Cold Water Survival Information Packet
Naval Safety Center
Updated 7/22/13
Ms. Kelsey Leo

Table of Contents **Pages**

- ☐ "Dress to Egress" (Source: *Approach,* September-October, 2010) 1
- ☐ *Predicted Water Immersion Survival Times for Anti-Exposure Ensembles*. Barry S. Shender, PhD and Wendy Todd, NAVAIR Human Systems Department (Source: taken from http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA446406, Printed 6/19/2013) 4
- ☐ From The Merck Manual Diagnosis and Therapy: The Merck Manual Home Handbook for Health Care Professionals: Hypothermia, edited by Daniel F. Danzl. Copyright 2010-2013 by Merck Sharp & Dohme Corp., a subsidiary of Merck & Co, Inc, Whitehouse Station, NJ. Available at http://www.merckmanuals.com/professional/. Accessed 6/25/2013, from http://www.merckmanuals.com/professional/injuries_poisoning/cold_injury/hypothermia.html 14
- ☐ From The Merck Manual Diagnosis and Therapy: The Merck Manual Home Handbook for Health Care Professionals: Overview of Cold Injury, edited by Daniel F. Danzl. Copyright 2010-2013 by Merck Sharp & Dohme Corp., a subsidiary of Merck & Co, Inc, Whitehouse Station, NJ. Available at http://www.merckmanuals.com/professional/. Accessed 6/25/2013, from http://www.merckmanuals.com/professional/injuries_poisoning/cold_injury/overview_of_cold_injury.html 18
- ☐ From The Merck Manual Diagnosis and Therapy: The Merck Manual Home Handbook for Patients and Caregivers: Overview of Cold Injuries, edited by Daniel F. Danzl. Copyright 2010-2013 by Merck Sharp & Dohme Corp., a subsidiary of Merck & Co, Inc, Whitehouse Station, NJ. Available at http://www.merckmanuals.com/professional/. Accessed 6/25/2013, from http://www.merckmanuals.com/home/injuries_and_poisoning/cold_injuries/overview_of_cold_injuries.html?qt=cold%20injury&alt=sh 19
- ☐ "NOAA Aviation Safety Policy Handbook" (Source: NOAA, taken from http://www.corporateservices.noaa.gov/ames/administrative_orders/chapter_209/handbook_noaa_209_124.pdf, Printed 6/19/2013) 21
- ☐ "NOAA Aviation Safety Minimum Training Standards" (Source: NOAA, taken from http://www.omao.noaa.gov/aviationsafety/pdf/minimum_training_standards.pdf, Printed 6/19/2012) 33
- ☐ "Hypothermia" (Source: Westpac Marine Services, Inc.: Maritime Survival Experts, taken from http://westpacmarine.com/samples/Hypothermia_Chart.asp, Printed 6/19/2013) 35
- ☐ "Cold Water Survival" (Source: American Canoe Association, taken from http://c.ymcdn.com/sites/www.americancanoe.org/resource/resmgr/sei-educational_resources/brochure_cold_water_survival.pdf, Printed 6/19/2013) 36
- ☐ "What is Cold Water? A Question Revisited" (Source: Alaska Marine Safety Education Association, taken from http://www.ntsb.gov/news/events/2010/fishing_vessel/presentations/5-Hiscock-What-is-cold-water-Qtn-Revisited.pdf, Printed 6/19/2013) 38
- ☐ *Medical Aspects of Harsh Environments*, Vol. 1, Chapter 17: Cold Water Immersion. 2001. Lorentz E. Wittmers, MD, PhD; and Margaret V. Savage, PhD. (Source: taken from http://www.raems.com/MAHE/20.pdf, Printed 6/19/2013) 40
- ☐ OPNAV 3710.7U Ch. 8 62
- ☐ NAVAIR 13-1-6.7.2 69
- ☐ NWP 3-22.5 SAR TAC 70

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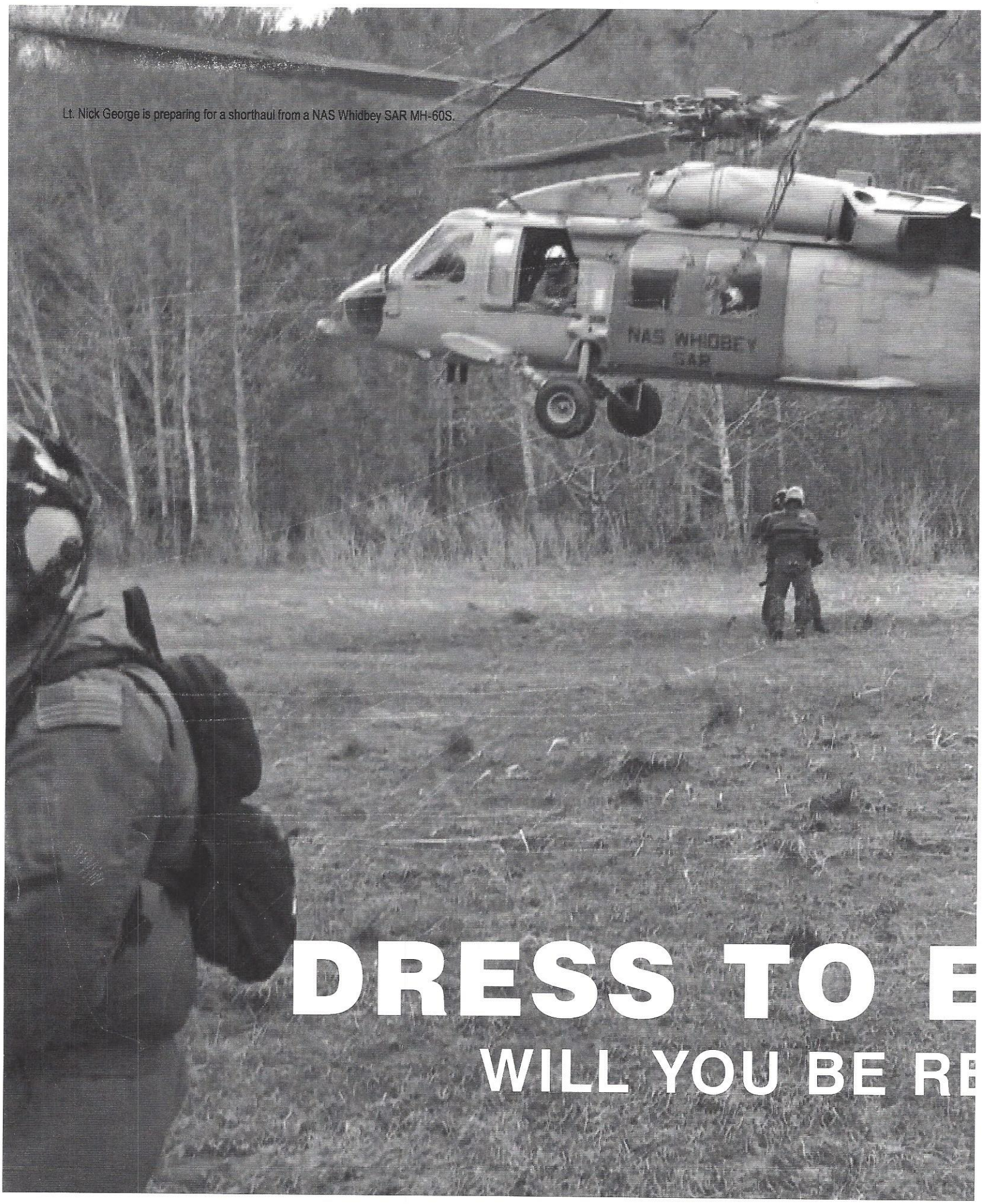

Lt. Nick George is preparing for a shorthaul from a NAS Whidbey SAR MH-60S.

DRESS TO E

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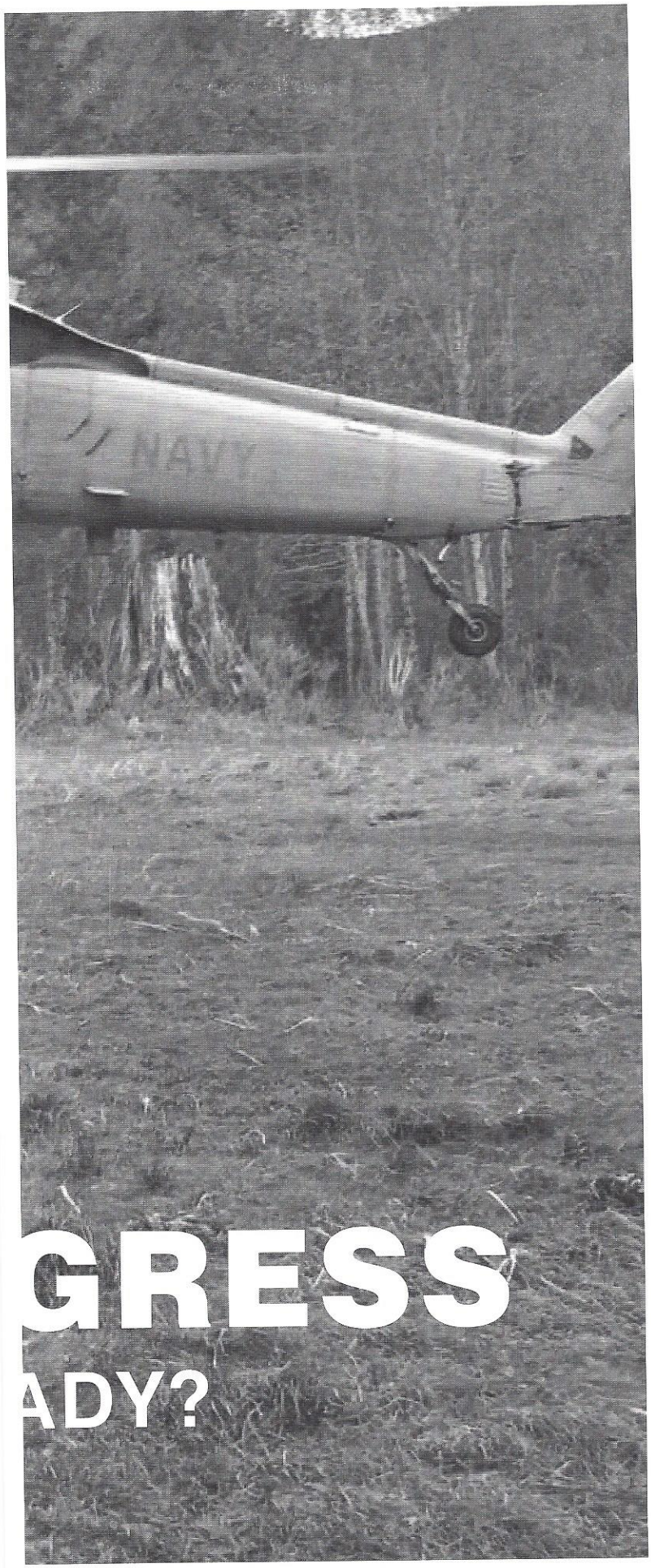

GRESS
ADY?

BY LTJG. MICAH A. KOLCUN

My day began with a 0500 wakeup, so I could get to the squadron and prepare for our brief. As the new guy in the squadron, I focused on preparing the kneeboard cards, putting up the briefing board, and printing the weather and NOTAMS. At 0800 the crew assembled for a standard brief. As we walked to the PR shop to dress for the flight, our PR stopped me and told me my survival vest was ready. Being the new guy, I had been borrowing vests. I was happy to finally have my own. I waited as our PRs did last-minute adjustments to it, and I walked to the jet without checking its contents. Not once during the brief or when putting on the gear did I think about what I'd do if I actually had to use it.

2

Just after starting our preflight, the safety officer came out and said we would be participating in a SAR exercise. The SAR coordinators directed us to a van to take us to the SAR bird. On the ride over, we were told the exercise would last for 24 hours on Mount Baker, a 10,700-foot mountain in the Cascades. I immediately began to dread the night. I realized I did not have a jacket or thermals, and I would be receiving a good lesson on dressing to egress. We arrived at the SAR hangar and received our brief during the helo ride to the mountain.

Ltjg. Scott Dearden starts a fire, while Lt. Nick George and Lt. Nathan Clayville standby to help.

NOT LONG AFTER TAKEOFF, we found a spot to land in the foothills of the Cascades. The terrain varies from 10,000 foot, snow-covered peaks, to low-lying valleys with dense woods and rivers. Such terrain can leave a crew battling the elements on a snow-covered mountain or dealing with muddy terrain infested with bugs. The weather changes quickly and the freezing level can drop down to as low as 1,500 feet in the spring. Rain and wind are a constant reality in the Cascades. A flightsuit and a T-shirt provide little protection against these combined factors.

As we got out of the helo with our instructors, we found ourselves in a valley near a river. Two of our crew were short-hauled to another location, leaving me and another ECMO with an exercise coordinator. To our relief we were told the exercise would only last a few hours, and we would receive training on survival and CSEL radios. The survival training involved finding water and food, building or finding shelter, locating a scattered crew, and signaling for help. Using our combat-survivor-evader locators (CSELs), we rendezvoused with the rest of our crew and proceeded with training. The last training point of the day involved CRM—in a survival scenario, it increases morale and the chance for survival. Keeping to their word, the SAR bird returned and hoisted us up for our return to NAS Whidbey.

I learned to always be aware of what gear I have. Even though Whidbey Island was a nice 60 F, we saw plenty of snow on top of the Cascade Mountains, and the freezing level was near 5,000 feet. Being slightly uncomfortable in the jet because of overdressing never will compare to the possibility of freezing to death on top of a mountain.

Lt. Nathan Clayville deploys smoke to signal rescuers.

I always will preflight my gear and use the extra five pounds of gear allowed. I should have taken a few extra minutes to make sure the new vest had everything in it, and all the equipment was working. As good as the CSEL radio is, it will not work without a battery. Also, having items to help you build a fire, a water filter or purification tablets, and a poncho would be a nice start to the extra five pounds of gear.

I now give a few moments to think about survival and mention it in the brief. This was an exercise, but it was also a good reminder not to get complacent with survival.

LTJG. KOLCUN FLIES WITH VAQ-139.

PREDICTED WATER IMMERSION SURVIVAL TIMES FOR ANTI-EXPOSURE ENSEMBLES

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ABSTRACT

NAVAIR has developed several new concepts for aviator anti-exposure assemblies. Regional insulation levels (immersed clo) of several configurations (a COTS drysuit, the CWU-86/P drysuit, varying types of undergarments including the Multi-Climate Protection system, and a COTS shorty wet suit) were determined using the Navy Clothing and Textile Research Facility's thermal manikin. The manikin was immersed in 20°C turbulent water and was positioned in either a USN or USAF floating posture. These data were used to predict core (rectal) and regional skin temperatures in water ranging from 35°F to 68°F using the Wissler model for three male cases: (1) 140lb. with 8mm mean skin-fold thickness (MST); (2) 170lb. with 10mm MST; (3) 205lb. with 12mm MST. During the first 30 min, high metabolic levels were used to model swimming followed by 330 min of resting metabolism to represent energy conserving behaviors. Model results were used to generate a table of estimated immersed survival times based on the predicted exhaustion of metabolic stores. The results demonstrated the relationship between the ability to survive and water temperatures, time immersed, level of insulation, and body type. These guidelines can be used by aircrew to choose anti-exposure clothing suitable for mission conditions.

INTRODUCTION

US Navy interest in garments providing integrated protection against chemical agents, hyperthermia, hypobaria, and hypothermia has led to fabrication of prototype multi-purpose garments. As part of the development process, these garments need to be tested for the protection they provide against these hazards. Mathematical modeling can be used to simulate the thermal protection provided by the various garment designs and minimize laboratory testing. It can also be used to establish guidelines on the amount of clothing insulation required to withstand exposures of various durations under conditions of thermal stress.

This paper reports on the theoretical evaluation of hypothermia protection provided by nine clothing configurations intended for cold over-water flights during simulated head-out cold water immersion (CWI) using the Texas Human Thermal Model[10] (THTM), as modified by NAVAIR for use with low CLO values[7]. THTM can aid in clothing design by allowing specification of insulation values for up to fifteen body segments. This is an improvement over earlier work, in which researchers based their conclusions on an overall mean clo value for garments[9]. This paper is the first of a two-part effort and reports on nine of seventeen configurations measured and modeled. Part 2 will report the immersed clo values and survival times for the remaining clothing configurations. Part 2 will also investigate whether flotation angle or restrictive flight gear items (torso harness, anti-G garment, and survival vest) have a practical effect on immersed clo values.

Currently, the only guidance provided to USN aircrew for surviving cold immersed mishaps is the OPNAV 3710.7T[12]. The instruction requires that anti-exposure suits (*i.e.* dry suits) be worn if the water temperature is less than 50°F. However, if the water temperature is between 50°F and 60°F, dry suit wear it is up to the judgment of the unit command based on Figure 1 and probable rescue times. Unfortunately, the command does not currently have objective detailed data upon which to determine what garments need to be worn and when. Therefore, the goal of this study was to develop a family of risk curves based on the level of garment insulation and anthropometrics to provide guidelines for safe immersed exposure times.

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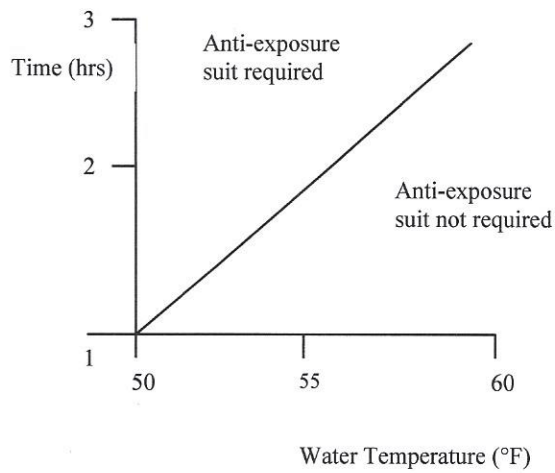

Figure 1. "Figure 8-2 Anti-Exposure Suit Requirements" reproduced from OPNAVINST 3710.7T[12].

METHODS

THTM provides predicted thermal response data for males only. The model can account for variations in weight, body fat (BF), and metabolic rate. For this study, three anthropometric cases were used: (1) 140 lb. and 16.8% BF (8 mm mean skinfold thickness (MST)); (2) 170 lb. and 19.2% BF (10 mm MST); and (3) 205 lb. and 21.2% BF (12 mm MST). The emergency scenario included high levels of activity to model swimming and boarding a raft during the first 30 min, followed by 330 min of inactivity to model resting in the raft conserving energy. Metabolic rates were calculated according to Brooks and Fahey[2] and are given in Table 1. The 360 min immersion scenario was determined for seven temperatures of calm water with 1 mph (30 knot) winds. (Note that it is not possible to include wave effects in the model; however immersed clo values were measured in continuous 1 to 1.5 foot waves.) Water temperatures were 35, 40, 45, 50, 55, 60, and 68°F.

Estimates of rectal temperature (Tre) and central temperature (Tc) were generated as a function of immersion time. Tc was defined as the predicted temperature located in the head at the level of the hypothalamus. The maximum possible exposure duration for each garment in each environment was defined as either completion of the 6 hour immersion or the point at which the THTM predicted metabolic fatigue. This occurred when the energy derived from aerobic metabolism was exhausted with a concomitant buildup of lactic acid (the byproduct of anaerobic metabolism), at which point shivering ceased. THTM indicated that fatigue had been reached by a transient rise in Tc.

THTM separates the body into fifteen regions including head, chest, abdomen, right and left thighs, calves, feet, biceps, forearms and hands. A clo value can be specified for each area. Clo is a measure of intrinsic insulation (*i.e.*, without the adhering boundary still air layer) defined as follows[4]: 1 clo of insulation equals 0.18°C*m^2*hr/kcal, or 5.55 kcal/m^2*hr*deg C. Immersed insulation values for nine different clothing configurations were obtained by the Naval Clothing and Textile Research Facility (NCTRF), Natick, MA from measurements using an immersed copper manikin and are given in Table 2. Three sets of clo values were supplied, labeled 120, 240 and 360 min. For modeling purposes, 120 min values were used during minutes 0-120, the 240 min values were used during minutes 121-240, and the 360 min values were used during minutes 241-360.

The clothing configurations used in this study comprise different combinations of dry suits, thermal liners, and undergarment layer(s) with the helmet, wool socks, and boots held constant (Table 3). Because the chief intent of this work was to provide decision making guidelines, typical clothing combinations by mission platform type were tested. Each clothing component is described below.

CLOTHING COMPONENTS

Dry Suits:

CWU-62B/P Series Anti-Exposure Coverall. This Navy dry suit is a one-piece coverall with permanently installed booties and wrist/neck seals. The body and booties are made of a water-impermeable PTFE-trilaminate fabric, heat-sealed to exclude water. The wrist and neck seals are made of latex rubber and are custom fitted to a watertight condition to each wearer.

CWU-86/P Anti-Exposure Coveralls. This Navy dry suit is essentially a ruggedized version of the CWU-62B/P, enabling the CWU-86/P to be worn without the flight coverall. In addition, the fabric used for the body has a durable water repellent finish. The wrist seals are neoprene rubber, and the neck seal is latex rubber, and each is custom fitted to a watertight condition to each wearer.

Multifabs Survival™ OTS-600 ("Over-The-Side"). This commercial dry suit is a one-piece coverall with permanently installed booties and wrist/neck seals. The body and booties are made of a water-impermeable PTFE-trilaminate fabric, heat-sealed to exclude water; however the inner surface is fleeced for extra insulation. The wrist seals are neoprene rubber, and the neck seal is latex rubber, and each is custom fitted to a watertight condition to each wearer.

Thermal Liners:

CWU-23/P Liner. This USAF liner is a one-piece coverall with long sleeves and long legs with a shorter-than-normal inseam to clear the tops of flight boots. The body is made of polypropylene netting backed with 100% cotton.

MCP (Multi-Climate Protection) Heavyweight Liner. This Navy liner comprises a long-sleeved top and pant made of black 200-weight aramid double velour. The zip-neck top has close fitting knit cuffs, a mock turtleneck collar, and an aramid mesh shirt-tail hem to reduce bulk. The liner pant has a front fly, an elastic waist, an aramid mesh crotch and inseam to reduce bulk, and elastic stirrups.

XCEL® Icon Shorty Wetsuit. This commercial wetsuit is not designed to be a thermal liner, but some Navy aircrews would like to wear it as one during conditions when a dry suit is too much, but a flight suit with thermal underwear is not enough. The "Icon" shorty wetsuit is a 1 mm thick neoprene with smooth finish inner surfaces and nylon tricot laminate outer surfaces. It has short sleeves and short legs.

Multifabs Survival™ Thermal Insulating Garment. This commercial liner is constructed of a polyester batting sandwiched within layers of woven polyester microfiber fabric. It has long sleeves, long legs, and rib knit cuffs at the neck, wrist, and ankles.

Thermal Underwear

CWU-43/P and CWU-44/P. This Navy undergarment set comprises a top and pant made of an aramid waffle-weave knit. The top has a turtleneck and long sleeves. The pant has long legs with close-fitting knit cuffs and elastic stirrups.

MCP Lightweight Underwear. This Navy undergarment set replaces the CWU-43/44s, and comprises a top and pant made of, aramid, raschel knit. The top has a crew neck, extended cuffs with thumbholes, and a shirt-tail hem. The pant has an elastic waist and stirrups.

MCP Mid-weight Underwear. This Navy undergarment set is constructed of an inner aramid fleece with a polyester-spandex face to provide a close fit. The top has a mock turtleneck in a close-fitting rib knit, and the shirt-tail hem is an aramid raschel knit to reduce bulk. The pant has stirrups, front fly, elastic waist, and raschel knit inseam gussets to reduce bulk.

Flight Gear:

Standard Wool Socks. These are made of 100% wool knit, and are knee high. Wool socks are worn over the booties of the anti-exposure suits used in this study.

CWU-27/P Flight Coverall. This quad-service garment is a long-sleeved coverall made of a 4.4 ounce plain weave aramid cloth. It has pockets on the chest, thighs, calves, and left arm. The wrists are wrap cuffs, and the ankles zip to allow a closer fit. This garment is worn on the outside of the OTS-600 and CWU-62 series dry suits. It is not considered to add immersed insulation because it wets through.

HGU-84/P or 68/P Helmet. These Navy helmets are each composed of a lightweight shell constructed of a multi-layer mixed composite of graphite fabric and ballistic nylon cloth, a polystyrene liner, and a 5-layer thermo-plastic inner liner that is dimpled to reduce bulk and allow airflow. A knit cloth cover encases the inner liner. The helmet acts to insulate the head from heat loss.

PCU-56/P Parachute Torso Harness. This Navy harness is an open structure that is fitted tightly to the torso. Thick nylon webbing passes around the shoulders, chest, seat, and legs, and a nylon cloth panel zips closed in the front.

CSU-13B/P Anti-G Suit. This USAF/Navy garment is a "chaps" wrap-around style with cutouts at the knees, groin, and seat. The garment comprises polyurethane-coated nylon bladders encased in aramid cloth pockets, the whole being secured to the body by zippers at the inside legs and side waist. The anti-G- suit is adjusted by lacings to a tight fit to the individual wearer.

CMU-33/P Survival Vest. This Navy garment is constructed of a flame resistant (FR) nylon mesh with FR nylon webbing pocket mounts and heavy aramid cloth pockets over the surface. It is fitted snugly but not tightly to the wearer.

Aircrew Safety Boots. These Navy flight boots are constructed of calfskin lined with full-grain, glove-leather uppers; cold-rolled carbon steel toe caps, padded toe boxes, removable cushioned insoles, and nitrile rubber outsoles.

Table 1. Metabolic rates for males modeled in this effort.

Male Weight (lb.)	Basal (W)	Exercise (W)	Resting (W)
140	97.6	237.1	122.0
170	118.6	292.9	146.4
205	139.5	348.7	174.3

Table 2. Total and regional immersed clo values.

Clothing Configuration	Time (min)	Total	Torso	Head	Legs	Feet	Arms	Hands
1	120	0.08	0.20	0.04	0.21	0.28	0.20	0.01
	240	0.07	0.17	0.03	0.17	0.24	0.18	0.01
	360	0.07	0.17	0.03	0.17	0.20	0.18	0.01
2	120	0.12	1.02	0.15	0.46	0.29	0.79	0.01
	240	0.10	0.42	0.06	0.35	0.28	0.41	0.01
	360	0.09	0.32	0.05	0.32	0.27	0.32	0.01
3	120	0.17	0.57	0.17	0.39	0.21	0.48	0.02
	240	0.17	0.56	0.19	0.31	0.20	0.45	0.02
	360	0.16	0.55	0.19	0.29	0.19	0.44	0.03
4a	120	0.15	0.73	0.68	0.44	0.26	0.30	0.02
	240	0.14	0.73	0.65	0.36	0.24	0.20	0.02
	360	0.13	0.71	0.65	0.34	0.20	0.16	0.02
4b	120	0.13	0.31	0.72	0.20	0.30	0.27	0.02
	240	0.12	0.29	0.67	0.18	0.29	0.24	0.02
	360	0.12	0.28	0.67	0.17	0.29	0.22	0.02
5	120	0.22	1.05	0.71	0.59	0.31	0.57	0.02
	240	0.21	1.03	0.70	0.52	0.28	0.52	0.02
	360	0.21	1.00	0.70	0.49	0.24	0.49	0.02
6	120	0.12	0.64	0.48	0.45	0.28	0.49	0.01
	240	0.12	0.62	0.39	0.38	0.27	0.46	0.01
	360	0.12	0.62	0.92	0.36	0.25	0.47	0.01
7	120	0.12	0.69	0.50	0.39	0.31	0.45	0.01
	240	0.12	0.67	0.86	0.33	0.31	0.44	0.01
	360	0.12	0.65	0.61	0.29	0.32	0.43	0.01
8	120	0.06	0.14	0.02	0.07	0.13	0.05	0.01
	240	0.06	0.14	0.02	0.07	0.13	0.05	0.01
	360	0.06	0.14	0.02	0.07	0.13	0.05	0.01

RESULTS

For each subject, water temperature, and clothing configuration, predicted Tre was computed and a predicted time to fatality was determined. According to THTM, fatality time represents the point at which the body is unable to generate sufficient internal metabolic heat for survival. Common sense dictates that aircrew be extracted from the water prior to time of fatality; thus a survival time limit was calculated subtracting 20 min from the time of predicted fatality (Table 4). Therefore, as a guide for rescue, the values presented in Table 4 represent the estimated *survival* time limit by which immersed male aircrew should be extracted from the water.

As expected, results from an ANOVA study indicated there was a significant effect of body fat content, water temperature and clothing insulation on survival time. Thus, the predicted ability of stouter individuals to survive long periods of water immersion is higher than for leaner individuals wearing more insulative garments.

Note that the clo values for the head were widely variable even though the same helmet was worn for each run. NCTRF observed that the lower (close to zero) clo values for the head were consistent with water washing over the bare head. Thus, they hypothesized that the waves for some runs could have been higher or rougher than in others, forcing water up under the helmet.

To determine the consequences of this variation, a range of head insulation values were modeled and compared the total time to fatality for the different body types and configurations. It was found that there was a difference, albeit small, on the total time to fatality; stouter individuals were less affected by low head insulation compared to lean individuals. However, since it was not known what the "real" wave effect on head insulation value should be and it was not feasible to repeat or add trials, it was decided to present the data as they are, representing the uncontrollable nature of open-water turbulence.

Table 3: Clothing configurations

	USN TACAIR		USN HELO/PATROL				USAF		USN NONSPECIFIC
	1	2	3	4a	4b	5	6	7	8
CWU-62 Dry Suits									
CWU-86/87 Dry Suits			●	●	●	●	●	●	
OTS-600 Dry Suit	●	●							
CWU-72, 81, and 82/P Liners									
CWU-23/P Liner								●	
MCP Heavyweight Liner			●	●		●			
Xcel Icon Shorty Wetsuit									●
Thermal Insulating Garment							●		
CWU-43, 44/P underwear		●						●	
MCP Lightweight underwear				●	●				
MCP Mid-weight underwear						●			
Standard Wool Socks	●	●	●	●	●	●	●	●	●
CWU-27/P Flight Suit	●	●							●
HGU-84 or 68/P Helmet	●	●	●	●	●	●	●	●	
PCU-56/P Torso Harness	●	●							
CSU-13B/P Anti-G Suit	●	●							
CMU-33 Series Survival Vest	●	●							
Aircrew Safety Boots	●	●							
45° flotation angle							●	●	
90° flotation angle	●	●	●	●	●	●			

USING TABLE 4 TO MAKE OPERATIONAL DECISIONS

Aircrew who are scheduled for flights over cold water can use Table 4 to select the garments they will need to wear using the following steps.

1. Consult with their command to determine likely rescue time given visible light, weather conditions, mission range and duration, and availability of search and rescue assets.
2. Determine the water temperature over which he/she will be flying.
3. Choose the body type in the table that most closely resembles themselves, using body fat as the primary variable, and erring on the lean side.
4. Determine survivability time by matching the water temperature row with the garment configuration chosen. Note that ambient air temperature is not a variable in immersed survival time, because water is much more conductive than air.

Example:

A 135lb. 27% BF female is scheduled for an unescorted night flight that will depart Norfolk, VA and terminate approximately three hours later on an aircraft carrier in the Atlantic. The coldest water temperature over which the crew will fly is 53°F. The ambient air temperature is 38°F. Her command estimates that arrival of rescue aircraft from the ship or shore could take at

most 2 hours from time of alert. Experience has taught the crew that, at night, it can take up to an hour to locate someone even if the location is known within yards. She also knows that it takes the rescue swimmer at least 15 minutes to lower, hook-up and complete the hoist. Therefore, she decides to be prepared for 195 minutes survival time.

Since body insulation is more important for survival than mass[6,7], she uses the data provided for the male with 21.2% body fat. She selects the 50°F water temperature row, but since there is no 195 minute column in the table, she chooses to dress for 235 minutes as the safe bet, and dresses in configuration #4b, the CWU-86/P dry suit worn over lightweight MCP underwear. She does not worry that she is "over-dressing" for the mission conditions, because the model does not predict for females who are known to lose more body heat than men[3], and also does not account for wave effects, fatigue, last mealtime, injuries, attitude, etc., which also compromise survivability.

Table 4. Predicted immersed survival time (min) for nine clothing configurations (described in Table 3), listed from least (#8) to most (#5) insulation provided.

	Configuration:	*8*	*1*	*4b*	*3*	*4a*	*2*	*7*	*6*	*5*
Weight / Body Fat	Water Temp °F									
140 lb	35	20	60	80	130	145	160	160	160	250
16.8%	40	30	70	100	175	190	190	205	205	310
	45	40	100	130	220	235	250	280	280	360
	50	60	130	175	310	325	310	340	360	360
	55	80	190	250	325	360	340	360	360	360
	60	130	265	360	360	360	360	360	360	360
	68	295	360	360	360	360	360	360	360	360
175 lb	35	30	70	90	145	160	160	175	175	250
19.2%	40	40	90	115	175	190	205	220	220	310
	45	60	100	145	235	250	235	280	295	360
	50	80	145	205	325	325	280	360	360	360
	55	100	205	280	360	360	340	360	360	360
	60	160	310	360	360	360	360	360	360	360
	68	340	360	360	360	360	360	360	360	360
205 lb	35	40	80	100	160	160	175	190	190	265
21.2%	40	60	100	130	190	205	220	235	235	340
	45	70	130	175	250	265	265	310	310	360
	50	100	175	235	340	340	340	360	360	360
	55	130	250	325	360	360	360	360	360	360
	60	205	340	360	360	360	360	360	360	360
	68	360	360	360	360	360	360	360	360	360

WET SUIT VS DRY SUIT FOR "WARMER" WATER TEMPERATURES

In contrast to the fictional decision made above, aircrew often try to wear the bare minimum possible to reduce the distraction due to heat stress. Many feel that a dry suit, even worn with no long underwear, is just too hot for missions over cold water in warm weather. Previous, extensive research has long established superiority of dry suits over full wetsuits to keep wearers

sufficiently warm in water temperatures of less than 55°F[1,4,8,9]. Nearly as much research has shown that shorty type wetsuits are effective in "warmer" water temperatures (65 to 80°F).

In order to determine if a short, thin wetsuit could fill the gap between no immersion protection and full dry suit protection while keeping aircrew comfortable during routine flight duties, configuration 8 ("Icon" shorty wetsuit with flight suit over top) was included. In addition to estimating survival time, predicted time to heat exhaustion was also determined using the USARIEM Heat Stress Decision Aid Model (HSDA) version 2.0[11].

A worst-case scenario was chosen that represented a hardworking jet pilot or helicopter aircrew flying in warm weather yet over cold water. The specifications included a 200 W work rate, warm ambient air temperature (70°F/50% R.H.), full solar load (*e.g.*, glass canopy or aircraft door open), and no evaporative cooling (no aircraft air conditioning or 0 knots wind speed). According to the HSDA model, a full 300 min mission without rest periods or relief from the environment would be achievable for the standard human in the model (154 lb., 67.7 inch male). HSDA does not account for females nor body size/composition. Table 4 indicates that a 295 min survival is probable in above 60°F water temperatures for each body type. Thus it appears that a thin shorty wetsuit is a feasible compromise for both coldwater immersion protection without excess heat stress during 295 min 70°F air/60°F water temperature flight missions, assuming a 295 min alert-to-rescue time.

RECOMMENDATIONS FOR FUTURE RESEARCH

- Develop a validated version of THTM and HSDA to estimate thermal responses for women.
- Conduct a HSDA heat stress simulation for the remaining eight garments. These heat stress data combined with the immersion survivability estimates can be used to generate a family of curves to provide comprehensive mission planning guidance.

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BIOGRAPHIES

Barry S. Shender, Ph.D. has worked for the NAVAIR Human Systems Department (4.6) since 1987 at Warminster and Patuxent River. He is currently holds the position of NAVAIR Human Systems Senior Scientist and is a NAVAIR Fellow. Dr. Shender is a Fellow of the Aerospace Medical Association (AsMA) and the Chair of AsMA Science and Technology Committee. He led the team that received the 2003 SAFE Association Award for Team Achievement for the Aircrew Integrated Life Support System program. His technical accomplishments have focused on life support in aviation systems, specifically in determining the relationship between physiologic and cognitive and motor responses to exposures to environmental stresses and the prevention of spinal injury during maneuvering flight, ejection and crash. He is the program manager of two ONR Future Naval Capabilities Warfighter Protection programs in the areas of Injury Prevention and Aircrew Integrated Life Support Systems. Both programs include joint service participation through Defense Technology Objectives and Joint Warfighter Capability Objectives. He has over 68 publications in the crew protection, physiology, and human performance.

Wendy Todd has been a military clothing developer for thirteen years, the last nine of these at the Naval Air Warfare Center. She earned a Master of Science in Clothing and Textiles from Virginia Tech in 1991.

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Hypothermia

Hypothermia is a core body temperature < 35° C. Symptoms progress from shivering and lethargy to confusion, coma, and death. Mild hypothermia requires a warm environment and insulating blankets (passive rewarming). Severe hypothermia requires active rewarming of the body surface (eg, with forced-air warming systems, radiant sources) or core (eg, inhalation, heated infusion and lavage, extracorporeal blood rewarming).

Primary hypothermia causes about 600 deaths each year in the US. Hypothermia also has a significant and underrecognized effect on mortality risk in cardiovascular and neurologic disorders.

Etiology

Hypothermia results when body heat loss exceeds body heat production. Hypothermia is most common during cold weather or immersion in cold water, but it may occur in warm climates when people lie immobile on a cool surface (eg, when they are intoxicated) or after very prolonged immersion in swimming-temperature water (eg, 20 to 24° C). Wet clothing and wind chill increase risk of hypothermia.

Conditions that cause loss of consciousness, immobility, or both (eg, trauma, hypoglycemia, seizure disorders, stroke, drug or alcohol intoxication) are common predisposing factors. The elderly and the very young also are at high risk. The elderly often have diminished temperature sensation and impaired mobility and communication, resulting in a tendency to remain in an overly cool environment. These impairments, combined with diminished subcutaneous fat, contribute to hypothermia in the elderly—sometimes even indoors in cool rooms. The very young have similarly diminished mobility and communication and have an increased surface area/mass ratio, which enhances heat loss. Intoxicated people who lose consciousness in a cold environment are likely to become hypothermic.

Pathophysiology

Hypothermia slows all physiologic functions, including cardiovascular and respiratory systems, nerve conduction, mental acuity, neuromuscular reaction time, and metabolic rate. Thermoregulation ceases below about 30° C; the body must then depend on an external heat source for rewarming. Renal cell dysfunction and decreased levels of ADH lead to production of a large volume of dilute urine (cold diuresis). Diuresis plus fluid leakage into the interstitial tissues causes hypovolemia. Vasoconstriction, which occurs with hypothermia, may mask hypovolemia, which then manifests as sudden shock or cardiac arrest during rewarming (rewarming collapse) when peripheral vasculature dilates.

Immersion in cold water can trigger the diving reflex, which involves reflex vasoconstriction in visceral muscles; blood is shunted to essential organs (eg, heart, brain). The reflex is most pronounced in small children and may help protect them. Also, hypothermia due to total immersion in near-freezing water may protect the brain from hypoxia by decreasing metabolic demands. The decreased demand probably accounts for the occasional survival after prolonged cardiac arrest due to extreme hypothermia.

Symptoms and Signs

Intense shivering occurs initially, but it ceases below about 31° C, allowing body temperature to drop more precipitously. CNS dysfunction progresses as body temperature decreases; people do not sense the cold. Lethargy and clumsiness are followed by confusion, irritability, sometimes hallucinations, and eventually coma. Pupils may become unreactive. Respirations and heartbeat slow and ultimately cease. Initially, sinus bradycardia is followed by

slow atrial fibrillation; the terminal rhythm is ventricular fibrillation or asystole. However, these rhythms are potentially less ominous than in normothermia.

Diagnosis

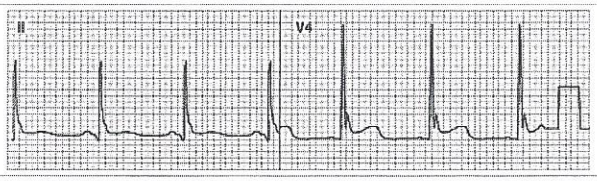
- Core temperature measurement
- Consideration of intoxication, myxedema, sepsis, hypoglycemia, and trauma

Diagnosis is by core temperature, not oral temperature. Electronic thermometers are preferred; many standard mercury thermometers have a lower limit of 34° C. Rectal, bladder, and esophageal probes are most accurate.

Laboratory tests include CBC, glucose (including bedside measurement), electrolytes, BUN, creatinine, and ABGs. ABGs are not corrected for low temperature. ECG typically shows J (Osborn) waves (see Fig. 1: Cold Injury: Abnormal ECG showing J (Osborn) waves (V4).) and interval prolongation (PR, QRS, QT), although these findings are not always present. Causes are sought. If the cause is unclear, alcohol level is measured, and drug screening and thyroid function tests are done. Sepsis and occult head or skeletal trauma must be considered.

Fig. 1

Abnormal ECG showing J (Osborn) waves (V4).



Clinical Calculator
Corrected QT Interval (QTc)
Provided by MD CALC

Prognosis

Patients who have been immersed in icy water for 1 h or (rarely) longer have sometimes been successfully rewarmed without permanent brain damage (see Drowning: Prognosis), even when core temperatures were very low or when pupils were unreactive. Outcome is difficult to predict and cannot be based on the Glasgow Coma Scale. Grave prognostic markers include evidence of cell lysis (hyperkalemia > 10 mEq/L), intravascular thrombosis (fibrinogen < 50 mg/dL), and presence of a nonperfusing cardiac rhythm (ventricular fibrillation or asystole). For a given degree and duration of hypothermia, children are more likely to recover than adults.

Treatment

- Drying and insulation
- Fluid resuscitation
- Active rewarming unless hypothermia is mild, accidental, and uncomplicated

The first priority is to prevent further heat loss by removing wet clothing and insulating the patient. Subsequent measures depend on how severe hypothermia is and whether cardiovascular instability or cardiac arrest is present. Returning patients to a normal temperature is less urgent in hypothermia than in severe hyperthermia. For stable patients, elevation of core temperature by 1° C/h is acceptable.

If hypothermia is mild and thermoregulation is present (indicated by shivering and temperature typically 31 to 35° C), insulation with heated blankets and warm fluids to drink are adequate.

Fluid resuscitation is essential for hypovolemia. Patients are given 1 to 2 L of 0.9% saline solution (20 mL/kg for

children) IV; if possible, the solution is heated to 40 to 42° C. More fluid is given as needed to maintain perfusion.

Active rewarming: Active rewarming is required if patients have cardiovascular instability, temperature < 32.2° C, hormone insufficiency (such as hypoadrenalism or hypothyroidism), or hypothermia secondary to trauma, toxins, or predisposing disorders. If body temperature is at the warmer end of the range, external rewarming with forced hot air enclosures may be used. External heat is best applied to the thorax because warming the extremities may increase metabolic demands on a depressed cardiovascular system. Patients with lower temperatures, particularly those with low BP or cardiac arrest, require core rewarming.

Core rewarming options include

- Inhalation
- IV infusion
- Lavage
- Extracorporeal core rewarming (ECR)

Inhalation of heated (40 to 45° C), humidified O_2 via mask or endotracheal tube eliminates respiratory heat loss and can add 1 to 2° C/h to the rewarming rate.

IV crystalloids or blood should be heated to 40 to 42° C, especially with massive volume resuscitations.

Heated lavage of the bladder or GI tract transfers minimal heat, although closed thoracic lavage through 2 thoracostomy tubes is very efficient in severe cases. Peritoneal lavage with dialysate heated to 40 to 45° C requires 2 catheters with outflow suction and is expecially useful for severely hypothermic patients who have rhabdomyolysis, toxin ingestions, or electrolyte abnormalities.

There are 4 types of ECR: hemodialysis, venovenous, arteriovenous, and cardiopulmonary bypass. ECR measures require a prearranged protocol with appropriate specialists. Although they are intuitively attractive and heroic, these measures are not routinely available, and they are not commonly used in most hospitals.

CPR: CPR is not done if patients have a perfusing rhythm, even if pulses are not palpable. Fluids are given, and active rewarming is done. Hypotension and bradycardia are expected when core temperature is low and, if due solely to hypothermia, need not be aggressively treated. Patients with a nonperfusing rhythm require CPR. Chest compressions and endotracheal intubation are done. Defibrillation is difficult if body temperature is low; one attempt with a 2 watt sec/Kg charge may be made, but if ineffective, further attempts are generally deferred until temperature reaches > 30° C. Advanced life support should be continued until temperature reaches 32° C unless obviously lethal injuries or disorders are present. However, advanced cardiac life-support drugs (eg, antiarrhythmics, vasopressors, inotropes) are usually not given. Low-dose dopamine (1 to 5 μg/kg/min) or other catecholamine infusions are typically reserved for patients who have disproportionately severe hypotension and who do not respond to fluid resuscitation and rewarming. Severe hyperkalemia (> 10 mEq/L) during resuscitation typically indicates a fatal outcome and can guide resuscitation efforts.

Key Points

- Measure core temperature using an electronic thermometer or probe.
- Above about 32° C, heated blankets and warm drinks are adequate treatment.
- Below about 32° C, active rewarming should be done, typically using hot air enclosures, heated, humidified O_2, warm IV fluid, and sometimes heated lavage or extracorporeal methods (eg, cardiopulmonary bypass, hemodialysis).
- At lower temperatures, patients are hypovolemic and require fluid resuscitation.
- CPR is not done if there is a perfusing rhythm; when it is done, defibrillation is deferred (after one initial attempt) until temperature reaches about 30° C.
- Advanced cardiac life-support drugs are usually not given.

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16

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Overview of Cold Injury

Exposure to cold may cause decreased body temperature (hypothermia) and focal soft-tissue injury. Tissue injury with freezing is frostbite. Tissue injury without freezing includes frostnip, immersion foot, and chilblains. Treatment is rewarming and selective, usually delayed, surgical treatment for injured tissues.

Susceptibility to all cold injury is increased by exhaustion, undernutrition, dehydration, hypoxia, impaired cardiovascular function, and contact with moisture or metal.

Prevention

Prevention is crucial. Several layers of warm clothing and protection against moisture and wind are important even when the weather does not seem to threaten cold injury. Clothing that remains insulating when wet (eg, made of wool or polypropylene) should be worn. Gloves and socks should be kept as dry as possible; insulated boots that do not impede circulation should be worn in very cold weather. A warm head covering is also important. Consuming ample fluids and food helps sustain metabolic heat production. Paying attention to when body parts become cold or numb and immediately warming them may prevent cold injury.

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Overview of Cold Injuries

The skin and the tissues under it are kept at a constant temperature (about 98.6° F, or 37°C) by the circulating blood and other mechanisms. The blood gets its heat mainly from the energy given off by cells when they burn (metabolize) food—a process that requires a steady supply of food and oxygen. A normal body temperature is necessary for proper functioning of all the cells and tissues in the body. In a person with low body temperature, most organs, especially the heart and brain, become sluggish and eventually stop working.

Body temperature falls when the skin is exposed to colder surroundings. In response to this fall in temperature, the body uses several protective mechanisms to generate additional heat. For example, the muscles produce additional heat through shivering. Also, the small blood vessels in the skin narrow (constrict), so that more blood is diverted to vital organs, such as the heart and brain. However, as less warm blood reaches the skin, body parts such as the fingers, toes, ears, and nose cool more rapidly. If body temperature falls much below about 88° F (about 31° C), these protective mechanisms stop working, and the body cannot warm itself. If body temperature falls below 83° F (about 28° C), death is likely.

Cold injuries are less likely to occur, even in extremely cold weather, if the skin, fingers, toes, ears, and nose are well protected or are exposed only briefly. The risk of cold injuries increases in the following circumstances:

- When the flow of blood is too slow
- When food intake is inadequate
- When dehydration or exhaustion occur
- When the environment is wet or when a body part contacts something wet
- When the person comes into contact with a metal surface
- When insufficient oxygen is available, as occurs at high altitude

Keeping warm in a cold environment requires several layers of clothing—preferably wool or synthetics such as polypropylene, because these materials insulate even when wet. Because the body loses a large amount of heat from the head, a warm hat is essential. Eating enough food and drinking enough fluids (particularly warm fluids) also help. Food provides fuel to be burned, and warm fluids directly provide heat and prevent dehydration. Alcoholic beverages should be avoided, because alcohol widens (dilates) blood vessels in the skin, which makes the body temporarily feel warm but actually causes greater heat loss.

Cold injuries include hypothermia, frostnip, chilblains, immersion foot, and frostbite. Other problems related to the cold include Raynaud syndrome (see Peripheral Arterial Disease: Raynaud's Syndrome) and allergic reactions to the cold (see Allergic Reactions and Other Hypersensitivity Disorders: Physical Allergy).

Did You Know...

- Drinking alcoholic beverages actually makes the body colder because the widening of blood vessels that makes a person feel warm allows more heat to escape from the body.

19

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NOAA Aviation Safety Policy Handbook

SECTION 1. PURPOSE
SECTION 2. SCOPE
SECTION 3. BACKGROUND
SECTION 4. POLICY
SECTION 5. DEFINITIONS
SECTION 6. RESPONSIBILITIES
SECTION 7. PROCEDURES
SECTION 8. TRAINING
SECTION 9. AUTHORITIES
SECTION 10. REFERENCES

SECTION 1. PURPOSE

The National Oceanic and Atmospheric Administration (NOAA) is responsible for providing a safe working environment for its workforce, and for partners who are exposed to the risks associated with flying on aircraft owned or operated by NOAA. The purpose of NOAA Administrative Order (NAO) 209-124 is to make aviation safety the number one priority for all aviation operations by creating policy that:

a. ensures aircraft meet airworthiness and operational safety standards;

b. ensures personnel are provided with aviation safety training and aviation life support equipment (ALSE); and

c. establishes a corporate NOAA Aviation Safety Board (NASB) and Aviation Safety Program (ASP) to provide policies, procedures, tools and training that follow the Safety Standards Guidelines for Federal Flight Programs codified in sections 102-33.140 and 102-33.155-185 of title 41 of the Code of Federal Regulations (41 CFR 102-33.140 and 41 CFR 102-33.155-185).

SECTION 2. SCOPE

.01 Except as provided in Section 2.02, this handbook applies to all NOAA personnel flying on any aircraft in the performance of their official duties, and to all individuals flying on aircraft owned or operated by NOAA. For purposes of this order, aircraft operated by NOAA includes aircraft:

a. rented, chartered, leased, or owned by NOAA or NOAA personnel, and used to conduct official business; and

b. operated by public or private entities on behalf of NOAA through written support agreements with NOAA.

.02 This order does not apply to the use of:

a. air carriers for transportation;

b. aircraft for the acquisition of products or data (including products or data acquired through grants) where no NOAA personnel fly on the aircraft in any capacity; or

c. aircraft for movement of cargo where no NOAA personnel fly on the aircraft in any capacity.

SECTION 3. BACKGROUND

.01 NOAA operations often require flights for transportation or mission operations accomplished in both *rotary* and *fixed wing* aircraft operated by NOAA or other federal agencies of the U.S. Government. These may include the armed forces, state and local governments, foreign governments, and civilian aviation service providers. These aircraft operators may be providing the service directly to NOAA or to another party. Examples of routine NOAA flight operations include hazardous weather research, aerial damage assessment, air chemistry, forecaster training, coastal and offshore surveys, enforcement, and remote sensing.

.02 An aircraft operated by the U.S. Government, or one owned and operated by the government of a state, the District of Columbia, or a territory or possession of the United States or a political subdivision of one of these governments, may be considered to be operating as a "public aircraft" as defined in sections 40102 and 40125 of title 49 of the U.S. Code. Except for certain airspace rules that apply to all aircraft (reference Federal Aviation Act of 1958, Title 49 U.S.C. Subtitle VII), the Federal Aviation Administration (FAA) has no legal jurisdiction over public aircraft operations. As such, public aircraft are not subject to many federal aviation regulations, including requirements relating to aircraft certification, maintenance, and pilot certification.

.03 To ensure the safety of federal employees while operating in public aircraft, federal agencies are required to develop agency-specific flight program standards that meet or exceed applicable civil or military rules. These standards must be incorporated in contracts and agreements as set forth in Safety Standards Guidelines for Federal Flight Programs codified by regulations set forth in 41 CFR 102-33.140 and 41 CFR 102-33.155-185.

SECTION 4. POLICY

.01 NOAA is responsible for ensuring that:

a. aircraft owned or operated by NOAA meet airworthiness and operational safety standards; and

b. all qualified non-crewmembers who fly on aircraft owned or operated by NOAA for mission operations, and all NOAA personnel who fly as qualified non-crewmembers on any aircraft for mission operations in the performance of their official duties, are:

1. appropriately trained in aviation safety; and

2. provided appropriate ALSE.

.02 The Director, Office of Marine and Aviation Operations (OMAO). The Director, OMAO, shall broadly administer NOAA's aviation safety policy through the Aviation Safety Program Manager (ASPM). The Director, OMAO shall approve all revisions to the NOAA Aviation Safety Handbook.

.03 NOAA Aviation Safety Board (NASB).

a. The NASB is composed of both voting and non-voting personnel appointed by Line and Staff offices as governed by the Terms of Reference The NASB is chaired by the ASPM. Duties, functions, responsibilities and procedures are delineated section 6.

b. Voting members of the NASB must meet the aviation safety training and qualification standards outlined in the NASB Terms of Reference.

SECTION 5. DEFINITIONS

.01 Accident (Aircraft) - is defined by the National Transportation Safety Board (NTSB) as an occurrence associated with the operation of an aircraft that takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage.

.02 Aircraft - is defined by 14 CFR 1.1 as a device that is used or intended to be used for flight in the air.

.03 Armed Forces - means the U.S. Army, Navy, Air Force, Marine Corps, and Coast Guard, including their Regular and Reserve components which includes the National Guard. The U.S. Civil Air Patrol and the U.S. Coast Guard Auxiliary are not considered armed forces.

.04 Aviation Life Support Equipment (ALSE) - is equipment that protects crewmembers and others aboard an aircraft, or assists in their safe escape, survival, and recovery during an accident or other emergency.

.05 Aviation Services - means procurement of the use of an aircraft for mission operations or transportation.

.06 Crewmember - is defined in 41 CFR 102-33.20 as a person assigned to operate or assist in operating an aircraft during flight time. Crewmembers perform duties directly related to the operation of the aircraft (e.g., as pilots, co-pilots, flight engineers, navigators) or duties assisting in operation of the aircraft (e.g., as flight directors, crew chiefs, electronics technicians, mechanics).

.07 Data Services - means the procurement of products or data that may be acquired through the use of an aircraft.

.08 Government Aircraft – is a federal aircraft or a commercial aircraft hired as a commercial aviation services aircraft (as defined by 41 CFR 102-33.20).

.09 Incident (Aircraft) - as defined by the NTSB, means an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations.

.10 Mission Operations - are all operations other than transportation. Mission operations include, but are not limited to: aerial surveys, airborne data collection, forecaster training, and aerial photography.

.11 Near Miss - means: (1) a near midair collision associated with the operation of an aircraft in which a possibility of collision occurs as a result of unplanned proximity of less than 500 feet to another aircraft, or a report is received from a pilot or a flight crew member stating that a collision hazard existed between two or more aircraft; (2) any situation involving aircraft in which evasive action was required to avoid a collision (such as emergency maneuvering to avoid a bird strike or collision with any object); or (3) any "close-call" incident that could have resulted in a fatality or serious injury, or that could have jeopardized the safety of the flight.

.12 NOAA Aircraft – is an aircraft that NOAA owns (holds title to or has vested rights in the title) or an aircraft that NOAA leases and holds the option to purchase.

.13 NOAA Personnel - is any NOAA employee or NOAA contract employee, or any other individual who meets the definition of a NOAA employee under 5 USC Ch. 81 (Federal Employees Compensation Act).

.14 Observer - is any qualified non-crewmember who monitors the performance of the governmental function for which the aircraft is being operated. Observer status is determined by the NOAA Line/Staff Office Project Manager or Principal Investigator responsible for the flight and shall not be granted to an individual more than once every four months on average or more than three times per year over any given calendar year. As a minimum, observers will complete online training as described in this handbook.

.15 Over Water Flight - are flight operations over water and beyond power off gliding distance from a suitable emergency landing location on shore.

.16 Privately Owned Aircraft - is defined in 41 CFR 300-3.1 as an aircraft that is rented, chartered, leased, or owned by an employee for personal use. It is not rented, chartered, leased, or owned by a government agency or an employee for use in carrying out official government business.

.17 Qualified Non-Crewmember - is defined in 41 CFR 102-33.20 as a person flying onboard a government aircraft whose skills or expertise are required to perform or are associated with performing the governmental function for which the aircraft is being operated (qualified non-

crewmembers may be researchers, law enforcement agents, fire fighters, agricultural engineers, biologists, etc.).

.18 Transportation - is the use of aircraft for the exclusive purpose of moving individuals from point to point. Any individual that participates in an Over Water Flight or Cold Water operation more than once every four months, on average, or more than three times per year over any given calendar year must complete the training listed in this handbook even if the flight operation is for transportation only.

SECTION 6. RESPONSIBILITIES.

.01 NOAA Aviation Safety Board (NASB).

a. The NASB is composed of the following personnel:

Voting Members:
- Aviation Safety Program Manager (ASPM) - Chairperson
- NOAA Aircraft Operations Center (AOC) Representative
- NOAA Safety and Environmental Compliance Office Representative
- National Marine Fisheries Service (NMFS) Representative
- National Ocean Service (NOS) Representative
- Office of Oceanic and Atmospheric Research (OAR) Representative
- National Weather Service (NWS) Representative
- National Environmental Satellite, Data and Information Service (NESDIS) Representative

Non-Voting Observers:
- NOAA General Counsel Representative
- NOAA Acquisitions and Grants Office Representative
- NOAA Workforce Management Office Representative
- NOAA Program Planning and Integration Representative

Executive Secretary:
- Aviation Safety Program staff designee

b. The NASB shall:

1. approve aviation safety training and ALSE requirements;

2. approve minimum aviation safety standards to be included in NOAA's contracts for aviation services and data services;

3. approve aviation safety and risk assessment tools developed by the NOAA ASP;

4. solicit and address the aviation safety issues and needs of NOAA;

5. review reports from NOAA aviation accidents and potentially dangerous incidents and recommend preventative measures to the ASPM;

6. review results of NOAA aviation safety audits to monitor compliance with NOAA aviation safety policy;

7. review proposed revisions to the NOAA Aviation Safety Handbook and make a recommendation to the Director, OMAO, to approve changes;

8. seek pertinent expertise on aviation safety matters before the NASB; and

9. report to the NOAA Safety Council circumstances adversely impacting safety and/or efficiency of the NOAA ASP.

.02 The ASPM shall:

a. possess significant aviation operational field experience and maintain Interagency Committee for Aviation Policy (ICAP) Federal Aviation Safety Officer credentials;

b. maintain the Aircraft Operator Database (AOD) described in Section 7.05;

c. facilitate the acquisition of aviation safety training identified in Section 8;

d. acquire, distribute, and maintain ALSE identified in Section 8;

e. provide aviation safety tools and instruction on the use of such tools, including risk assessment matrices and mishap response checklists;

f. provide assistance to NOAA contracting officials by:

1. providing language for inclusion in all relevant contracts and agreements that sets forth airworthiness and safety standards; and

2. serving as a source evaluation board and technical evaluation panel advisor to evaluate potential offeror's aviation-related technical proposals;

g. host an annual NOAA aviation safety conference;

h. administer the NOAA aviation safety awards program; and

i. maintain a NOAA aircraft accident and incident database and enter data from NOAA aircraft accidents and incidents into the Federal Aviation Accident Incident Reporting System (AAIRS) as required by 41 CFR 102-33.445 through 102-33.450, Management of Government Aircraft.

.03 NOAA Line Office Assistant Administrators (AAs) and Staff Office equivalents shall:

a. designate in writing primary and alternate Line/Staff Office representatives to the NASB, as applicable;

b. hold the Line/Staff Office NASB representatives, in their performance appraisals, accountable for NASB duties; and

c. ensure Line/Staff Office compliance with this Order.

.04 NOAA Contracting Officers and Contracting Officers Technical Representatives (COTRs) shall ensure that:

a. contracts and agreements for which the contracting officer is responsible, that secure the use of an aircraft on which NOAA personnel will fly,

1. are only executed with:

(a) aircraft operators listed on the AOD described in Section 7.05; or

(b) aircraft operators exempt in accordance with Section 2.02 of NAO 209-124 (repeated in Section 2.02 of this handbook).

2. include language setting forth airworthiness and operational safety standards.

b. the ASPM or designee is consulted as a source selection board or technical evaluation panel advisor for all contracts and agreements subject to the provisions of this Order in order to evaluate the air service providers' technical proposals for ability to comply with airworthiness and operational safety standards.

.05 Crewmembers shall:

a. have crewmember duties specified in their position description or be appointed in writing as a crewmember by the Commanding Officer of AOC;

b. meet or exceed all crewmember certification and medical standards, training qualifications, flight experience, and flight currency prescribed in the NOAA AOC Aircraft Operations Manual for the type(s) of aircraft and the flight environment exposed to when flying for NOAA;

c. ensure copies of all crewmember certificates, medical certificates, training received, results from standardization/evaluation check flights, and copies of flight logs are in their aviator information file at NOAA's AOC;

d. abide by all operational procedures prescribed by the NOAA AOC Aircraft Operations Manual;

e. notify the NOAA Aviation Medical Examiner of any changes in medical condition that might impact their fitness for flight duty; and

f. when renting, chartering, or leasing an aircraft to fly operationally for NOAA, do so exclusively from operators listed on the AOD.

SECTION 7. PROCEDURES.

.01 Type of flight operation. Prior to departure, the NOAA Line/Staff Office Project Manager or Principal Investigator responsible for the flight shall determine whether the flight is for mission operations or transportation (as defined in Section 5) in order to determine whether the training and equipment requirements set forth in Section 8 apply.

.02 NOAA personnel are authorized to fly on the following aircraft:

a. NOAA aircraft;

b. non-NOAA aircraft owned by an air service provider listed on the AOD;

c. non-NOAA aircraft owned and operated by other departments, agencies, or instrumentalities of the United States; by state or local governments; or by the governments of countries that meet the Federal Aviation Administration International Aviation Safety Assessment Program Category 1 rating (including the armed forces of those countries); or

d. privately owned aircraft (POA) owned by NOAA personnel, provided that: use of a POA is authorized by NOAA in accordance with the Federal Travel Regulations; the POA is used exclusively for transportation; and the pilot carries no other personnel onboard.

.03 NOAA personnel are authorized to fly mission operations:

a. while serving as a qualified non-crewmember, when the individual:

1. has completed the appropriate aviation safety training prescribed in this handbook, or if deemed an observer (see definition below) by the Line/Staff Office Project Manager or Principal Investigator responsible for the flight, has received a pre-flight safety briefing from a member of the aircraft flight crew; and

2. possesses, or has immediately accessible in the aircraft, applicable aviation life support equipment (ALSE) as prescribed in NAO 209-124 and described in Section 8; or

b. while serving as a crewmember, when the individual meets the medical standards, aviation safety training, and ALSE requirements set forth in the NOAA AOC Aircraft Operations Manual for the position assigned.

.04 Non-NOAA personnel may be authorized to fly on aircraft owned or operated by NOAA.

In instances involving mission operations, non-NOAA personnel serving as qualified non-crewmembers must satisfy the following conditions:

a. completion of appropriate aviation safety training prescribed in this handbook, or if deemed an observer (see definition in Section 5) by the NOAA Line/Staff Office Project Manager or Principal Investigator responsible for the flight, receipt of a pre-flight safety briefing from a member of the aircraft flight crew; and

b. possession of, or has immediate access in the aircraft to applicable ALSE prescribed in NAO 209-124 and described in Section 8.

.05 Aircraft Operator Database (AOD). The NOAA Aviation Safety Program Manager (ASPM) shall maintain a web-based AOD, which is a list of air service providers (both foreign and domestic) qualified to provide aviation services to NOAA. Operators in this database are found to meet or exceed NOAA airworthiness and operational safety standards.

a. Use of aircraft in the database shall be limited to those types of operations for which they have been qualified (e.g., an aircraft qualified for remote sensing may not be used for transportation unless specifically cleared for transportation). POA will not be listed on the AOD.

b. NOAA personnel may request additional aircraft operators be evaluated for inclusion on the AOD by submission of a written request to the NOAA ASPM.

.06 Aviation Safety Training is required for all personnel serving as qualified non-crewmembers unless they are deemed an observer by the NOAA Line/Staff Office Project Manager or Principal Investigator responsible for the flight. Section 8 lists aviation safety training required for NOAA personnel who fly as qualified non-crewmembers on any aircraft for mission operations in the performance of their official duties and for all qualified non-crewmembers who fly on aircraft owned or operated by NOAA for mission operations. Each NOAA Line/Staff Office Project Manager or Principal Investigator shall be responsible for ensuring all individuals under their supervision who are required to fly receive the aviation safety training required by this Order.

.07 ALSE will be provided to individuals who fly on aircraft owned or operated by NOAA. Examples of NOAA ALSE are in Section 8. ALSE shall be:

a. issued by the Aviation Safety Program (ASP) to NOAA units in sufficient quantity to support unit flight requirements;

b. issued to the individual by the NOAA unit, or provided by the aircraft operator as required by contractual agreement;

c. maintained and inspected to industry standards by the ASP if owned by NOAA; and

d. worn by, or readily accessible to, personnel at all times while in flight.

.08 Aircraft Accidents and Incidents are required to be reported to the NTSB as prescribed by 49

CFR 830, "Notification and Reporting of Aircraft Accidents or Incidents and Overdue Aircraft, and Preservation of Aircraft Wreckage, Mail, Cargo, and Records."

a. All NTSB reportable accidents and incidents that occur while conducting official NOAA business must be reported by the aircraft operator working under contract or other written agreement with NOAA:

1. to the NOAA ASPM; and

2. to the NOAA Contracting Officer overseeing the contract.

b. NOAA personnel involved in an accident, incident, or near-miss involving an aircraft owned or operated by NOAA must report the occurrence in accordance with NAO 209-1, NOAA Safety Policy, and any superseding Department of Commerce (DOC) and/or NOAA guidance.

c. Accidents and incidents involving aircraft owned or operated by NOAA will be investigated in accordance with the policies and procedures set forth by the NOAA Incident Investigation Program.

.09 Requests for Waiver to provisions of this handbook shall be presented in writing to the Director, OMAO, with a copy to the ASPM. Based on waiver requests, the ASPM will assemble a Review Board to recommend appropriate waiver response to the Director, OMAO. The Director, OMAO, is the approval authority for all waivers to provisions.

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Section 8. NOAA AVIATION SAFETY TRAINING AND ALSE REQUIREMENTS.

Note: Aviation Safety Training and Aviation Life Support Equipment (ALSE) Requirements may be modified by the NASB. The most current information will be posted at (http://www.omao.noaa.gov/aviationsafety).

.01 Aviation safety training is an essential component of the NOAA Aviation Safety Program. The following table outlines training requirements for qualified non-crewmembers participating in Mission Operations flights for NOAA:

Aviation Safety Training							
Training Method		NOAA E-Learning			Egress Video	Classroom & Hands-on*	Classroom & Hands-on*
Training Frequency		Annual	Annual	Annual	Annual	Once every 5 years	One time
Flight Purpose and Environmental Conditions	Personnel	NOAA Aviation Policy and Procedures	Basic Aviation Safety and Survival	Aviation Health	Water Ditching, Safety and Survival		Aviation Safety and Cold Weather Survival
Operations over land	NOAA	✔	✔	✔			
	Non-NOAA		✔	✔			
Operations over water	NOAA	✔	✔	✔	✔	✔	
	Non-NOAA		✔	✔	✔	✔	
Operations in cold weather (<32˚F)	NOAA	✔	✔	✔			✔
	Non-NOAA		✔	✔			✔

***Note:** Reasonable Accommodations may be considered for a qualified individual with a disability.
Note: NOAA Personnel may request more frequent training than what is listed above.

.02 In addition to aviation safety training requirements, NOAA has a requirement for use of ALSE as indicated in the table below:

Aviation Life Support Equipment (ALSE) required to be carried in the aircraft or worn by personnel				
Flight Purpose and Environmental Conditions	Life Raft of sufficient capacity for all aircraft occupants	Personal Flotation Device (PFD) (Life Vest)	Personal Emergency Locator Transmitter	Anti-Exposure Suit
Operations over water	✔	✔	✔	
Operations over cold water (<59° water temp and/or <32° air temp)	✔	✔	✔	✔

Note: Personal issue and/or use of a Helicopter Emergency Egress Device (HEED), Helicopter Aircrew Breathing Device (HABD), or other compressed air breathing device for underwater egress is only authorized for individuals who have received training to use the particular device.

SECTION 9. AUTHORITIES

5 USC Chapter 81:
http://finduslaw.com/federal_employment_compensation_act_feca_5_u_s_code_chapter_81

14 CFR 1.1:
http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&rgn=div8&view=text&node=14:1.0.1.1.1.0.1.1&idno=14

41 CFR 102-33.20:
http://law.justia.com/cfr/title41/41-3.1.1.2.9.html

49 U.S.C. Subtitle VII:
http://www.tsa.gov/assets/pdf/49_USC_Chapters_401_to_501.pdf

49 CFR 830:
http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title49/49cfr830_main_02.tpl

49 CFR sections 40102 and 40125 International Civil Aviation Organization (ICAO), a United Nations agency, Annexes 1, 6, and 8 of the Chicago Convention standards. Federal Aviation Administration International Aviation Safety Assessment Program:
http://www.faa.gov/about/initiatives/iasa/

SECTION 10. REFERENCES

NAO 209-1, NOAA Safety Policy: http://www.corporateservices.noaa.gov/~ames/NAOs/Chap_209/naos_209_1.html

NAO 216-104, Management and Utilization of Aircraft:
http://www.rdc.noaa.gov/ames/NAOs/Chap_216/naos_216_104.html

NAO 217-106, Transportation of Non-government Personnel as Passengers on NOAA Vessels, Aircraft, and Motor Vehicles:
http://www.corporateservices.noaa.gov/~ames/NAOs/Chap_217/naos_217_106.html

NOAA Aviation Safety Board Terms of Reference: http://www.omao.noaa.gov/aviationsafety/safety_board/AvnSafetyBoardTOR.pdf

NOAA Aircraft Operations Center (AOC) Aircraft Operations Manual: in Draft available from AOC

NOAA Aviation Safety
Minimum Training Standards

Aviation safety training is an essential component of the NOAA Aviation Safety Program. The following table outlines training requirements for qualified non-crewmembers participating in Mission Operations flights for NOAA:

Aviation Safety Training						
Training Method		NOAA E-Learning		Egress Video	Classroom and Hands-on	Classroom and Hands-on
Training Frequency		annual	annual	annual	once every 5 years	one time
Flight Purpose and Environmental Conditions	Personnel	NOAA Aviation Policy and Procedures	Basic Aviation Safety and Survival	Water Ditching, Safety and Survival		Aviation Safety and Cold Weather Survival
Mission Operations over land	NOAA	√	√			
	Non-NOAA		√			
Mission Operations over water	NOAA	√	√	√	√	
	Non-NOAA		√	√	√	
Mission Operations in cold weather (<32F air temp)	NOAA	√	√			√
	Non-NOAA		√			√

Note: NOAA Personnel may request more frequent training than what is listed above

In addition to aviation safety training requirements, NOAA has a requirement for use of Aviation Life Support Equipment (ALSE) as indicated in the table below:

Aviation Life Support Equipment (ALSE) required to be carried in the aircraft or worn by personnel				
Flight Purpose and Environmental Conditions	Life Raft of sufficient capacity for all aircraft occupants	Personal Floatation Device (PFD) (Life Vest)	Personal Emergency Locater Transmitter	Anti-Exposure Suit
Mission Operations overwater	√	√	√	
Mission Operations over cold water (<59F water temp and/or <32F air temp)	√	√	√	√

NOAA ALSE or equipment of similar design should be used in the training environment whenever possible.

To qualify as an approved aviation safety training source for water survival and cold weather survival, at a minimum, the following subjects must be covered:

Water Ditching Safety and Survival

Water survival training must include hands-on training in a swimming pool or in open water. Each student must participate in the water-portion of the training.

- Basic survival swimming skills
- Emergency landings
- Crash survival
- Ditching at sea
- Emergency egress
- Survivor Emergency First-Aid
- Survival vest
- Utilization of life preservers
- Utilization of flares & signaling devices
- Utilization of flares & signaling devices
- Operation of personal locator beacons
- Survival in open water
- Hypothermia prevention
- Utilization of signal mirrors
- Utilization of Survival radios
- Utilization of dye markers
- Utilization of life rafts and contents

Additional requirements for cold water (<59F water temp and/or <32F air temp)

- Anti-exposure systems
- Cold water survival skills

Cold Weather Land Survival

- Survival psychology
- Clothing & footwear requirements
- Cold weather injuries
- Winter shelters
- Water location
- Snowmelting devices
- Cold weather survival kits
- Signaling methods
- Using aircraft and equipment as tools for survival
- Animal predators
- Firemaking skills
- Food Requirements for cold weather
- Priorities in a cold environment
- Travel considerations
- Avalanche Hazards

Westpac Marine Services, Inc.

Maritime Survival Experts

- The Tech Files

Hypothermia

Hypothermia Chart

IF THE WATER TEMPERATURE (F) IS:	EXHAUSTION OR UNCONSCIOUSNESS	EXPECTED TIME OF SURVIVAL IS:
32.5	Under 15 Minutes	Under 15 - 45 Minutes
32.5 - 40.0	15 - 30 Minutes	30 - 90 Minutes
40.0 - 50.0	30 - 60 Minutes	1 - 3 Hours
50.0 - 60.0	1 -2 Hours	1 - 6 Hours
60.0 - 70.0	2 - 7 Hours	2 - 40 Hours
70.0 - 80.0	3 - 12 Hours	3 Hours - Indefinitely
OVER 80.0	Indefinitely	Indefinitely

The use of an Immersion Suit or other buoyant thermal protective device will greatly enhance survival time.

Chart is for general reference only.

How cold is my water?

Hypothermia Facts

Body thermal conductivity in water is 26 times faster than when exposed to air. If you have a life raft, board as soon as possible.

50 degree water equals 15 minutes before incapacity and/or unconsciousness with life jacket on.

50 degree water equals 9 minutes before incapacity and/or unconsciousness without a life jacket.

Chart and facts courtesy of Winslow Life Raft Company

How cold is my water?

How to Combat Hypothermia

Keeping your body out of the water is the most effective means. Life rafts are everyone's first choice since they keep you out of the water, provide shelter along with equipment. If you are not going offshore immersion suits are your next best choice. While they do not get your body out of the water, immersion suits provide excellent thermal insulation.

If dedicated life saving equipment is not in your budget figure out ahead of time what you are going to do. A dinghy is an alternative providing it can be quickly launched. If you always travel with another vessel good communications can get help there quicker. At times even items like plastic coolers become the only survival aid available although in cold waters they would not be much help.

Westpac Marine Services, Inc.
2316 Jefferson Ave.
Tacoma, WA 98402-1405
(253) 627-6000

revised 4/2012

35

Be Prepared - Cold Water Can Kill

Cold water is extremely dangerous. It quickly robs the body of its strength, diminishes coordination and impairs judgment. Immersion in water as warm as 50 – 60 degrees can initiate what has been determined to be "Cold Water Shock". When a paddler capsizes and is suddenly immersed in cold water the body's first reflexive action is to gasp for air, followed by increased heart rate, blood pressure and disorientation and can even lead to cardiac arrest. Without proper equipment and apparel, the body can become incapacitated in just a few minutes and without a lifejacket this can be a very dangerous and often fatal combination. When paddling in places where the water temperature is 60 degrees Fahrenheit or colder, a wetsuit is a must and a drysuit is highly recommended. This is also the case if the combined air and water temperatures are below 120 degrees Fahrenheit.

A second dangerous situation that can occur in cold water or cold weather is Hypothermia. Hypothermia occurs when exposure to the elements prohibits the body from reheating and maintaining its core temperature. Typical symptoms of hypothermia include: shivering, impaired judgment, clumsiness, loss of manual dexterity and slurred speech.

AMERICAN CANOE ASSOCIATION

The **American Canoe Association** (ACA) is a member-based nonprofit organization (501(c)3) that promotes fun and responsible canoeing, kayaking, and rafting. Founded in 1880, the ACA actively advocates recreational access and stewardship of America's water trails. For more information and to become a member, visit **www.americancanoe.org**.

ACA
AMERICAN CANOE ASSOCIATION
Kayak & Canoe Recreation

American Canoe Association
Phone: (540) 907-4460
Fax: (888) 229-3792

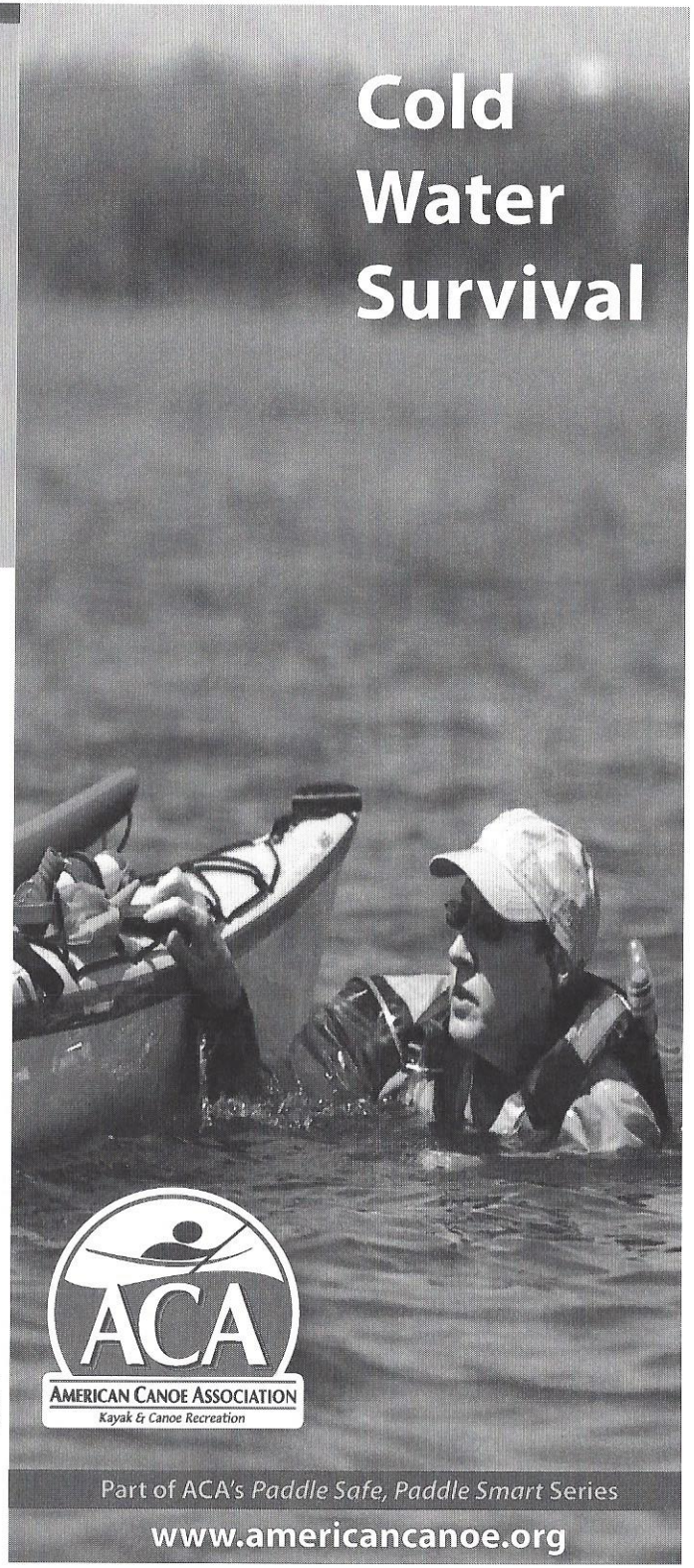
www.americancanoe.org

Making the world a better place to paddle. Since 1880.

YOUR BOATING DOLLARS AT WORK

Produced under a grant from the Sport Fish Restoration and Boating Trust Fund, administered by the U.S. Coast Guard.

Cold Water Survival



ACA
AMERICAN CANOE ASSOCIATION
Kayak & Canoe Recreation

Part of ACA's *Paddle Safe, Paddle Smart* Series

www.americancanoe.org

Prevent

Plan your trip and "think smart"
Know the water temperature and weather forcast before you set out.

Fuel Your Body
Keep your body well fueled with high carbohydrate foods and lots of water.

Insulate your Body
Avoid wearing cotton clothing when paddling in cool temperatures.
Dress in layers using synthetic fabrics such as polyester fleece to prevent getting overheated or chilled from perspiration.
Carry a waterproof jacket designed for splash and/or rain protection.
Anytime the water temperature is less than 60degrees Fahrenheit, wear specialized insulating clothing (wetsuit or drysuit) capable of protecting you while in the water.

Keep in mind that the warmth and comfort range of a dry suit can be flexible based on the clothing worn underneath it.

Wear a warm hat that will stay on your head in the water. A fleece-lined skullcap is ideal.

Have spare, dry clothing and store in a sealed dry bag while on the water.

Watch Out for your Group
Know your emotional and physical limitations.
Group members need to constantly assess the behavior of others in their group. Look for changes in behavior, withdrawal, sluggishness, talking less or a member not eating enough. These are all symptoms of fatigue and may suggest a problem that the group needs to address.

Assess

The most typical symptoms of hypothermia (in order of onset) are:

- Shivering
- Impaired judgment
- Clumsiness
- Loss of dexterity
- Slurred speech
- Inward behavior
- Shivering stops
- Muscle rigidity
- Unconsciousness
- Death

Treat

Mild hypothermia
(victim shivering but coherent):
*If possible, take action before this stage. You may still have time to either stop the trip or take out early. Planning for an early take out and/or shuttle half way pays dividends.
Move victim to place of warmth. Remove wet clothing; give warm, sweet drinks; no alcohol or caffeine. Keep victim warm for several hours. The "window of opportunity" is closing fast. By this time you are already well on your way to experiencing hypothermia.

Moderate hypothermia
(shivering may decrease or stop):
Victim may seem irrational with deteriorating coordination. Treat the same as above but no drinks.
Victim should be kept lying down with torso, thighs, head and neck covered with dry clothes, coats or blankets to stop further heat loss. Seek medical attention immediately.

Severe hypothermia
(shivering may have stopped):
Victim may resist help or be semiconscious or unconscious. Removed from water, victim must be kept prone, on back and immobile. Victim must be handled gently. Cover torso, thighs, head and neck with dry covers to stop further heat loss. Arms and legs must not be stimulated in any manner. Cold blood in extremities that suddenly returns to the core may induce cardiac arrest. Seek medical attention immediately.

Victim appears dead
(little or no breathing, no pulse, body rigid):
Assume victim can still be revived. Look for faint pulse or breathing for 2 minutes. If any trace is found, do not give CPR. It can cause cardiac arrest.
Medical help is imperative. If pulse and breathing are totally absent, trained medical personnell should start CPR.

AMSEA
Alaska Marine Safety Education Association

What Is Cold Water? A Question Revisited

by Richard Hiscock

An article entitled "What is Cold Water? The Surprising Answer" (***Marine Safety Update***, December 1997) examined the issue of what water temperature should be considered "cold." It not surprisingly concludes that waters below 70°F should be considered "cold." Yet, the US Coast Guard has established 59°F (10°C) as its definition of cold water. We need to examine how and why there is such a disparity between these two conclusions.

In 1983 the Coast Guard proposed requiring immersion suits on cargo vessels operating on "cold waters" and exempting vessels operating on "warm waters" – defined as 60°F – and vessels carrying covered lifeboats.

After the sinking of the *Marine Electric* in 1983 Congress, reacting to the exemption for vessels with covered lifeboats, required by statute "immersion suits on vessels . . . that operate in the Atlantic Ocean north of 35 degrees North latitude or south of 32 degrees South latitude and in all other waters north of 35 degrees North latitude or south of 35 degrees latitude." Further, the Coast Guard was not allowed to exempt vessels that carried covered lifeboats. The Coast Guard was also required to submit a report to Congress on warm water exemption and the latitude at which it applied. It is from this report that the "59°F rule" defining cold water evolved.

The Coast Guard report relied primarily on a review of past casualties more than the available science, and concluded that, " . . . 60°F water is 'safe' for an unprotected person for just under 2 hours. The 50% rate of survival is estimated to be at least 4.5 hours. Therefore, water at 60°F should provide the unprotected survivor in the water with enough time to make it to a lifeboat or liferaft floating in the area. If no lifeboat or liferaft is in the area, it also provides some time for rescue to arrive."

> *A human body cools when immersed in water of a temperature less than 92°F. The warmest open ocean water in any latitude at any time of the year is 84°F.*

In 1991 the Coast Guard studied small passenger vessel casualties and "concluded that lifejackets, life floats, and buoyant apparatus had proven adequate (i.e. provided adequate water immersion survival rates) in all studied casualties where water temperature was 60°F or more."

The 59°F rule was "formalized" in ***Navigation and Vessel Inspection Circular (NVIC) 7-91***, "Determination of Cold Water Areas" and established 32°N and 32°S worldwide as the regulatory demarcation line for immersion suit regulations. The NVIC states:

"A critical water temperature **seems** to be around 15° C (59° F). To the unprotected person, water at this temperature is painful and hypothermia **seems to progress** much faster than in warmer waters. In water above this temperature, most people are able to survive at least several hours. (Emphasis added.)

Unfortunately, these conclusions are not supported by the scientific evidence, available since at least the mid-1940s, that most ocean water should be considered cold when considering all the impacts of immersion in cold water: cold shock, swimming failure, hypothermia, and post rescue collapse.

In a presentation to the Commercial Fishing Industry Vessel Safety Advisory Committee in November 2003 RADM Alan M. Steinman, USPHS / USCG (Ret) summarized the conclusion of a 2001 report, "Survival in Cold Water" prepared by Dr. C. J. Brooks for

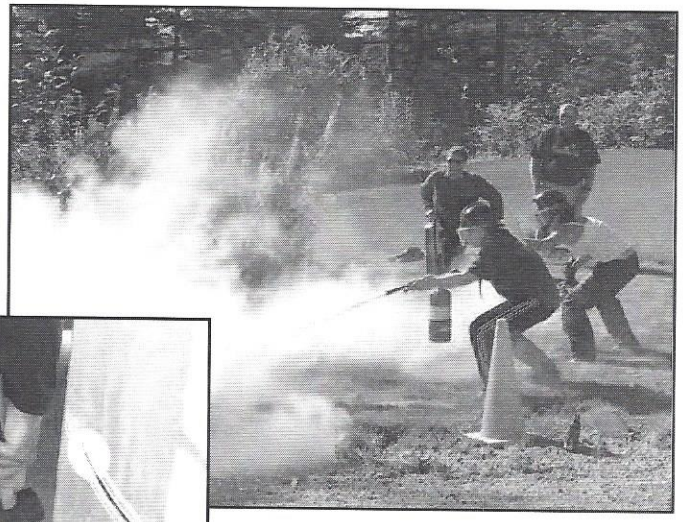
Continued on next page . . .

Marine Safety Instructor Training Scheduled

It's not too soon to think about attending the next session of AMSEA's six and one-half day Marine Safety Instructor Training (MSIT). It will be held April 5 through 11, 2011 in Seward, Alaska.

Although best known for preparing instructors to teach commercial fishermen, others who teach boating or cold-water safety also find this training extremely useful.

To learn more, or to register contact AMSEA at 907-747-3287 or visit us online. Find a calendar and descriptions of all of AMSEA's scheduled classes of all types at www.amsea.org



During a September 2010 MSIT course in Sitka participants learned shipboard firefighting techniques and used AMSEA's vessel damage simulator to practice emergency repairs at sea.
AMSEA photos.

Cold Water

. . . *Continued*

Transport Canada:

"Cold water (below 68°F) predominates in North American oceans, lakes and rivers. Merchant vessels sailing these cold waters need to provide adequate protection for their crews in case of accidental immersion."

But, a report of the Joint United States and Canadian Exposure Suit Development Group from 1943 summarizes what we need to know about the impact of cold water on the body, and states clearly that those impacts may occur on virtually any ocean at any time of the year.

A human body cools when immersed in water of a temperature less than 92°F. The warmest open ocean water in any latitude at any time of the year is 84°F. Individuals exposed to water of this temperature undergo significant cooling, and need the protection of a waterproof suit in the water.

Individuals even in warm climates, while sitting on liferafts lose body heat rapidly due to evaporative cooling, unless provided with a waterproof suit. The rate of loss of body heat increases rapidly as the temperature of the air and water falls.

It is long past time for the Coast Guard to revisit the definition of cold water. Clearly 59°F does not adequately define those waters where protective devices, specifically immersion suits and liferafts, are necessary survival equipment.

Richard Hiscock is a long-time safety advocate, former member of the Commercial Fishing Industry Vessel Advisory Committee, and an advisory for USCG Fishing Vessel Casualty Task Force. He recently spent two years as Senior Professional Staff on the Subcommittee on Coast Guard and Maritime Transportation of the U.S. House of Representatives.

Chapter 17

COLD WATER IMMERSION

LORENTZ E. WITTMERS, MD, PHD*; AND MARGARET V. SAVAGE, PHD†

INTRODUCTION

REGULATION OF BODY HEAT CONTENT

PHYSIOLOGICAL RESPONSES TO COLD WATER IMMERSION

GENDER DIFFERENCES IN THERMOREGULATION
- Body Characteristics
- Temperature Regulation and the Menstrual Cycle
- Differences in Response to Cold Water Immersion

PROTECTIVE CLOTHING

NEAR-DROWNING: HYPOTHERMIA AND THE DIVING RESPONSE

ACCLIMATIZATION

SUMMARY

ATTACHMENT BY *V. HARTMANN* AND *W. HAENERT*

*Associate Professor, Department of Medical and Mo-lecular Physiology, and Director of the Hypothermia and Water Safety Laboratory, University of Minnesota School of Medicine, Duluth, Minnesota 55812

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INTRODUCTION

The body core temperature is maintained daily within a narrow range, despite wide variations in environmental (ambient) conditions and activity levels.[1] In fact, the body core temperature is so consistent that for centuries physicians have used deviation from this normal temperature as an indication of a departure from the healthy state.[2] Maintenance of a normal temperature and the normal variations of the circadian and lunar rhythms are achieved by changes in all physiological systems, one of the most important of which is alteration in skin blood flow.[3] In response to the perception of skin temperature, behavioral adjustments are made in clothing, environment, or both, to avoid sweating or shivering (ie, to maintain the core level). When exposed to more extreme environmental conditions, powerful physiological effector mechanisms are called into play to defend against hyperthermia and hypothermia. Active vasodilation of blood vessels of the skin and secretion of sweat keep body temperature within a few degrees of normal even in severe conditions of increased ambient temperature, such as marathon running on a hot day.[4] On the other hand, the defenses against hypothermia are less effective. Individuals exposed to severe cold are unable to maintain thermal steady states for extended periods despite maximum vasoconstriction and high rates of shivering.

REGULATION OF BODY HEAT CONTENT

The physics of heat loss following cold water immersion dictate a more rapid drop in core temperature than from exposure to a cold air environment.[5] Figure 17-1 illustrates the dramatic difference in body (core) temperature drop when the same individual was exposed alternately to 0°C air and immersed in 10°C water. Magnitude of heat loss and eventual decrease in core temperature depends to a great extent on how much of the body is actually immersed.[6] In the following discussion, *immersion* is defined as submerged to the neck.

When a body is immersed in water it is obvious that evaporative and radiant heat exchange can no longer occur between the subject and the environment. The major heat exchange in water occurs by means of conduction with the surrounding water. The exceptions to this are the nonimmersed body parts, in most cases the head. The head can represent a significant site of heat loss to the environment owing to its minimal insulation and lack of vasoconstriction.[7] For example, when the ambient temperature is 4°C, the uncovered head could be responsible for heat loss representing 50% of resting heat production, increasing to 75% at an ambient temperature of –15°C.[8]

The heat dissipation capacity of water is considerably greater than that of air, as the ratio of heat conductivity of water to air is approximately 24:1.[9] A body immersed in calm water is surrounded by a relatively stable "boundary layer" of fluid. Heat is conducted from the skin into this boundary layer as a function of the temperature gradient, heat transfer coefficient, and surface area of contact,[10] as Equation 1 demonstrates:

$$H = K A (T_w - T_{sk}) \quad (1)$$

where H represents heat transported, K the heat transfer coefficient, A the surface area of contact between skin and water, T_w the temperature of water, and T_{sk} the temperature of the skin.

Conservation of body heat and maintenance of core temperature during immersion depends on the temperature of the water. If there is no net heat loss or gain by the body during immersion, the water temperature is within the thermoneutral zone (also called the neutral zone or the vasomotor zone). The

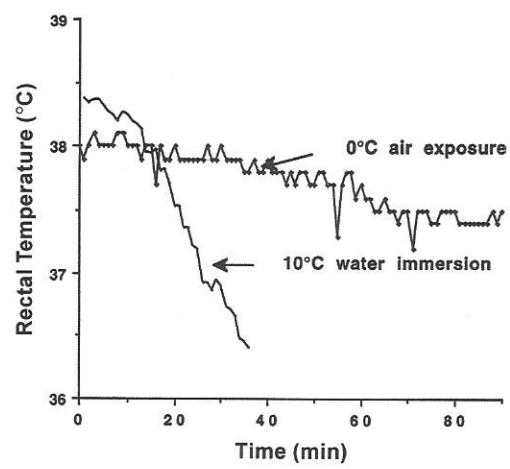

Fig. 17-1. Rectal temperature versus time relationship in one human volunteer under two types of cold stress: 0°C air and 10°C water. The subject is a young white man of average build, fat content, and physical fitness. He is dressed the same for both sessions. Note that even though the water temperature is 10°C higher than the air temperature, the decrease in core temperature is much more rapid in the water immersion, owing to the increased conductivity of the water compared with that of air.

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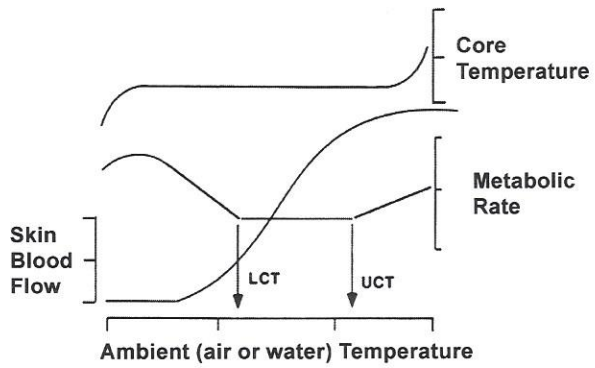


Fig. 17-2. The relationships between core temperature, metabolic rate, and skin blood flow as a function of ambient temperature. The thermoneutral zone is represented by the horizontal segment of the metabolic rate curve and is bounded by the upper critical temperature (UCT) and the lower critical temperature (LCT). In the thermoneutral zone the core temperature is maintained constant by alterations in heat exchange at the surface, represented here by changes in skin blood flow.
Adapted with permission from Eckert R, Randall D, Augustine G. *Animal Physiology: Mechanisms and Adaptations.* New York, NY: WH Freeman; 1978: 580.

ambient temperature defining the thermoneutral zone is a very narrow range around 35°C.[11,12] Within this limited range of ambient temperatures, nude subjects maintained their core temperature nearly constant for at least 1 hour without shivering or sweating. This ability to maintain a steady state in core temperature was attributed to changes in skin blood flow; that is, vasomotor control.[12,13] In the thermoneutral zone, skin blood flow is under the reflex influence of skin temperature. An increase in skin temperature results in a rapid increase in skin blood flow and vice versa. It is from this thermoneutral zone that the body moves when cold water immersion occurs, calling into play powerful compensatory mechanisms. The concept of the thermoneutral zone and temperature regulation is summarized in Figure 17-2.

As the water temperature falls below the lower critical temperature, peripheral vasoconstriction can no longer effectively prevent heat loss. Therefore, heat loss exceeds the heat produced by the basal metabolic processes, and heat production must be increased to maintain the core temperature. The lower critical temperature is a function of subcutaneous fat thickness and ranges between 30°C and 34°C.[14] Increased heat production can be accomplished by an increase in metabolic rate,[5] voluntary muscle work (exercise), or shivering, in any combination. Although these three mechanisms will contribute to the maintenance of core temperature, in a cold water environment, the added physical activity associated with exercise will tend to disrupt (ie, to mix) the boundary layer and, to some extent, facilitate heat loss. These mechanisms (increased heat production and maximal vasoconstriction) may be able to stabilize core temperature for some time. However, if the cold stress is of sufficient magnitude and is continued for a long enough time, heat loss will eventually exceed heat production, leading to a decrease in core temperature and eventually to hypothermia. As the core temperature declines past a critical level, the rate of both tissue metabolism and shivering will be depressed, resulting in an accentuated drop in core temperature due to this depression of heat-production mechanisms.

The problem of maintaining core temperature during cold water immersion can be modeled as a simple two-compartment system in which the body core is separated from the surrounding environment by an insulating shell (Figure 17-3). Heat can move from the core through the shell by conduction, essentially a diffusive process, but this mechanism is a very slow transport process, owing to the distances involved. The major pathway for heat movement out of, or heat exchange with, the core and into the shell and subsequently facilitating transfer

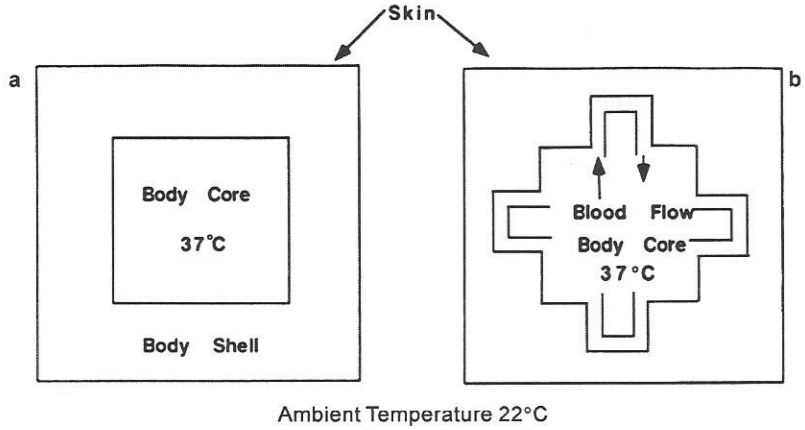


Fig. 17-3. A summary of the Shell–Core model of heat flow in the body. (**a**) If the blood flow to the shell is minimal, it will provide the largest insulating capacity and therefore retain heat and maintain core temperature. (**b**) When vasodilation in the shell occurs, the insulating capacity of the shell drops and heat is lost from the core.
Adapted with permission from Vander A, Sherman J, Luciano D. *Human Physiology: The Mechanisms of Body Function.* 7th ed. Boston, Mass: WCB McGraw-Hill; 1997: 628.

EXHIBIT 17-1

RANGER TRAINING INCIDENT REPORT

On 15–16 February 1995, three students in training to become US Army Rangers, ranging in age from 23 to 27 years, died of hypothermia during a routine patrol at the Florida Ranger camp. Failure in supervision and judgment, lack of situational awareness, and lack of control placed Ranger students in water too cold, too deep, and too long for safe operations.

The Ranger Training Brigade trains about 3,000 Ranger students each year. This training takes place in Fort Benning, Georgia, the mountains of northern Georgia, and in the swamps of Florida. The tragedy that occurred to class 3-1995 was a result of unfortunate human errors. However, it does bring to light the need to validate Army water exposure guidance tables.

These Ranger students died during the swamp phase of their training. This is the third and final phase of Ranger School, conducted at Camp Rudder, Florida. By this point in the ranger training process, the philosophy is to allow the student chain of command to make their own decisions involving navigation, judgment, and leadership. The Ranger Instructors (RIs) will only intervene when student errors have made the mission impossible, or make the training unsafe.

According to Ranger training standard operating procedures in preparation for the swamp field training exercise (FTX), water levels are checked 10 days and then again 2 days prior to the FTX. On the initial check, water levels were noted to be 12 to 18 inches lower than those encountered during the last FTX. However, during the 2-day prior check the water level had risen 18 to 24 inches. Data from the National River Forecasting Agency indicated that the river was rising and would reach flood stage around 15 February. This information was not used by the Florida Ranger Training Brigade. The typical way water depth was measured was by visually checking various landmarks in the area rather than through a quantified, repeatable process.

The general forecast for the FTX was partly cloudy with temperatures ranging from 60°F to 70°F. Winds were from the south at 10 to 15 mph, with a 30% chance of rain. From the site recon on 14 February, water depth was noted as knee to mid-thigh deep. Water temperature on 15 February was 52°F, but rose to around 54°F to 59°F during the day.

The general mission for Class 3-1995 was to move 8 to 10 km downriver via a Zodiac boat, move a short distance (700–800 m) through the swamp, and move the remaining few kilometers over ground to their objective. On 15 February the FTX was given the go ahead. The Ranger students embarked downriver in their Zodiac boats.

At approximately 1400 hours, C Company's student platoon leader missed his drop site. Because of the Ranger Training philosophy described above, the RI allowed him to continue downriver. B Company followed C Company downriver. A Company found their drop site and debarked their boats onto dry land. The completed their mission as planned. The decision to allow the student chain of command to continue downriver placed the RIs of B and C companies in an unfamiliar area of the swamp. This is one of the critical factors of this FTX.

Current Ranger standards allow students to be in chest-deep water of 50°F to 55°F for a maximum of 3 hours. If the water temperature is from 56°C to 60°F, the time limit increases to 5 hours. If the whole body is submerged, the time limit is no more than 5 minutes for either condition.

B and C companies found a drop site and reported that the water levels were much higher than briefed. Because of the current it was impossible to move back upriver to a different drop site. The Ranger students decided to move through the swamp away from the river, the general idea being that the water level would have to drop as they approached high ground. The first man entered the water at 1600 hours. Movement through the swamp was much more difficult than anticipated. After the students had been in the water for 1.5 hours, early signs of hypothermia were becoming evident. At this point the RIs took administrative control of the patrol and called for the first of several medical evacuation (medevac) requests.

(**Exhibit 17-1** *continues*)

Exhibit 17-1 *continued*

The RIs decided the best way to reach high ground and get out of the water was by constructing rope bridges to cross the deep water. Because this contingency had not been planned for, it took about 30 to 45 minutes to complete the rope bridges and move all of the students across the water obstacle. During this time the students waited in the chest- to neck-deep water, causing their bodies to continue to cool. After crossing these water obstacles the companies were forced to continue their movement through the swamp.

The medevac helicopter was over the Ranger students by 1740 hours. It was not until 1840 hours that the medevac helicopter departed with the hypothermic students. This delay was caused by the confusion of the current situation as well as problems with extracting the three students from the swamp. All of these students survived.

Once the helicopter departed, the RIs attempted to get the students moving in an organized fashion toward higher ground. The students were reluctant to respond. Their legs were cramping and most were beginning to feel better by staying in one place. During the medevac, the rotor wash of the helicopter combined with the current of the river had caused a group of students to drift away from the main element. These students attempted to push on to high ground on their own. One RI organized a small group to move ahead of the main element. This group was to build a fire to help the students in the main element to rewarm, as well as to guide the lost group to their location.

By approximately 2100 hours, most of the students had reached high ground. However, several students were still missing in the swamp. RIs began searching for the missing Ranger students as individuals at the fire ignited flares to help guide the search. At this point another medevac helicopter arrived. The helicopter was called for seven students in critical need of medical attention. However, because of limited room aboard the helicopter, only five of these students were able to be evacuated. This medevac attempt was greatly hampered by all the confusion on the ground. In panic, the "lost" Ranger students had removed the red lenses from their flashlights. This caused problems for the pilot and crew because the signal for the medevac pickup point is a flashing white light. As the medevac attempt continued, RIs resumed their search. At 2200 hours, two students remained missing in the swamp. All other medevacs were called off because of the weather and the lack of logistical planning. The search was called off at 0340 hours to prevent any further casualties.

Of the soldiers who were successfully medevaced, one died in the emergency room. The two soldiers left behind were carried to the road and picked up by a forward line ambulance and transported to the emergency room. Both of these men were pronounced dead at approximately 0200 hours. At 0530 hours the search resumed for the last missing Ranger student. He was found at approximately 0730 hours lying on a log in the swamp less than 75 feet from high ground. This soldier was pronounced dead at 0853 hours.

The subsequent investigation of this incident prompted the Ranger Training Brigade to task the US Army Research Institute of Environmental Medicine to validate their water safety tables.

Exhibit compiled from material provided by the Public Affairs Office, US Army Infantry Center, Fort Benning, Georgia; 27 March 1995.

into the environment, is by way of blood flow between the two compartments. The size or thickness of the shell is in fact determined by (*a*) the blood flow to it and (*b*) the effective area available for heat transport. An increase in blood flow to a body region effectively decreases the size of the shell, resulting in an increase in heat loss. Peripheral vasoconstriction, on the other hand, increases the shell by increasing its thickness and decreasing the effective area for heat transport. This results in an increased insulating capacity, restricting heat loss and maintaining core temperature.

Hypothermia can be insidious, as exemplified by the deaths of four soldiers (15-16 Feb 1995) who were undergoing the rigorous training to become US Army Rangers (Exhibit 17-1). From a physiological perspective, the students suffered from secondary hypothermia. They were in the ninth day of the final phase of their training at the Ranger School, Camp Rudder, Florida. The training was intense, and as part of that training the men were allowed three meals over 2 days. More than likely, the dif-

ference between the environmental air temperature (60°F–70°F) and the water temperature (52°F) played a role in their deaths. The warm air temperature may have given the false impression that the water was also warm. The men were moving in water at 52°F for a minimum of 1.5 hours. Thus, insufficient calories and sleep coupled with intense, prolonged exercise in cold water led to the deaths of four soldiers. As a consequence, the US Army Research Institute of Environmental Medicine (USARIEM), Natick, Massachusetts, developed new water exposure tables for the Rangers, the particulars of which are privileged information.[15]

All body regions do not respond with the same magnitude of peripheral vasoconstriction when placed under a cold stress. The trunk and head show minimal vasoconstriction, with the areas of maximal heat loss being the neck, lateral thorax, upper chest, and groin.[16] Vasoconstriction of the fingers and toes may cause discomfort significant enough to jeopardize military operations, even though the core temperature is normal. Insulating capability of the shell is a function not only of blood flow but also of fat content. The more body fat contained in the shell, the less the reduction in core temperature for a given immersion water temperature,[17] or the greater likelihood that the core temperature will stabilize at a given water temperature.[18] The importance of the subcutaneous fat layer is illustrated by the successful English Channel swimmers, all of whom are well endowed with this insulation layer.[9]

PHYSIOLOGICAL RESPONSES TO COLD WATER IMMERSION

The body's response to cold water immersion progresses from an initial stress situation to eventual hypothermia and death, depending on time and intervention. During the initial phases of immersion and the stress of cold water exposure, hypothermia is *not* the major concern; other stresses on the body's function are more life threatening. Tipton, Golden, and Hervey[19,20] have approached the various physiological changes associated with water immersion in a stepwise fashion (Table 17-1). Based on their four stages—initial immersion, short-term im—mersion, long-term immersion, and postimmersion-and depending on the temperature of the water, it is unlikely that hypothermia would become a problem until some point in stage 3, long-term immersion. The magnitude (severity) of the physiological changes in each of the stages will depend on a number of factors: water temperature, circulation (ie, water current) or body movement or both, body size, body fat content, and the presence or absence of protective gear (clothing). Stage 4, postimmersion, encompasses changes in core temperature (afterdrop) that may occur following the immersion incident. Note that treatment for hypothermia (rewarming methodology and postimmersion collapse) will not be covered in this chapter, but interested readers can find the topic discussed in Chapter 16, Treatment of Accidental Hypothermia, and in publications by researchers in Great Britain.[21,22]

TABLE 17-1

STAGES OF WATER IMMERSION

Stage	Description	Immersion Time (min)
1	Initial immersion	0–3
2	Short-term immersion	3–15
3	Long-term immersion	≥ 30
4	Postimmersion	Core temperature may fall, but after the incident (ie< afterdrop)

Source: Tipton MJ. The concept of an "integrated survival system" for protection against the responses associated with immersion in cold water. *J R Nav Med Serv.* 1993;79:11–14.

The initial response to immersion (stage 1) has a respiratory and cardiovascular component. Respirations may become uncontrolled, with reflex gasping and hyperventilation. This panic response will decrease the breath-holding time and may lead to aspiration with subsequent drowning.[23] Hyperventilation, possibly reaching five times resting values, is associated with an increase in both tidal volume and breathing frequency. The increased ventilation will result in a decrease in the partial pressure of carbon dioxide in the alveolar gas ($PACO_2$) and subsequently in arterial blood ($PaCO_2$), an acute respiratory alkalosis leading to cerebral vasoconstriction (with its effects on mental function), and possibly tetanic convulsions.[24] As the immersion time progresses, the minute ventilation decreases toward normal, the tidal volume remains increased, and the $PACO_2$ remains somewhat depressed.[25]

Heart rate response to cold water exposure depends on the length of exposure time and whether or not complete submersion has occurred. If the

victim's face is immersed while he is breath-holding, then heart rate may decrease (bradycardia), an example of one component of the "diving response" or "diving reflex."[26,27] The complete diving reflex consists of the following components:

1. decrease in heart rate,
2. increase in total peripheral resistance,
3. decrease in cardiac output (ie, stroke volume), and
4. increase in mean arterial pressure.

In humans this cardiovascular reflex will occur during face-only immersion[28] as well as in total body immersion.[29] The predominant neural drive input to the myocardium associated with the diving reflex is parasympathetic in origin. However, the general cold stimulus also activates the sympathetic neural pathway to the myocardium and drives the systemic changes in total peripheral resistance, resulting in the redistribution of organ (tissue) blood flow.[30] This competition between augmented sympathetic and parasympathetic activity may be responsible for arrhythmias that occur at the end of—or just following—face immersion.[31]

If total submersion or face immersion is absent or if breath-holding face immersion has ended, the remaining cardiovascular adjustments are a result of the initial cold stress. There is a dramatic increase in heart rate, which subsides after a few minutes but remains above preimmersion levels; the colder the water, the higher the heart rate. Other cardiovascular sequelae of cold-induced sympathetic activation are also evident: increased systemic arterial pressure, increased total peripheral resistance, and increased cardiac output. During this early sympathetic discharge phase, myocardial conduction abnormalities may be observed, such as atrial and ventricular extrasystoles and sinus arrhythmias.[32]

The initial cardiovascular responses to sympathetic activity will eventually subside as the core temperature falls. Heart rate, cardiac output, and systemic arterial pressure will fall as a function of decreasing core temperature.[33] Individual organ (heart, liver, kidney, and brain) blood flow will also progressively decrease at the rate of approximately 5% per degree Centigrade in core temperature drop (estimated from data in Blair[34]).

The kinetics and conductance of ion channels in the myocardium are temperature dependent. Hypothermia will result in alterations in electrophysiological mechanisms, prolonged action potentials, and refractory period and progressive bradycardia. At temperatures between 28°C and 30°C, the myocardium becomes susceptible to ventricular tachyarrhythmias.[35]

The initial cold immersion insult may result in death from drowning, cardiovascular collapse, or both, but *not* from hypothermia. If the initial entry into the cold water is gradual (staged) or is a common occurrence for the individual (eg, cold water swimmers and divers), then the cardiovascular and respiratory changes may be significantly attenuated.[23] If the victim survives the initial insult, the hyperventilation will subside, reducing the ventilation to match the metabolic needs. Heart rate will decrease toward preimmersion levels, with the final value depending on the water temperature. Peripheral vasoconstriction will persist during stages 2 and 3 as a means of preventing heat loss and maintaining core temperature.

The peripheral circulatory beds, such as fingers, toes, and ears, demonstrate a paradoxical response to cold exposure.[36,37] The initial vasoconstriction induced by the cold exposure is followed in 5 to 15 minutes by a vasodilation of variable duration and magnitude (cold-induced vasodilation, CIVD). This is followed by a cyclic vasoconstriction-dilation phenomenon with a frequency of 3 to 5 per hour.[38,39] This CIVD will result in an increase in skin temperature and may contribute to an increase in body heat loss. The magnitude, and therefore the importance, of the CIVD decreases as cold exposure time is prolonged and body heat content and core temperature decrease (CIVD is also discussed in Chapter 15, Nonfreezing Cold Injury).

In stages 2 and 3, shivering will begin in an attempt to increase heat production. The onset of shivering occurs at a skin temperature of 26°C.[40] As the core temperature continues to fall, shivering will increase, reaching a maximum at a core temperature of approximately 35°C.[41] A continued decrease in core temperature will be accompanied by suppression of shivering, with final cessation at a core temperature around 30°C.[42]

The further physiological changes associated with cold water immersion in stage 3 will depend on both the water temperature and the exposure time. For the purposes of this discussion it is assumed that the victim is minimally clothed and in a negative heat balance; that is, losing more heat to the environment than can be produced by metabolic processes, shivering, and muscular activity. The rate of core temperature drop will be a function of the water temperature. Figure 17-4 is a compilation of rates of core temperature cooling from 17 sets of published data.[40,43–59] The subjects in these experiments cannot be considered matched for all con-

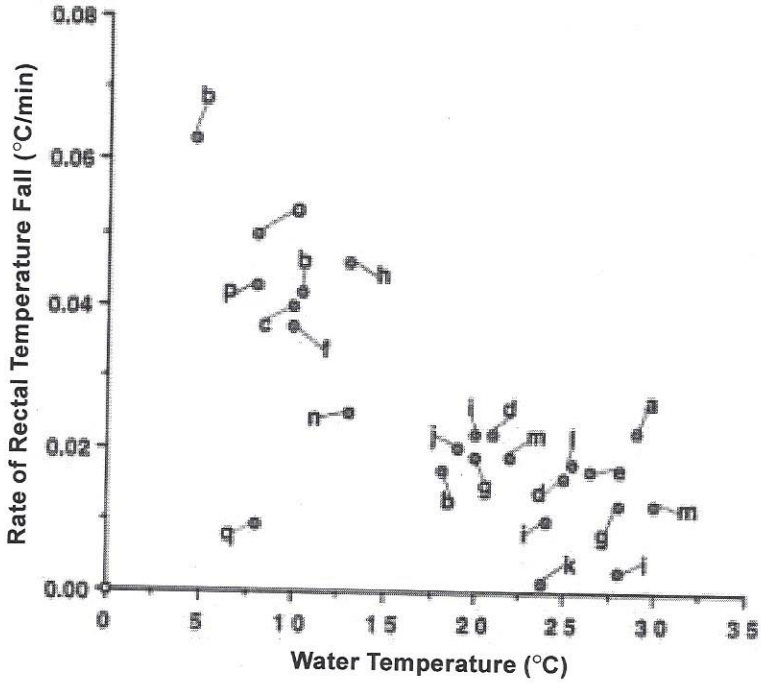


Fig. 17-4. The rate of core cooling data as a function of water temperature was extracted from 17 separate published reports (sources a–q, below) on experiments employing human volunteers. For the most part, the subjects were young white men of average build, fat content, and physical fitness. The subjects were not wearing any clothing or employing any devices that were designed to protect against cold exposure.
Data sources: (a) Hayward MG, Keatinge WR. Progressive symptomless hypothermia in water: Possible cause of diving accidents. *Br Med J.* 1979;1:1182. (b) Hayward JS, Eckerson JD, Collis ML. Thermal balance and survival time prediction of man in cold water. *Can J Physiol Pharmacol.* 1975;53:21–32. (c) Hayward JS, Eckerson JD, Collis ML. Thermoregulatory heat production in man: Prediction equations based on skin and core temperature. *J Appl Physiol.* 1977;43(2):377–384. (d) Israel DJ, Heydn KM, Edlich RF, Pozos RS, Wittmers LE. Core temperature response to immersed bicycle ergometer exercise and water temperatures of 21°, 25°, and 29°. *J Burn Care Rehabil.* 1989;10(4):336–345. (e) Veicsteinas A, Rennie DW. Thermal insulation and shivering threshold in Greek sponge divers. *J Appl Physiol.* 1982;52(4):845–850. (f) Wittmers LE, Pozos RS. In situ hypothermia testing. In: Laursen GA, Pozos RS, Hemple FG, eds. *Human Performance in the Cold.* Bethesda, Md: Undersea Medical Society Inc; 1983: 153–168. (g) McArdle WD, Toner MM, Magel JR, Spina RJ, Pandolf KB. Thermal responses of men and women during cold-water immersion: Influence of exercise intensity. *Eur J Appl Physiol.* 1992;65:265–270. (h) Martin S, Diewold RJ, Cooper KE. Alcohol, respirations, skin and body temperature during cold water immersion. *J Appl Physiol.* 1977;43(2):211–215. (i) McArdle WD, Magel JR, Gergley TJ, Spina RJ, Toner MM. Thermal adjustments to cold-water exposure in resting men and women. *J Appl Physiol.* 1984;56:1565–1571. (j) Rochelle RD, Horvath SM. Thermoregulation in surfers and nonsurfers immersed in cold water. *Undersea Biomed Res.* 1978;5(4):377–390. (k) Beckman EL, Reves E. Physiological implications as a survival during immersion in water at 75°F. *Aerospace Med.* 1966;37(11):1136–1142. (l) Weihl AC, Langworthy HC, Manalaysay AR, Layton RP. Metabolic responses of resting man immersed in 25.5°C and 33°C water. *Aviat Space Environ Med.* 1981;52(2):88–91. (m) Martin S, Cooper KE. Alcohol and respiratory and body temperature changes during tepid water immersion. *J Appl Physiol.* 1978;44(5):683–689. (n) Graham T, Baulk K. Effect of alcohol ingestion on man's thermoregulatory responses during cold water immersion. *Aviat Space Environ Med.* 1980;51(2):155–159. (o) Giesbrecht GG, Sessler DI, Mekjavie IB, Schroeder M, Bristow GK. Treatment of mild immersion hypothermia by direct body-to-body contact. *J Appl Physiol.* 1994;76(6):2373–2379. (p) Bristow GK Sessler DI, Giesbrecht GG. Leg temperature and heat content in humans during immersion hypothermia and rewarming. *Aviat Space Environ Med.* 1994;65:220–226. (q) Bourdon L, Jacobs I, Bell D, Ducharme MB. Effect of triazolam on responses to a cold-water immersion in humans. *Aviat Space Environ Med.* 1995;66(7):651–655.

tributing variables. They were, however, for the most part, young, fit men of average body type not participating in any type of exercise or wearing any special clothing to protect against heat loss during the time of immersion. The data demonstrate the magnitude of core temperature drop as a function of water temperature. These data illustrate the variability from experiment to experiment when evaluating core temperature changes as a function of cold stress.

In emergencies, physiological compensatory mechanisms such as shivering, pulse, and loss of reflexes can be used to obtain a rough estimate of core temperature. Table 17-2 summarizes the relationship between core temperature and signs and symptoms of hypothermia. The data are divided into three ranges of core temperature: mild hypothermia, 37°C to 33°C; moderate hypothermia, 32°C to 27°C; and severe hypothermia, 26°C to 18°C.

Military research into human performance in extreme environments is conducted by many nations. In 1996, Commander Wolf J. Haenert, MD, PhD, Medical Corps, German Navy, visited the Naval Health Research Center, San Diego, California, and subsequently submitted to Robert S. Pozos, PhD, then head of the Department of Applied Physiology there, a translated report on the German experience with survivors of shipwrecks during World War II. The report, written by Dr. V. Hartmann, a

TABLE 17-2

SIGNS, SYMPTOMS, AND PHYSIOLOGICAL CHANGES ASSOCIATED WITH PROGRESSIVE HYPOTHERMIA

Stage of Hypothermia	Core Temperature Rectal, °C (°F)	Signs and Symptoms
	37 (98.6)	Normal rectal temperature
Mild	36	Increased metabolic rate due to exercise and shivering
	35	Maximum shivering thermogenesis
	34	Amnesia, dysarthria, and judgment problems
	33	Ataxia and apathy
Moderate	32	Stupor; oxygen consumption 75% of normal
	31	Shivering stops
	30	Possible cardiac arrhythmias; pulse and cardiac output 66% of normal
	29	Decreasing consciousness, pulse, and respirations; dilated pupils
	28	Increased sensitivity to ventricular fibrillation; pulse and oxygen consumption 50% of normal
	27 (80.6)	Loss of voluntary motion and reflexes
Severe	26	Major acid–base problems; no response to pain
	25	Cerebral blood flow 30% of normal; possible pulmonary edema
	23	Loss of corneal and oculocephalic reflexes
	22	Maximum risk of ventricular fibrillation; oxygen consumption 25% of normal
	20	Pulse 20% of normal
	19 (66.2)	Electroencephalogram flat
	18	Asystole

Adapted with permission from Danzl DF, Pozos RS. Accidental hypothermia. *N Engl J Med.* 1994;331(26):1757.

medical officer in the German Navy, and Dr. Haenert (who also translated the report), is presented in toto in the Attachment at the end of this chapter. It contains a key observation about afterdrop and documents the rewarming of victims of hypothermia with hot water. In addition, it mentions rewarming victims of hypothermia with a fire. In field situations, many different methods are used to rewarm victims of hypothermia. However, rewarming with hot water is not possible except aboard ship, and even then, caution should be exercised by monitoring heart rate and blood pH. Warming with fire has disadvantages in that it promotes peripheral vasodilation, which can promote afterdrop. Even in 1944, the advantages of protective clothing were noted.

GENDER DIFFERENCES IN THERMOREGULATION

Differences in thermal regulation between men and women were reported in the early 1940s.[60] However, only since the late 1970s have the scientific community and funding agencies turned their efforts to address these gender differences.[61] The data are at some points confusing and, to say the least, incomplete.

Body Characteristics

Some of the differences in temperature regulation observed between men and women may be attributed to anthropomorphic characteristics. Compared to men, women tend to be of smaller stature, with resultant larger surface area-to-body mass ratio and lower total thermal mass; these contribute to a more rapid heat loss and decrease in core temperature when exposed to cold stress.[62] The lower muscle mass of women (vs men) will produce less metabolic heat from both exercise and shivering, leading to a decreased ability to supply heat to the core. The thicker subcutaneous fat layer in women will provide more insulating capacity in the shell and to some extent retard heat loss. However, the net result for women is a faster cooling rate when exposed to an environmental cold stress.[63]

Temperature Regulation and the Menstrual Cycle

The reproductive system has an important effect on female thermoregulation.[63] In the follicular phase of the menstrual cycle (the first half of the cycle, beginning with the onset of menses and ending with ovulation), women thermoregulate similarly to men if both genders are at comparable fitness levels.[64] However, during the luteal phase of the menstrual cycle (the second half, from ovulation to the onset of menses), hormonal and physiological changes associated with ovulation significantly affect thermoregulation. Resting core temperature is elevated,[65] and onset of sweating occurs at a higher temperature, suggesting that the set point for temperature regulation has been elevated.[66]

During the luteal phase, finger blood flow shows a greater cold-induced vasoconstriction and a slower recovery when compared with the follicular phase of the menstrual cycle.[67] It has also been observed that there are menstrual cycle changes in the blood flow of the forearm, leg, and calf.[68] Regulation of cutaneous blood flow in response to cold exposure is primarily under sympathetic control, and studies have demonstrated the influence of estrogen on the sympathetic nervous activity. Evidence from animal studies indicates that estrogen induces an up-regulation (vasoconstriction) of α_2-adrenoreceptors.[69,70] Although much less investigated, the same effects seem to be true for progesterone.[71]

Cold-induced vasospastic disorders such as Raynaud's phenomenon are more common in women, with the female-to-male ratio ranging from 2:1 to 9:1.[72] The onset of these vasospastic attacks occurs with menarche[73]; the attacks subside after menopause.[74] The frequency and severity of cold-induced vasospastic episodes also vary with the phase of the menstrual cycle and subside during pregnancy.[75,76]

Behavioral differences are also associated with the menstrual cycle. In the luteal phase, women sense changes in skin temperature more quickly than during the follicular phase.[77] In addition, women have a higher skin temperature preference in the luteal phase.[78] Both these modifications are consistent with an increase in the temperature set point.

Differences in Response to Cold Water Immersion

Data suggest that women exhibit a more rapid drop in core temperature than men when immersed in cold water.[43,79] This increased rate of core temperature fall is present if both genders are matched for body fat content. Increased body fat in women does provide insulation during water immersion; however, the larger surface area-to-mass ratio and the lower thermal mass contributing to heat production will result in women's faster initial cooling rate during water immersion, compared with that of men.[61]

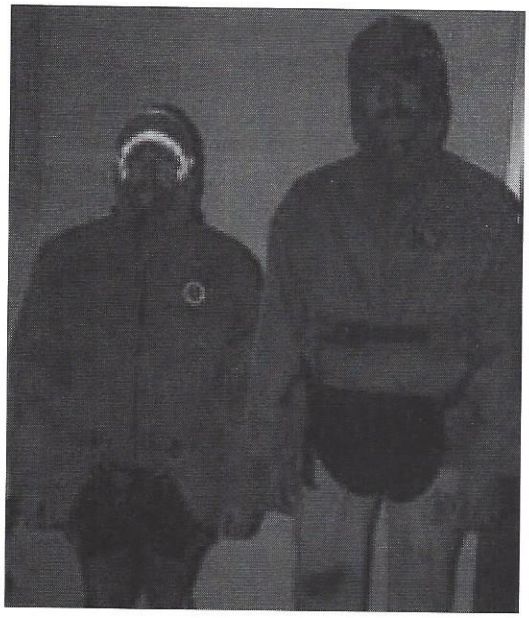
As mentioned earlier, exercise during cold water immersion may produce sufficient heat to retard the drop in core temperature. For men and women of the same body fat composition, decreases in core temperature are greater for women in the resting state or when performing light exercise; however, with more intense exercise, women maintain a higher core temperature than men.[44] If men and women exercise at the same absolute work intensity, there is no difference in cooling rate.[43,79] Under these conditions the women are exercising at a higher percentage of their maximal aerobic power and are therefore producing a greater amount of heat per unit thermal mass. Women exercising at the same percentage of their maximal aerobic power as men will cool at a faster rate, illustrating the imbalance between heat loss and production.[45]

PROTECTIVE CLOTHING

Two types of protection can be provided for survival in the case of cold water immersion: flotation devices and hypothermia protection. Therefore, it is beneficial during stage 1 of immersion to be equipped with some type of personal flotation device. The minimal function of this device is to float the victim in such a manner as to keep the face out of the water. The victim will not have to expend energy to stay afloat and will be protected from drowning if or when hypothermia progresses to the point that voluntary efforts to maintain flotation are no longer possible.

Numerous garments have been designed for hypothermia protection during accidental cold water immersion. One such garment is constructed to function as workable clothing in air, and will provide both flotation and hypothermia protection if the individual falls into cold water (Figure 17-5).

a



b

Fig. 17-5. (**a**) These are examples of a flotation jacket with hypothermia protection capabilities. Note the groin protection, which minimizes the flow of water through the jacket. (**b**) This deck suit has hypothermia protection capabilities. Core temperature data from both garment types and a control dressed in street attire are presented in Figure 17-6.

These suits and jackets do not keep the victim dry; water enters the garment and is trapped between the victim's body and the suit. Body heat, provided in part by shivering, warms the trapped water, which in this case represents the "boundary layer," and the suit's insulating capacity minimizes the heat loss to the surrounding environment. Figure 17-6 plots data from a subject who was immersed in 10°C water on three different occasions, dressed as follows[46]:

1. As a control, the subject wore street clothes (cotton underwear, shirt, jeans, socks, and tennis shoes) with flotation provided only by a neck collar.
2. The subject wore a jacket equipped with a groin flap to minimize water movement through the jacket.
3. Later, the subject also wore a flotation full-body suit.

The subject's core (rectal) temperature reached 35.6°C by 30 minutes in the control condition, by 60 minutes when clothed in the jacket, and remained above this level for 3 hours when clothed in the full body suit.

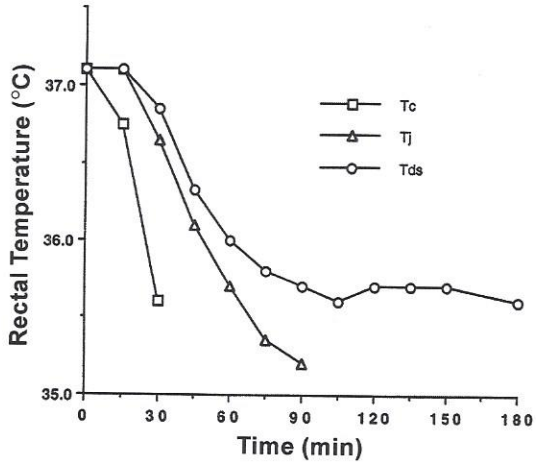


Fig. 17-6. Data representing the rectal temperature versus time plots of a single volunteer undergoing three testing conditions. The subject is a young white man of average build, fat content, and physical fitness. The three water immersions took place at least one week apart, and the water temperature each time was 10°C. In the control condition (T_c) the subject was clothed in regular street attire; in the other two conditions the subject wore either a jacket (T_j) or a deck suit (T_{ds}) designed for hypothermia protection.

Fig. 17-7. This flotation survival suit has hypothermia protection capabilities. Note that the gloves, feet (not shown), and hood are part of the suit, and are intended to keep water entry down to a few cubic centimeters. The subject is entering a tank with the water temperature set at 0°C, in a 2-phase system. Core temperature data from this garment are presented in Figure 17-8.

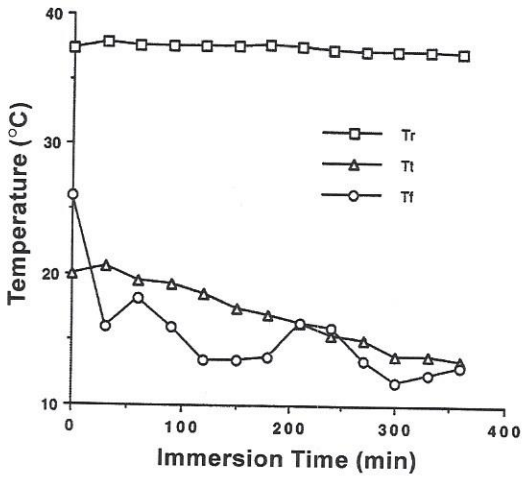


Fig. 17-8. A summary of a volunteer's 6-hour immersion in ice water (temperature range 1°C–3°C). The protective device worn was a survival suit of the dry type, as depicted in Figure 17-7. T_r represents rectal temperature, T_f represents skin temperature on the ventral aspect of index finger, and T_t represents skin temperature on the ventral aspect of the large toe. Adapted with permission from Wittmers LE, Pozos RS. In situ hypothermia testing. In: Laursen GA, Pozos RS, Hemple FG, eds. *Human Performance in the Cold.* Bethesda, Md: Undersea Medical Society Inc; 1983: 166.

The efficiency of long-term survival suits (Figure 17-7), which are designed to keep the victim dry and provide hypothermia protection, is illustrated in the data plotted in Figure 17-8. These one-piece, full-body suits allow little or no water into the garment when the subject falls into the water. In this test, the subject was immersed in ice water for 6 hours, and his core temperature remained above 37°C for the entire exposure.

In general, as these data show (see Figures 17-6 and 17-8), some type of flotation device and protective clothing are essential for survival when the victim is in danger of long-term exposure to cold water immersion.

Many military operations require clandestine operations involving Special Forces or US Navy SEALs, who travel to their targets in open minisubmarines and subsequently swim to shore. These operations require scuba diving gear and, in cold water, various kinds of insulating suits. In most operations of this nature, the personnel experience severely cold feet or hands rather than hypothermia. Although the personnel have adequate oxygen and insulation for their truncal regions, pronounced vasoconstriction of the digits—even though they are wearing special gloves and footwear—remains a major challenge for the execution of cold water submersible operations.

NEAR-DROWNING: HYPOTHERMIA AND THE DIVING RESPONSE

The preceding discussion has for the most part been limited to immersion cold stress under conditions in which the head of the victim remains out of the water. If, however, submersion results in hypoxia due to aspiration or laryngospasm, the accident is classified as a drowning. On the other hand, if the victim is recovered, successfully resuscitated, and lives for "some time" (usually 24 h), the event is classified as a near-drowning.[80,81]

The cases of near-drowning most often reported in the popular press involve victims who are young,[82] have fallen into cold water (= ≤ 10°C), at the time of recovery are profoundly hypothermic, and have been submerged for a relatively long time. The maximum reported immersion time of a survivor is 66 minutes.[83] The question most often asked is *why* do these individuals survive when others do not. Which scientific explanation best explains the

why remains controversial and the reason for this is best expressed by Gooden,[84] who believes that a major obstacle in the rigorous scientific study of survival from near-drowning is the paucity of objective data from the time the victim enters the water to arrival at the hospital.

Theories for the survival from near-drowning include the following:

1. externally induced hypothermia, resulting in brain and body cooling,[47] or internal and external hypothermia induced by drowning;
2. the diving response, resulting in oxygen conservation; and
3. a combination of the first two.

Published approaches to near-drowning survival either support mechanisms that combine both the diving response and hypothermia or discount the diving response as irrelevant and attribute survival to a rapid-cooling phenomenon.

If we assume that the diving response is of minimal or no importance with respect to preservation of life in the near-drowning scenario, and that the entire beneficial effect resides in the decrease in body temperature, then the water must be extremely cold and heat must be lost at a very rapid rate. Observations in subjects undergoing head-out water immersion (see Figure 17-4) show that even in very cold water (eg, 5°C), the rate of core temperature drop is only 0.06°C per minute. It must be pointed out that the body has very effective measures to counter the onset of early hypothermia (ie, peripheral vascular constriction to conserve heat and shivering thermogenesis to produce more heat). The decrease in core temperature may not be rapid enough to provide sole protection for the central nervous tissue. Hypothermia can also be induced by aspirating cold water, which if combined with external cooling, would cool the core very fast.

The diving response has been described in some detail earlier in this chapter. It is present in children, is more pronounced if stimulated by cold water, and is increased under conditions of excessive stress. Face immersion and apnea are accompanied by bradycardia, a decreased limb (ie, peripheral) blood flow, decreased kidney and splanchnic blood flow, and a decreased heat loss. The decrease in organ blood flow would tend to minimize oxygen utilization by those tissues. Also, the decreased heart rate and cardiac output will further reduce cardiac work and therefore oxygen consumption by the myocardium. The overall result is a decrease in metabolism, providing an oxygen-conserving function.[82] In real life, possibly, drowning and the diving response work together to cause a drop in core temperature.

ACCLIMATIZATION

To be consistent with the definitions given by Young,[85] cold *acclimatization* (or acclimation) means in this chapter "physiological adjustments in response to chronic cold stress."[85(p419)] On the other hand, cold *adaptation* refers to "genetic effects manifested as a result of natural selection."[85(p419)] The problem in the evaluation of cold acclimatization arises from the wide range in exposure intensity. The magnitude of the intensity is determined by surface area of exposure, ambient temperature, and environmental media (air or water). Because this chapter discusses immersion situations, acclimatization will be limited to cold water exposure.

Depending on the severity of the cold exposure, acclimatization can occur with or without an associated decrease in core temperature. For example, commercial fishermen are required to use their hands in extremely cold water for extended periods while the remainder of their body is relatively well protected from the elements.[86,87] Under these conditions, the subjects show a reduced vasoconstrictor response to cold stress. An example of this reduced vasoconstriction on exposure to cold is seen in arctic explorers (Figure 17-9). This alteration of the physiological response to cold will supply warm blood to the extremities, preventing frostbite and freezing injuries as well as prolonging dexterity. However, owing to the fact that the total area of exposure is small and the remainder of the body is protected, there will be no decrease in core temperature.

The next level of exposure would consist of repeated total body immersion for short periods of time. Under these conditions there is little or no change in core temperature; however, there is a delayed onset of shivering.[88] Because even a short immersion in cold water is a major stress, longer exposures magnify the problem and make it very difficult to measure physiological changes that may reflect acclimatization. To minimize these difficulties and evaluate acclimatization, the subject's response to cold air exposure, a much lesser stress, is evaluated following repeated cold water immersion. This approach was applied by Young and colleagues[89] and Bittel.[90] Both studies showed a de-

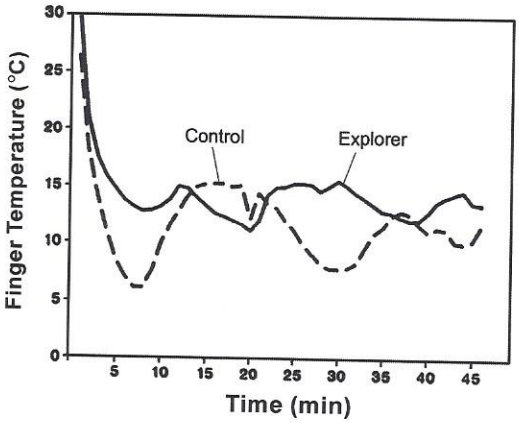


Fig. 17-9. The data represent the skin temperature of the subjects' right index finger immersed in ice water (0°C) as a function of time. The group of arctic explorers is compared with a group of controls matched for gender, age, and body type. Skin temperature is a function of skin blood flow. The explorers show much less rapid vasoconstriction when exposed to the ice water, and the magnitude of the drop is less than that seen in the control group. Adapted with permission from Hoffman RG, Wittmers LE. Cold vasodilatation, pain and acclimatization in arctic explorers. *J Wilderness Med.* 1990;1:230.

layed onset of shivering and a lower mean skin temperature in cold water-acclimatized subjects. The rectal temperature results did not match; Bittel's data showed little difference between acclimatized and nonacclimatized subjects, whereas Young's showed a lower rectal temperature at the start and a larger drop in rectal temperature in the acclimatized subjects.

The decreased skin temperature in the acclimatized subjects reduces the driving force (ie, the temperature gradient) for movement of heat from the skin into the environment (see Equation 1). This decrease in skin temperature results in a larger gradient between core and shell; therefore, a redistribution of heat internally with a decrease in shell thickness. However, the end result is an increase in effective insulation and thus, conservation of heat.

SUMMARY

The information presented in this chapter has focused on the physiological and behavioral responses to cold water immersion. When compared with cold air exposure, cold water is a much greater stress, drawing heat away from the body approximately 20-fold faster than air of the same temperature. Protection against heat loss in cold water environments is possible, as long as personnel wear protective garments (ie, jackets and suits) as discussed. However, the suddenness of cold water accidents may preclude the opportunity to wear cold water protective gear. In such cases, the onset of hypothermia and drowning is swift and lethal.

Initially, cold stress results in peripheral vasoconstriction. This vascular response provides a method of conserving heat, essentially limiting heat delivery from the body core and increasing the external insulating layer. As the cold exposure continues, heat loss is compensated for by increased heat production, either from shivering or from muscle contraction. However, when heat loss exceeds heat production, core temperature starts to drop and the subjects proceed toward hypothermia. Changes in the individual's physiology and behavior will signal the magnitude of the core temperature drop and indicate the precautions to be taken or the treatment to be given.

It should be emphasized that cold water immersion, even when the water temperature is relatively mild (but below core temperature) has a great potential for producing the life-threatening condition of hypothermia. In addition, cold water may cause cardiovascular collapse, or drowning, or both.

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Chapter 17: ATTACHMENT

SHIPWRECK AND HYPOTHERMIA: EXPERIENCES GAINED BY THE GERMAN NAVY, 1939–1945

As a result of the loss of documents at the end of World War II, the German Naval Medical Service has not been able as yet to prepare a comprehensive medical report, but only managed to present an overview obtained by individual existing reports. Thus, it is also no longer possible to determine the number of naval personnel who died as a result of hypothermia or fatigue or the number of civilians killed during the great ship foundering in the course of the evacuation of the East in 1945. According to estimates, however, tens of thousands of people died in the icy floods.

Like the states of the western allies, the German Naval Medical Service was inadequately prepared for hypothermia problems of shipwrecked persons at the beginning of the war. Although many members of the Navy had been shipwrecked during World War I, the rescue capabilities at the beginning of the century were limited to such an extent that most persons had already died when they were recovered, and the cause of death was simply considered "drowning." Thus, an original clinical picture of hypothermia was neither assumed nor scientifically examined until the outbreak of World War II.

The 1940 publications of *The Medical Advisor for Submarines* and the *Bulletin on Medical Measures to be Taken in the Case of Submarine Accidents* did not yet deal with issues concerning hypothermia or cold water rescue. Only the improved rescue capabilities, and in particular, the events during the occupation of Norway in spring 1940, with a large number of shipwrecked persons in the cold waters of the Skagerrak and North Sea as well as the now frequent sea engagements in the northern area, forced those in command to intensively work on medical issues concerning distress at sea. The Army and Air Force only started to deal with similar problems after the mass occurrence of cold injuries during the winter battle near Moscow in 1941, and because of the large number of ditched aircraft crews suffering from cold injuries. At this point, it should be specifically pointed out that the Naval Medical Service was in no way involved in the hypothermia experiments in concentration camps, although it profited passively by the results of these experiments.

For the invasion operation, almost the entire German fleet was standing in Scandinavian waters in the morning hours of 9 April 1940. There were various sea engagements and several thousands of shipwrecked German forces. The available reports give evidence of the amazingly inadequate preparation and of the ignorance of the crews and embarked personnel, as well as of the poor medical facilities in view of the risks imposed by shipwreck and hypothermia. What alarmed the helpers again and again was the frequently observed phenomenon of the "afterdrop." After the foundering of a troop carrier, 79 members of the Army were drifting in the Skagerrak at a water temperature of 1°C. Thirty of the crew had taken off their clothes to enable them to swim better; the rest wore protective clothing. None of those who remained clothed died; after they were rescued and had changed into dry clothes they were fit for duty again. Those who had removed their clothes lay shivering in the berths of the destroyer crew after their rescue. Subjectively, they felt well and still comprehensively discussed the individual phases of the torpedoing. Suddenly, one after the other fell silent and lifelessly sank back onto the berth. They all died within 6 hours. The ship's doctor, who was overtaxed with the treatment of the casualties, immediately administered Lobelin and cardiovascular drugs to the collapsed patients, but without success (Tidow, 1960, p38).

At the same time, the cruiser *Blücher,* with a crew of 1,400 men and approximately 650 embarked Army soldiers, was torpedoed in the Oslo Fjord. The water temperature in this area was 2°C, the air temperature 0°C. The distance from the foundering ship to the dry land was only 300 to 400 meters, or about 20 minutes' swimming. Still, hundreds of soldiers died from fatigue or hypothermia. The surviving third ship's doctor, naval medical assistant Dr Pietsch, reported:

> On the smaller islands many numb persons were lying who refused to jump into the water despite shouts from the shore to swim the last meters to the shore. Upon that, I jumped into the water, reached some islands and was able ... to take 6 men ashore. In one case resuscitative measures were unsuccessful. All others were recovered in front of lighted fires some faster, others slower (Medical Action Report, pp116–117).

Only after June 1941 did the Naval Medical Office in the German Naval Supreme Command for ships and boats without doctors issue preliminary directives for the treatment of rescued shipwrecked persons. The directives demanded the *slow* warming of patients suffering from severe hypothermia. The patients were initially to be kept in cool rooms, rubbed, and packed in dry clothes. These directives, however, taking individual circumstances into account, were already slightly modified to the following:

> The decision as to which rescued persons are to be treated as patients suffering from hypothermia cannot alone be made on the basis of duration of stay in the water and the prevailing water temperature. The degree of hypothermia varies from individual to individual. Therefore, the objective impression must be also taken into consideration.

This directive attached particular importance to the careful transport of patients suffering from hypothermia on the receiving ship.

By 1942, the principles of treatment had changed. Now the *rapid* warming therapy was propagated as the best treatment method for patients suffering from severe hypothermia. This opinion was retained until the end of the war. Thus, the *Medical Advisor for Submarines* formulated in 1944:

a. Shipwrecked persons suffering from hypothermia must in any case be subjected to an immediate intensive warming. This rewarming is accomplished by means of
   - hot baths at about 45°C, or
   - hot showers at about 45°C, or
   - repeated pouring over with fairly hot water.

b. As an additional measure, cold compresses are applied to the forehead.
c. Cardiac stimulants are to be slowly injected after the body has warmed internally, otherwise there is a risk of shock.
d. The administration of alcohol has is to be avoided until circulation, respirations and consciousness are completely normal again (*Medical Advisor for Submarines*, 1944, p32).

In addition, the regulation pointed out for the first time that in cases of immersions, unnecessary swimming movements should be avoided and only should rely on the floating capacity of the life jacket.

In the course of time, the positive effect of an appropriate and adequate clothing of the shipwrecked person in the water became more and more evident and led to changes in training. The crew members who during the first years of the war had taken off their warming clothing before jumping into the water in order to be able to swim better were now "repeatedly reminded to keep all clothes on the body, whenever possible" (Missler, 1981, p19). The success of such measures became evident during the foundering of a destroyer in the polar sea in May 1942. Thirty-eight crew members, most of the personnel from the upper deck with life jackets underneath their protective clothing reached—after a longer period of swimming at a water temperature of 1°C and an air temperature of –10°C and a wind force of 5—floating parts of the wreck that were constantly flooded by the sea. Six hours after the sinking, a submarine took in the shipwrecked persons. During the examination, the rescue personnel noticed that the upper bodies were in parts still dry while the outer clothing had turned into icy armor, which had to be cut open with knives and saws. Therapeutically, the rapid rewarming was performed; however, three boiler men wearing lighter clothing died after a short time.

Various reports also point out the important role of a stable psychical constitution and a strict discipline of shipwrecked persons suffering from hypothermia. For example, in autumn 1942, a lifeboat with 4 survivors and 20 corpses reached the coast of northern Norway after a cruise of almost 9 days. At wind force 7, a sea disturbance of 5–6, with only a small supply of food and inadequate clothing, the passengers were completely soaked and suffering from hypothermia. The chief coxswain had the command in the boat and held the control fin in his arms with his last ounce of strength, because his hands were frostbitten and he could no longer use them. During the cruise many of the passengers suffered from states of delusion and confusion and force had to be used to prevent them from jumping overboard. Discipline was good until the end.

In another case, a rescued shipwrecked person in the wintry Baltic Sea in 1945 reported on a person who was shipwrecked for the second time and who, in an almost hopeless situation, motivated a group of swimmers to hold out until their rescue (compare Missler, 1981).

The extraordinarily different circumstances in the area of submarine warfare in relation to shipwreck and hypothermia is illustrated by the following report on the last mission of the submarine U 550 at the East Coast of the United States on 16 April 1944 (compare Haenert, 1994). It shows in an exemplary manner how shipwrecked submarine crews were not always taken in by enemy vessels but were sometimes abandoned to their fates:

> During a convoy battle, the type IX C submarine with a crew of 57 men was pursued with depth charges by superior US screen units and forced to surface. When the upper hatch was opened, three destroyers lying in a circle around the submarine fired at it with their internal guns. Resistance was no longer possible amidst the hail of shells; rather, the U 550 quickly foundered so that the crew left the submarine in two groups and swam away from the wreck. The only rescue facilities on board the submarine were divers and several one-man inflatable lifeboats. As protective clothing, parts of the crew wore a leather combination; others had not found the time to put on warmer clothing. The embarked naval medical assistant, Dr Torge, did not have the opportunity to take any additional lifesaving measures. The larger group of about 40 persons under the command of the first officer on watch swam toward the nearest US destroyer, as ordered. The destroyer, however, suddenly pulled away and did not make any rescue attempt. All of the soldiers died of hypothermia. The second group, 13 members of the crew, swam in the 5°C cold water for about 15 minutes to the USS *Joyce* drifting the vicinity, which took them aboard. On board, medical treatment was provided to those who suffered from moderate hypothermia or gunshot injuries.

With the activation of the small combat elements of the German Navy late in 1944, hypothermia problems gained a new significance. The crew members of these very different surface and subsurface vessels were particularly exposed to the cold. Therefore, the Navy tested cold protection measures in September 1944 for the first time. The first tests were performed on the foam suits of the Air Force, during which the soldiers noticed not only the significant insulation provided but also the good buoyancy and horizontal position in the water that the foam suits allowed. Later, the wool-in-plush underwear of the frogmen was also improved (compare Hartmann and Noeldeke, 1994).

Irrespective of all efforts aimed at improving hypothermia therapy and prophylaxis, the effects of hypothermia reached a sad climax during the disastrous foundering in the wintry Baltic Sea in the course of the evacuation of the eastern German territories. Expert prophylaxis and treatment were impossible from the very beginning, in the view of the large number of refugees. As examples of the terrible death toll at the end of the war stand two overcrowded refugee ships, the *Wilhelm Gustloff* and the *Goya*, which were torpedoed on 30 January and 17 April 1945, respectively, carrying about 6,000 people each, mainly women and children. Both ships sank and their passengers died of exposure to the cold.

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This attachment was written especially for this textbook by V. Hartmann and W. Haenert, 1996.

CHAPTER 8

Aeromedical and Survival

8.1 GENERAL

To improve the survivability of flight personnel, OPNAV (N88) has implemented the aircrew survivability enhancement program (ASEP). Sub-elements of this program are aviation life support systems (ALSS), CBRND, safety, human performance, and training. Guidelines and requirements contained here are considered minimum. Recommendations for changes or improvement in equipment, procedures, or training shall be addressed via the chain of command to COMNAVAIRFOR (N455) for evaluation and, if appropriate, implementation.

8.2 AVIATION LIFE SUPPORT SYSTEMS

The safety and survival equipment/requirements specified in paragraphs 8.2.1, 8.2.2, 8.2.3, and 8.2.4 of this manual are minimum requirements. Systems description, limits, procedures, deviations and authorization requiring a flight clearance shall be specified in an IFC, NATIP or NATOPS flight manual for the individual T/M/S aircraft. The latest equipment for use by aircrew personnel and passengers for flight in all naval aircraft is listed in aviation crew systems manuals, references (ad) through (at), and NAVAIR publications: references (aw) through (bb).

8.2.1 Aircrew Personal Protective Equipment Requirements

8.2.1.1 Aircrew

Note

All aircrew shall perform a pre-flight and post-flight inspection if their aircrew personal protective equipment

Items below marked * may be omitted by flight personnel flying in fixed-wing cargo/transport class aircraft if such flight does not involve carrier operations and omission is approved by the commanding officer.

a. *Protective helmet – The helmet shall be 100 percent covered with white reflective tape except as modified by approved aircrew system changes. Up to 30 square inches of light-colored reflective tape may be applied so long as the white tape remains visible from all directions. The use of reflective tape may degrade NVD performance. Temporary, nonreflective cloth covers may be worn over the reflective tape.

b. *Aircrew safety/flyer boots.

c. *Fire-resistant (aramid) flight gloves.

d. *Fire-resistant flight suit (aramid) – Aramid or cotton-type undergarments shall be worn. Suitable fire-resistant unit issue clothing (aramid) may be substituted for the flight suit for flight personnel in non-ejection seat aircraft.

e. *Identification tags – Two tags on a chain worn around the neck; alternately, one tag may be laced into the boot, and the other carried elsewhere on the person.

f. *Survival knife – Do not wear exposed or attached to the life preserver.

g. *Personal survival kit – Appropriate to the area of operations.

h. *Signal device – Required for all night flights and flights over water or sparsely populated areas.

i. Survival radios and beacons

(1) Survival radios

(a) An approved voice-capable survival radio shall be carried by each aircrewman on all flights, unless otherwise directed by aircraft NATOPS manuals.

(b) A voice-capable radio shall be packed with all multiplace rafts.

(2) Emergency beacons

(a) An approved automatically actuated line-of-sight emergency beacon shall be installed in all ejection seats. Emergency beacon shall remain automatically actuated unless the aircraft will be operated in hostile fire areas.

(b) Beyond-the-line-of-sight, emergency beacon shall be packed with all multiplace rafts carried on board aircraft when performing extended overwater flights outside of normal oceanic air traffic routes.

j. Flashlight – Required for all night flights.

8.2.11. k. Anti-exposure suits – Final determination with regard to actual wearing of anti-exposure suits shall be made by the commanding officer or officer in charge of the aviation unit concerned. The decision will be based on an ORM analysis and take all pertinent factors into account (i.e., class aircraft, type and duration of assigned mission, ambient cockpit temperatures and environment factors, suit wearability, combat versus noncombat environment, availability of SAR resources, and ALSS accessible to all personnel onboard the aircraft) refer to figure 8-1. The latest available type continuous-wear or quick-donning anti-exposure suits, as appropriate, shall be provided for flight personnel of naval aircraft when in the event of a mishap there would be a significant risk of water entry and when either of the following two conditions prevail:

(1) The water temperature is 50°F or below.

(2) The outside air temperature (OAT) is 32°F or below (based on the wind chill factor corrected temperature (see figure 8-2)).

COLD WATER IMMERSED FUNCTIONAL EXPOSURE LIMITS BY TYPE OF EXPOSURE PROTECTION

		CWU-86 OR CWU-62/P SERIES[1]				MULTICLIMATE PROTECTION SYSTEM[1]						OTS-600[1,2]	
		86 or 62/P	86 or 62/P, 23/P liner	86 or 62/P & 43,44/P underwear	86 or 62/P, 23/P liner, 43,44/P underwear	86 or 62/P, MCP LW underwear	86 or 62/P, MCP MW underwear	86 or 62/P, MCP LW & MW underwear	86 or 62/P, MCP HW liner	86 or 62/P, MCP HW liner & LW underwear	86 or 62/P, MCP HW liner & MW underwear	OTS	OTS & 43,44/P underwear
CWU-86 or 62/P Dry Suit		X	X	X	X	X	X	X	X	X	X		
OTS-600 Dry Suit												X	X
CWU-43-44/P Underwr				X	X								X
CWU-23/P Liner			X		X								
MCP Ltwt Underwr						X		X		X			
MCP Mdwt Underwr							X	X			X		
MCP Hvywt Liner									X	X	X		
	Water Temp °F												
8% Body Fat	35	≤ 30	≤ 45	≤ 75	≤ 150	≤ 60	≤ 90	≤ 105	≤ 135	≤ 150	≤ 240	≤ 60	≤ 165
	40	≤ 30	≤ 75	≤ 90	≤ 195	≤ 75	≤ 120	≤ 135	≤ 165	≤ 180	≤ 300	≤ 75	≤ 195
	45	≤ 55	≤ 90	≤ 120	≤ 255	≤ 90	≤ 150	≤ 180	≤ 210	≤ 225	≤ 360	≤ 90	≤ 225
	50	≤ 30	≤ 120	≤ 165	≤ 330	≤ 120	≤ 210	≤ 240	≤ 270	≤ 285	> 360	≤ 120	≤ 285
	55	≤ 60	≤ 165	≤ 225	> 360	≤ 180	≤ 300	≤ 315	≤ 300	> 360	> 360	≤ 150	≤ 345
	60	≤ 105	≤ 240	≤ 315	> 360	≤ 255	> 360	> 360	> 360	> 360	> 360	≤ 225	> 360
	68	≤ 225	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360
11 to 14% Body Fat	35	≤ 45	≤ 75	≤ 90	≤ 165	≤ 75	≤ 105	≤ 120	≤ 135	≤ 150	≤ 240	≤ 75	≤ 165
	40	≤ 60	≤ 90	≤ 105	≤ 210	≤ 90	≤ 135	≤ 150	≤ 165	≤ 180	≤ 315	≤ 90	≤ 195
	45	≤ 60	≤ 105	≤ 135	≤ 270	≤ 105	≤ 180	≤ 195	≤ 225	≤ 240	> 360	≤ 105	≤ 240
	50	≤ 75	≤ 150	≤ 180	≤ 345	≤ 150	≤ 240	≤ 255	≤ 300	≤ 315	> 360	≤ 135	≤ 300
	55	≤ 105	≤ 210	≤ 255	> 360	≤ 210	≤ 330	≤ 345	≤ 360	> 360	> 360	≤ 195	> 360
	60	≤ 150	≤ 285	≤ 345	> 360	≤ 300	> 360	> 360	> 360	> 360	> 360	≤ 270	> 360
	68	≤ 315	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360
15 to 18% Body Fat	35	≤ 60	≤ 90	≤ 105	≤ 195	≤ 90	≤ 135	≤ 135	≤ 165	≤ 180	≤ 270	≤ 90	≤ 195
	40	≤ 60	≤ 105	≤ 135	≤ 255	≤ 105	≤ 165	≤ 180	≤ 210	≤ 225	≤ 345	≤ 105	≤ 225
	45	≤ 90	≤ 150	≤ 180	≤ 315	≤ 150	≤ 210	≤ 225	≤ 270	≤ 285	> 360	≤ 135	≤ 285
	50	≤ 105	≤ 195	≤ 225	> 360	≤ 195	≤ 285	≤ 300	≤ 345	≤ 345	> 360	≤ 180	≤ 345
	55	≤ 150	≤ 270	≤ 315	> 360	≤ 270	≤ 360	> 360	> 360	> 360	> 360	≤ 240	> 360
	60	≤ 210	≤ 360	> 360	> 360	≤ 360	> 360	> 360	> 360	> 360	> 360	≤ 330	> 360
	68	≤ 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360
19 to 26% Body Fat	35	≤ 105	≤ 150	≤ 180	≤ 270	≤ 150	≤ 195	≤ 210	≤ 225	≤ 240	≤ 330	≤ 135	≤ 255
	40	≤ 120	≤ 180	≤ 210	≤ 315	≤ 180	≤ 255	≤ 255	≤ 285	≤ 300	≤ 360	≤ 165	≤ 300
	45	≤ 150	≤ 225	≤ 270	≤ 345	≤ 225	≤ 300	≤ 300	≤ 315	≤ 330	> 360	≤ 225	≤ 330
	50	≤ 210	≤ 285	≤ 300	> 360	≤ 285	≤ 330	≤ 345	> 360	> 360	> 360	≤ 285	> 360
	55	≤ 270	≤ 330	≤ 360	> 360	≤ 330	> 360	> 360	> 360	> 360	> 360	≤ 315	> 360
	60	≤ 315	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360
	68	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360
≥ 27% Body Fat	35	≤ 180	≤ 225	≤ 270	> 360	≤ 240	≤ 300	≤ 315	≤ 345	≤ 360	> 360	≤ 225	≤ 360
	40	≤ 120	≤ 270	≤ 330	> 360	≤ 300	≤ 360	≤ 360	≤ 360	> 360	> 360	≤ 285	> 360
	45	≤ 270	≤ 360	> 360	> 360	≤ 360	> 360	> 360	> 360	> 360	> 360	≤ 360	> 360
	50	≤ 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360
	55	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360
	60	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360
	68	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360	> 360

Note 1: All clothing configurations include aircrew safety boots, standard wool socks, HGU-84/P helmet, CWU-27/P flight coverall

Note 2: OTS ensembles are configured for tactical flight and also include CMU-33/P survival harness, PCU-56/P torso harness, CSU-13B/P anti-G suit

3710-F04b

Figure 8-1. Anti-exposure Suit Requirements (Sheet 1 of 2)

CAUTION

This table shows estimated Immersed Functional Exposure Limits based on laboratory tests and simulations. Actual functional Exposure limits will vary based on the individual personal fitness including rest, meals, activity level, injuries and mental attitude and factors such as sea state, ambient air temperature, and total immersed time.

Note

- This table depicts predicted Functional Exposure Limits and not Survival Time.
- Predictions are based on body fat / weight combinations of: 8% @ 155 lbs, 11-14% @ 166 lbs, 15-18% @ 177 lbs, 19-26% @ 193 lbs, 27% @ 216 lbs.

USING TABLE TO MAKE OPERATIONAL DECISIONS

(1) Consult with Operations to determine likely alert-to-rescue time. Allow for rescue of all aircrew.

(2) Determine the coldest water temperature (rounding down) of which you will be flying.

(3) Choose the body fat range that most closely resembles you, underestimating rather than overestimating.

(4) Determine functional exposure limit by matching the water temperature row with the type of individual exposure protection available.

Example:

An 18% body fat aircrewman is scheduled for an unescorted night flight with a total of five personnel that will depart NAS Norfolk and terminates approximately three hours later on a carrier at sea. The coldest water temperature over which the crew will fly is 53 degrees. Operations estimates SAR time to be approx 1 hour and 30 minutes to arrive on station. Taking into account 1 hour to locate the survivors and an additional 1 hour and 15 minutes to rescue all five crew members, the total in water time would be 225 minutes for the last crewmember. Thus, he needs to select clothing that will protect him for no less than 225 minutes. The aircrewman has been issued the CWU-62/P, CWU-23/P liner and CWU-43, CWU-44 underwear.

The aircrewman selects the "15-18%" body fat data range and 50 degree water temperature (rounding down). Based on the table, he determines that he can wear the underwear without the liner under the CWU-62/P to last for the 225 minutes estimated it will take for the SAR rescue.

Figure 8-1. Anti-exposure Suit Requirements (Sheet 2)

WIND SPEED MPH	WHAT THE THERMOMETER READS (degrees F.)											
	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
	WHAT IT EQUALS IN ITS EFFECT ON EXPOSED FLESH											
CALM	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68
10	40	28	16	4	-9	-21	-33	-46	-58	-70	-83	-95
15	36	22	9	-5	-18	-36	-45	-58	-72	-85	-99	-112
20	32	18	8	-10	-25	-39	-53	-67	-82	-96	-110	-121
25	30	16	0	-15	-29	-44	-59	-74	-88	-104	-118	-133
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109	-125	-140
35	27	11	-4	-20	-35	-49	-67	-82	-98	-113	-129	-145
40	26	10	-6	-21	-37	-53	-69	-85	-100	-116	-137	-148
	Little danger if properly clothed				Danger of freezing exposed flesh			Great danger of freezing exposed flesh				

3710-F05

Figure 8-2. Wind Chill Index

Note

Actual determination as to when anti-exposure suits must be worn by flight personnel shall be determined by the commanding officer or officer in charge. However, it is strongly recommended that anti-exposure suit use be mandatory when either of the above two criteria are met. The threat of lethal cold shock is very significant under these conditions and occurs within the first two to three minutes following immersion.

Flight personnel have the option to wear the provided anti-exposure suits as a personal decision whenever they deem circumstances merit their use.

Rescue swimmers shall not be deployed unless equipped with anti-exposure protection when water temperature is 60°F or below and/or OAT is wind chill factor corrected at 32°F or below.

(3) If the water temperature is between 50°F and 60°F, the commanding officer or officer in charge of the unit concerned must determine whether anti-exposure suits are necessary and when they are to be provided (figure 8-1) using ORM analysis based on SAR factors as follows:

(a) Assess maximum probable rescue time (which is a function of mission distance, SAR equipment, and SAR location).

(b) Determine the lowest water temperature in the mission area during the time period of flight.

(4) When OAT corrected for wind chill is at or below 50°F and anti-exposure suits are not mandated the wearing of fire-resistant (aramid) undergarments is recommended. Wearing double layers of these undergarments can significantly improve anti-exposure performance in a cold dry environment (e.g., survival situation resulting from overland mountainous flight profile).

WARNING

Immersion in water with a temperature of between 50° and 60° for as little as 2 hours can result in unconsciousness because of hypothermia. Wearing of the complete anti-exposure ensemble as authorized by (an) is the only configuration that ensures adequate thermal protection with water temperatures below 60°F.

Note

Without the full anti-exposure ensemble, aramid undergarments are of very little or no practical value for thermal protection during water immersion situations. Refer to table 5-2 of reference (ad) for the recommended underclothing based on water temperature.

(5) Only approved combinations of anti-exposure suit inner and outer liners authorized by reference (ae).

(6) When anti-exposure suits are not actually worn by occupants of aircraft in which the use of quick-donning suits is practical (i.e., large helicopters and patrol class aircraft), such suits shall be carried for each aircrew member as part of the aircraft survival equipment on flights conducted under the temperature conditions stated above. Exceptions to the above requirements are as follows:

(a) Fleet tactical support squadrons and other commands operating transport class aircraft in routine transport operations. (Functional checkflights, flights for airlift of hazardous cargo, and flights in combat zones are examples of other than routine operations.)

(b) When worn with approved inner garments, a full-pressure suit is authorized for use in place of the continuous-wear anti-exposure suit.

Note

The wearing of rubber wetsuits can result in rapid onset of fatigue as a result of dehydration. Since fatigue is more prevalent with the wearing of wetsuits, the rest, sleep, and flight time requirements of paragraph 8.3.2 may not be sufficient.

l. Anti-blackout suits (G-suits) shall be worn and connected on all flights in aircraft equipped for their use.

m. Inflatable life preservers shall be worn during all flights originating from or terminating on ships or landing platforms. Life preservers shall be readily available when operating from aerodromes in the vicinity of coastal waters or when operating from inland aerodromes where takeoff, route of flight, or approach path is over water. Occupants of ejection seat aircraft shall wear the appropriate life preserver at all times. Life preservers shall be worn when mission requirements dictate operation over water below 1,000 feet exclusive of normal departures or approaches (e.g., maritime patrol operations).

Note

The life preserver automatic inflation device, FLU-8/P, is designed for use in ejection seat aircraft only. It shall not be worn in aircraft where ditching is a recommended procedure, in helicopters, or on COD flights.

n. Laser eye protection (LEP) – LEP shall be worn in accordance with reference (bc) in a known or suspected laser threat environment (e.g., rangefinder, designator, etc.,) either in a single of multi-aircraft scenario.

o. Supplemental Emergency Breathing Devices (SEBD) – SEBD shall be carried by all helicopter, tiltrotor, E-2, and C-2 aircrew during overwater flight. Aircrew must complete applicable NASTP SEBD training elements prior to being issued personal SEBD equipment. The flight-approving authority may provide SEBD or similar approved equipment to any nonaircrewman who has successfully completed applicable training.

p. Appropriate aircrew CBRND protective equipment shall be worn or available for immediate use when operating in identified chemical, biological (CB) threat areas.

8.2.1.2 Rescue Aircrewmen Equipment

The minimum personnel equipment to be carried by the rescue swimmer shall be in accordance with applicable aircraft type NATOPS manual and reference (bd).

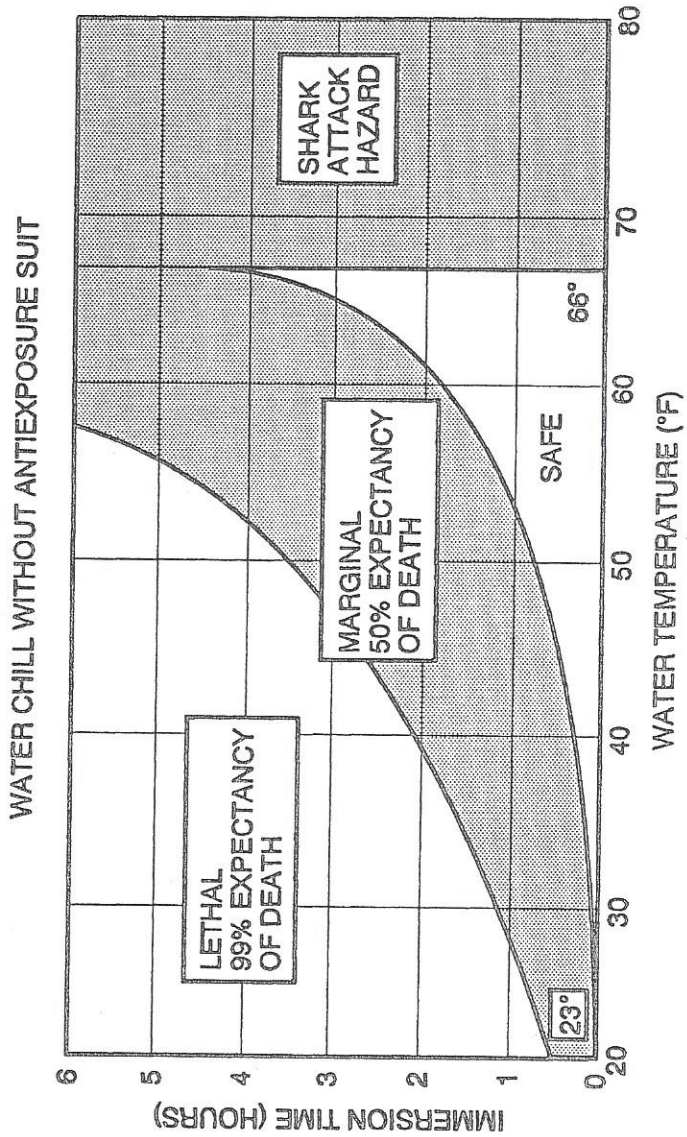
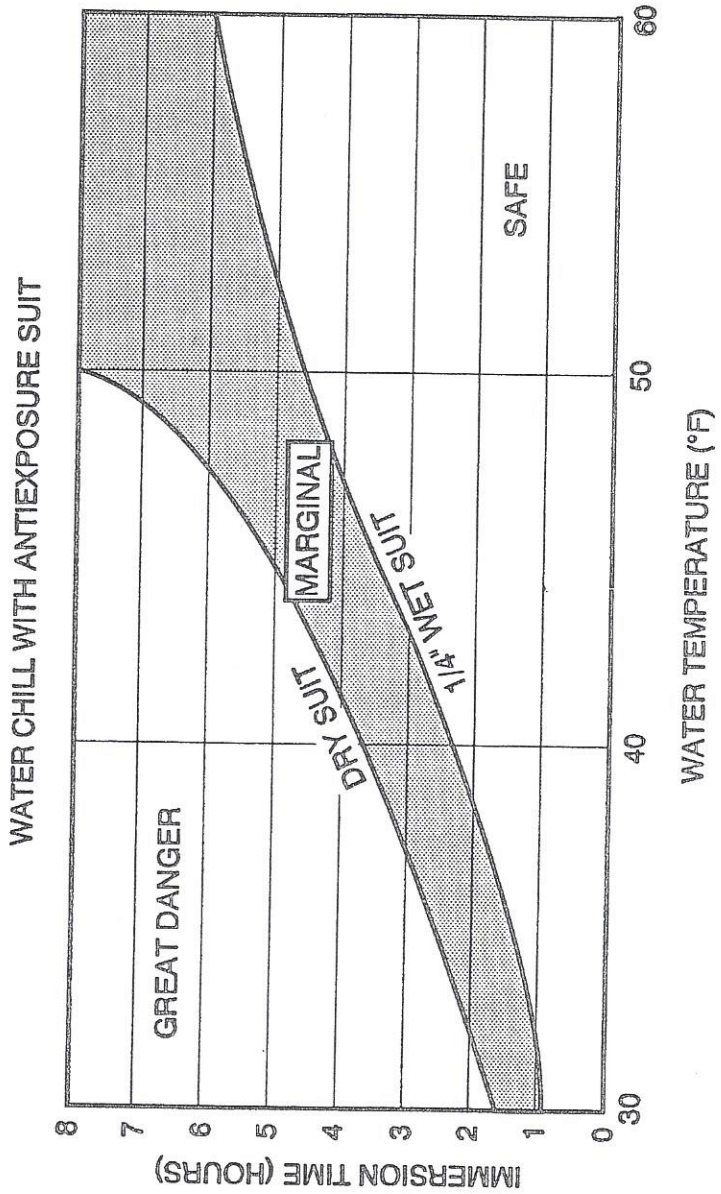
Table 5-11. Recommended Underclothing Based on Water Temperature

	Underwear			Liner		
	Rotary Wing	Fixed Wing Non-Ejection Seat	Fixed Wing Ejection Seat	Rotary Wing	Fixed Wing Non-Ejection Seat	Fixed Wing Ejection Seat
Water Temperature Above 60 degrees F	CWU-43 and CWU-44 or MCP Silkweight or MCP Midweight	CWU-43 and CWU-44 or MCP Silkweight or MCP Midweight	CWU-43 and CWU-44 or MCP Silkweight or MCP Midweight	Optional	Optional	Optional
Water Temperature 50 to 60 degrees F	CWU-43 and CWU-44 or MCP Silkweight and/or MCP Midweight	CWU-43 and CWU-44 or MCP Silkweight and/or MCP Midweight	CWU-43 and CWU-44 or MCP Silkweight and/or MCP Midweight	CWU-23/P or CWU-72/P or CWU-81/P and CWU-82/P or MCP Heavyweight	CWU-23/P or CWU-72/P or CWU-81/P and CWU-82/P	CWU-23/P or CWU-72/P or CWU-81/P and CWU-82/P
Water Temperature Below 50 degrees F	CWU-43 and CWU-44 (two sets) or MCP Silkweight and MCP Midweight	CWU-43 and CWU-44 (two sets) or MCP Silkweight and MCP Midweight	CWU-43 and CWU-44 (two sets) or MCP Silkweight and MCP Midweight	CWU-23/P or CWU-72/P or CWU-81/P and CWU-82/P or MCP Heavyweight	CWU-23/P or CWU-72/P or CWU-81/P and CWU-82/P	CWU-23/P or CWU-72/P or CWU-81/P and CWU-82/P

NOTES:

1. For proper anti-exposure protection, a CWU-86/P or CWU-87/P Flyer's Anti-Exposure Coveralls must be worn over the recommended underclothing.
2. SAR Swimmers who wear Mustang anti-exposure suits can substitute the exotherm liner in place of the CWU-23/P or CWU-81/P and CWU-82/P liners.

WATER AND WIND CHILL FACTORS



WATER AND WIND CHILL FACTORS (Cont.)