAN/CSGB-65.17-99.
5. Giesbreicht, G.G., Pu Wu, M., White, M.D., Johnson, C.F., Bristow, G.K. *Isolated Effect of Peripheral Arm and Central Blood Cooling on Arm Performance.* Aviat. Space Environ. Med 66:968 – 975.
6. Golden, F.St.C., Rivers, J.F. *The Immersion Incident.* Anesthesia, 1975; 30:364 – 373.
7. Golden, F.St.C, Hervey, G.R. *The "After-Drop" and Death after Rescue from Immersion in Cold Water. In Hypothermia Ashore and Afloat.* J.M. Adam (1981) ISBN 0 080 025750 X.
8. Hall, J.F., Polte, J.W. *Thermal Insulation of Air Force Clothing.* Wright Air Development Division. WADDS60-597. September, 1960.

9. Keatinge, W.R. *Survival in Cold Water.* Blackwell Scientific Publications. Oxford and Edinburgh., 1969. ISBN 632 05280 5.
10. McCance, R.A., Ungley, C.C., Crosfill, J.W.L., Widdowson, E.M. *The Hazards to Men in Ships Lost at Sea 1940 – 1944.* Medical Research Council Special Report Series No. 291. 1956.
11. National Transportation Safety Board of Canada. Report No. NTSB Nov-83-2.
12. Medical Research Council. *A Guide to the Preservation of Life at Sea after Ship Wreck.* Committee on the Care of Shipwreck Personnel: War Memorandum No. 8, 1943. HMSO London.
13. *The Talbot Report of Naval Life-Saving Committee.* London, 2 April, 1946.
14. Tipton, M.J. *The Relationship Between Maximum Breath Hold Time in Air and the Ventilating Responses to Immersion in Cold Water.* Eur. J. Appl. Physiol 1992: 64: 426 – 429.
15. Tipton. M.J., Kelleher, P.C., Golden, F.St.C., *Supraventricular Arrythmias Following Breath Hold Submersion in Cold water*. Undersea and Hyperbaric Medicine. Vol. 21. No.3, 1994.
16. Tipton, M.J., Eglin, C. Gennser, M., Golden, F.St.C. *Immersion Deaths and Deterioration in Swimming Performance in Cold Water.* The Lancet. Vol. 354. Aug 21, 1999.
17. Wallingford, R., Ducharme, M.B., Pommier, E., *Factors Limiting Cold-Water Swimming Distance While Wearing Personal Flotation Devices.* Evr. J. Appl. Physiol. (2000) 82: 24-29.

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