PROTECTIVE CLOTHING IN COLD WATER SURVIVAL

CAPT Alan M. Steinman, USPHS

LTJG Jennifer M. Lincoln: Our next presenter is Captain Alan M. Steinman, whose presentation is entitled *Protective Clothing in Cold Water Survival*. Dr. Steinman earned his Bachelor of Science degree from MIT in 1966 and his MD degree from Stanford University in 1971. He did his first year of residency training at the Mayo Clinic and joined the Public Health Service in 1972. He has served as flight surgeon at various U.S. Coast Guard air stations and in 1978 was assigned to Coast Guard Headquarters as Chief of Operational Medicine and medical advisor for search and rescue operations until 1984. During these years in the Coast Guard, he designed and performed numerous studies on hypothermia, sea survival, and protective clothing. He completed an occupational and preventive medicine residency at the University of Washington in 1987, earning a Master of Public Health degree. He was board certified in Occupational Medicine in 1988, and he was designated a fellow of the American College of Preventive Medicine in 1989. He served for 18 months as Chief of the Medical Branch, Division of Commissioned Personnel, Office of the Surgeon General, USPHS, before rejoining the Coast Guard in his current assignment as Chief of Wellness Branch, Operational Medicine Division, Office of Health and Safety. Dr. Steinman has an international reputation in hypothermia and cold water survival. He has published numerous research papers and text book chapters on the subjects and has served as advisor on cold water operations and sea survival to all branches of the armed forces.
Dr. Alan Steinman:

We are going to talk about sea survival, particularly in cold water. I want to tell you of the results of some of the experiments that we have done — looking at some of the suits, in fact, that Ken Coffland has shown you.

COLD WATER SURVIVAL

Cold water survival is an interesting topic, particularly for Alaska. You always have cold water up here. The problem with humans in cold water is twofold:

- First, you have to avoid drowning.
- Second, once you avoid drowning, you have got to avoid dying of hypothermia.

Avoiding Drowning

You are going to hear a little bit more about drowning from CAPT Perkins, our next speaker, I will not talk about that a lot. To summarize some of the obvious things of what someone has to do to avoid drowning, you have got to know how to swim, basically keeping your mouth and nose above the water. You must avoid panic. The sea state obviously impacts your ability to avoid drowning: what kind of clothing you are wearing, what kind of flotation device you are wearing, whether you have got a life raft or you have anything else to hang on to for buoyancy, and how close the Coast Guard is to coming to pick you up.

Controlling Hypothermia

The other half of the equation of survival in cold water has to do with hypothermia. That is what we are going to talk about here in the next few minutes. Here is the factor that impacts on your ability to withstand hypothermia in cold water: how big you are.

Basically, human beings, from the standpoint of cooling rate, the bigger and fatter you are, the longer your survival time. It is one of a few advantages of being obese in our society. The closer you are to a perfect sphere, the longer you are going to survive. It has to do with the surface-area-to- volume ratio.

Just because you are wearing a lot of buoyancy does not mean that you can be passive about your survival.

Obviously, if you are in a good state of health, you will survive longer. The colder the water, the quicker you will get cold; that is a no-brainier.

The rougher the seas, the faster you are going to cool. We are going to talk about rough seas a lot here in a few minutes.

What kind of protective clothing you are wearing has a major impact on your ability to survive. How much flotation you have has an impact. Finally, what you do in the water affects your survival. If you thrash around or hold still, each type of behavior is associated with a different cooling rate.

One thing you have got to understand (and the Coast Guard is constantly fighting this battle) is that just because you are wearing a flotation device that has a high buoyancy does not guarantee you are going to live. You have to understand that all those flotation devices are approved by the Coast Guard for their performance in calm water.

Often times, a swimming pool is used for these tests. That is not where people fish. That is what you have to understand about buoyancy. Just because you are wearing a lot of buoyancy does not mean that you can be passive about your survival.

You have got to do something to keep yourself alive. Your ability to hold your breath and to avoid panic, your degree of physical fitness, and your ability to move in the water and keep your mouth and nose above the water are critical survival skills in cold, rough seas.

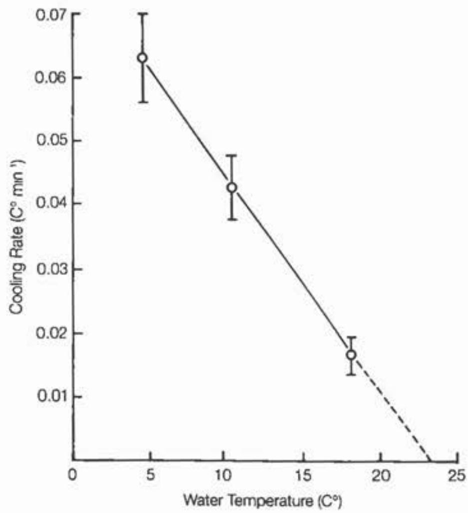

Figure 1. Relationship Between Water Temperature and Cooling Rates in Lightly Clothed Lean Males.

— Source: John Hayward

SURVIVAL SCIENCE

Now for a little bit of science. Data show the colder the water, the faster you get cold. People do experiments on these things. Figure 1 shows a linear relationship between water temperature and cooling rates, at least in lightly clothed lean males. Another interesting experiment, as discussed before, is that the fatter you are, the longer you are going to live in cold water.

We are going to talk about rough seas because this is what you have a lot of in Alaska and all over the Pacific Northwest. We are going to talk about protective clothing.

As I mentioned, Dr. John Hayward of the University of Victoria probably has done the biggest and most complete study on protective clothing back in 1976.[1] He has a lot of graduate students. He got his graduate students to participate in his experiment.

He got 20 of them and 20 different suits, and he had a 20-by-20 matrix of these suits and students. He looked at dry insulated suits, wet suits, uninsulated suits, and even a little one-person life raft that you could inflate orally.

We found that the next best thing in terms of insulation was uninsulated dry clothing, a dry suit that kept the water away from their body as a shell. This cut the cooling rate in half and doubled their survival time.

If you had a wet suit, custom fit and foam insulated, it quadrupled the subjects' survival time. It cut their cooling rate down to 0.23. If they had a dry, closed-cell, foam-insulated suit, they got seven times the protection — seven times the survival. That is what Dr. Hayward found in that big 20 by 20 matrix study.

Remember, this was all in calm water. That is not where people go fishing. This kind of situation in calm water is interesting, but we in the Coast Guard were interested in what happens if you put some of these folks in rough water.

We devised a calm-water versus rough-water experiment on the different kinds of equipment that we use in the Coast Guard and that are commonly used by the boating industry and the fishing industry. In our rough water situation, we used a Coast Guard rescue boat that was designed to take a 360-degree roll and come up fighting, but that is another story.

We went to a Coast Guard station in Washington on the mouth of the Columbia River. This is one of the world's nastiest and largest river bars and usually a reliable source of rough water. We got some volunteers from the Coast Guard. They were all air or boat crewmen, were very physically fit with about 12 percent body fat, lean and mean, experienced, good swimmers. This experiment was a bit risky. We wanted to minimize the chance of injury, and we wanted to have people that were fit enough to do this.

We outfitted them with a rectal temperature probe and the various skin temperature thermometers, and we had them all wired up — the subjects themselves called it probed up — and then we outfitted them in a variety of different suits. One was a standard military flight suit, equivalent to street clothes in insulation. Very little insulation. If you fell into the water wearing lightweight street clothes, this would be the kind of insulation you would have.

Then we put a shorty wet suit under the flight suit and measured the cooling rate. We looked at a custom-fit, two-piece wet suit. The custom-fit is the key. We are looking at the best possible insulation this garment could give our folks.

We looked at a couple of coveralls that are common in the fishing industry and the boating industry and even in the Coast Guard. One was a nylon, a loose-fitting coverall equivalent to what our helicopter crews use.

A similar suit was made out of Nomex® material; It is loose-fitting, foam-insulated suit is the key here. Both of those suits are loose-fitting, foam-insulated, which is in contrast to the wet suits that are tight-fitting foam-insulated.

We also had a float coat. This is a popular item. It is an insulated coat which, if you fell in the water, you could pull down a little beaver tail between your legs and create little wet suit panties for yourself. We wanted to see how that coat performed.

Finally, we had a couple of foam-insulated dry suits. These are similar to the one that Ken (Coffland) just showed you. They are dry suits, so they keep the water away from your body.

Next we took our subjects out to the bar and put them in the water. It was four- or five-foot swells, an occasional break, 0 to 2 knots of current, 50°F water and the drill was that they stay in the water for 90 minutes or until their rectal temperature went down to 35°C or 95°F, or they could come out anytime they wanted to. We measured their cooling rate.

Just because you are wearing a lot of buoyancy in the water does not mean that you are going to stay afloat all the time. You have got to fight to keep your head afloat and indeed these guys had to do that. They had to do a lot of swimming around, maneuvering in the water to keep their head above the water in a rough-sea situation. We also compared these same guys wearing the same suits in calm water. Here are the results.

The flight suit, which is the equivalent to street clothes, had the fastest cooling rate of all the garments. These guys in that garment cooled about 3 or 4°C per hour. It is very fast.

That was the control garment. If you fell in the water with street clothes, then you would have a very short survival time.

Let me just switch to the dry suits. They do quite well. The suit that Ken (Coffland) held up and the other suit that was a foam-insulated dry suit did the best. That is what we expected. We had no doubts that they would do quite well.

They both did well in the calm seas and actually had slower cooling rate in rough seas; that is a little bit misleading. They are only out there for 90 minutes, and by struggling to keep their face afloat and out of the seas, they were generating heat inside that dry suit and thereby slowing their cooling rate.

We looked at three loose-fitting garments: the float coat and the two coveralls. In calm water, if the subjects held still, they did quite well. In fact, these coveralls are almost as good as this wet suit. But in rough seas when they had to move around and swim, they generated a lot of flushing through that garment and doubled their cooling rates. Those are significant differences.

The wet suit was not too bad. It was tight-fitting. It did pretty well in calm water, and had an insignificant increase in cooling rate in rough water and the same with the shorty. That is because they are tight fitting suits and there is very little flushing underneath. So that was an interesting experience.

Basically, we learned that rough seas significantly degrade certain types of survival garments. Particularly the ones that are popular on some of our fishing boats. The float coats and those two loose-fitting coveralls are not going to give you the protection that the advertisers say, or you might think you get, if you go into a rough-sea situation.

To raise an issue, we come to a situation in which four USCG helicopter crewmen lost their lives. The helicopter ditched off Cape Cod in 1979. There was only one survivor.

We know that rough seas are a difficult survival situation. So suppose we have a boat capsizing or an aircraft ditching in rough seas, what should you do if you are the survivor? Let us have you take a little quiz so you get a stake in the results of this next experiment.

Suppose you are on a boat or an aircraft like this and it is ditched and let us say — let us make the situation worse this time. Let us say it is 40°F water — real cold water. Let us say it's 45 or 40°F air temperature with an 18-to-20 knot wind blowing. Okay. Now, you have got the choice. You are in the water next to this boat or aircraft. You can either stay in the water and hang onto the boat or the aircraft and then you run the risk of hypothermia if you stay in that cold water, or you can climb out of the water and get on top of the boat or the aircraft.

Now you have the cold air and waves hitting you and you have wind chill to worry about. So which is best from a survival stand point? From a hypothermia stand point? Should you stay in the water and risk hypothermia or get out and risk the wind chill problem? So, how many people would opt to get out of the water on top of the boat or aircraft? Okay. How many people would opt to stay in the water?

Some of you just made the wrong survival decision. Now you have a stake in this next experiment.

In one incident a family boat capsized, and they have opted to stay in the water. In another situation, a man opted to get out of the water onto the boat. That is basically what we did.

We got another crew to volunteer. They were all males again, and this time they were even leaner and meaner. Eleven percent body fat, pretty good state of physical fitness, 5'10"; 165 pounds was the average weight. Here are the garments again. Here is the flight suit we used as a control. There was our friend the wet suit again, a custom-fit, two-piece wet suit and the coverall, the loose-fitting coverall. Then we tested a Navy garment. This is a suit that the Navy uses for their jet pilots. It is a dry suit with some very thin, uninsulated rubber shell, basically a sandwich of Gortex® and Nomex®. Underneath it, they wear some loose-fitting thinsulate insulation.

Their problem was that in some of their ejection seat aircraft, the ejection seat goes through the canopy and sometimes tears the garments, so they wanted to know how a torn garment compares to an intact garment in terms of survival. So we tested this in an intact condition and then we put a big tear in the shoulder and did it again with a big hole in it. If you have a hole in a dry suit, it does not stay dry very long!

For weather conditions, it was either raining or overcast, so we avoided sunlight. Therefore the globe temperature, which measures radiant heat, was about the same as the rest of the air temperatures. We also had 15-to-18-knot winds in a sea state of three or four-foot breaking seas. Here is our experimental condition.

There is our capsized boat, some subjects in the water, one subject on top of the boat. For creating rough seas, we realized that in a great big 20-foot wave with a five-foot break, you do not get a lot of rough water up here on the face of the wave. You can ride up the face up this wall of green water, and it is okay.

It is not real turbulent until you get to the break. Then you are going to tumble. Well, we just picked this five-foot break here and gave our subjects that.

We used the wake of one of our rescue boats to make waves, and it did a very nice job of it. We hit them with the wake of the boat. It creates about a four- or five-foot breaking wave. Let me back up here and show you one other thing.

We also had to make wind. So we had three red devil blowers all hooked up together and funneled it through this ventilation duct and so that sits there and blows on the guy who is sitting on top of the boat, so he is sitting in front of an 18-knot wind speed and then there is this little garden hose with a sprinkler head to make sure that he stayed wet the whole time, simulating rain. So it was really a nasty little experiment.

That was very tough for these guys to do — but they were pretty good sports about it. So here we go: there are two guys in the water and the guy on the boat. Here comes our wave, and indeed, the wave is pretty nasty, basically buries the people in the water as they are trying to hold on. There is another guy over here somewhere and there are two people under here somewhere and even the guy in the boat gets blasted with this wave and, of course, this sprinkler head is a little superfluous in this kind of situation, but that is about what you see in a survival situation.

When you are out of the water in the wind, you are still getting waves breaking on you. There is a wave breaking right on top of the guy and a couple subjects under here.

We also tested a one-person life raft that we are still trying to get for our aviation crews. So they can egress a helicopter with a life raft on their back and this was a prototype life raft that had never been tested in cold water before and there is a wave breaking on that life raft.

Here is what we found. So you can see no matter what you are wearing, you are better off out of the water. So those of you who voted to get out of the water, you made the right survival decision. Actually, this audience did pretty well. Most of the time when I give this lecture, about half the audience votes incorrectly. You are always better off out of the water, no matter what you are wearing. That is what we found here. Then again, you see the distribution of garments. The flight suit provided the least insulation, of course. Since it was quite cold water, look how fast the cooling rate was — 6°C per hour. These lean guys would have had a survival time of probably one hour or less in this kind of situation.

The Navy dry suit, when it stayed intact, did quite well, as good as the suit that Ken showed you, the immersion suit. But when you put a hole in it, you find that a leaky dry suit without insulation does not do very well, and by the way, a leaky dry suit with insulation, which most of these things will do, also degrades your survival time.

The two loose-fitting coveralls were sort of intermediate between that and the wet suit. The wet suit, again, did quite well. But, you can see, if you get out of the water, even wearing a wet suit, you increase your survival time.

Here is how much water came into the suit when we put a rip in it. When the suit was intact, no water came in, basically. When we put a hole in the thing, it got about 7 kilograms of water by the time they had to come out. Even on the raft, it shows you how much water came in when the waves hit them, about 3 kilograms of water.

When you talk about survival time, it is not a real easy situation.

People always want to know "How long can I survive in whatever I am wearing in this kind of condition?" Well, it really depends on a lot of factors. What do you mean by survival time? We broke it down into three different categories. This one NATO uses — time to incapacity, with a core temperature of 34°C. I am not sure that I agree with that, but it is pretty conservative. They think at that temperature, you are not going to be able to activate your survival equipment, use your radios, use your signalling devices. So that is one estimate of survival time. A better one might be how long it takes you to become unconscious. If you are unconscious in rough seas, you are dead. That is basically it. I do not care what kind of buoyancy you have, if you are unconscious in rough seas, you are going to drown. There is going to be water in your face.

The other one, the ultimate one, is how long it takes to cool to cardiac arrest. We sort of assumed a temperature of 25°C — a core temperature for that. Basically as has been stated before, people who are fatter will have a longer survival time.□

REFERENCE

1. Haywood, John. *SAFE Symposium Proceedings*. 1976 Annual Meeting, Las Vegas, NV.

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