Image Cover Sheet

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TITLE

SURVIVAL SUIT PERFORMANCE

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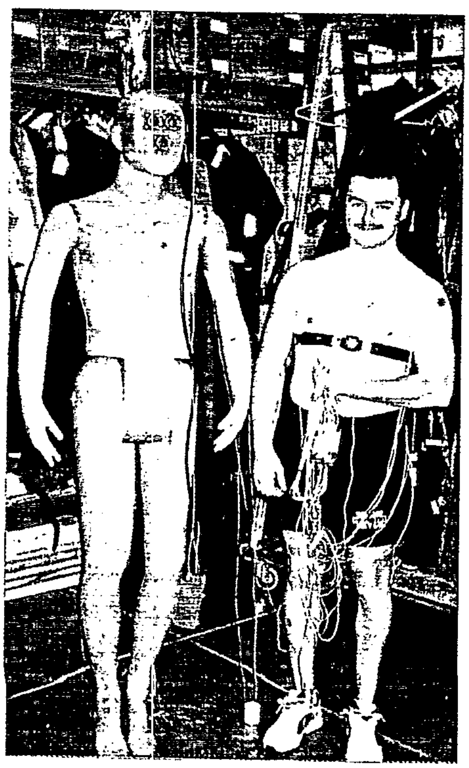
Survival suit performance

What effect does wave motion have on the insulation of a survival suit? Captain Chris Brooks, Deputy Director General of Canada's Defence and Civil Institute of Environmental Medicine, describes the pioneering work being done in this field.

DCIEM 97-P-03

Figure 1: The CORD Group Thermal Instrumented Manikin (TIM) stands by the side of Wendell Durnford who is fully instrumented with heat flow discs and data loggers prior to dressing and immersion.



Burton, Gagge and Bazett originally conceived the CLO as the Unit of Clothing Insulation. In 1940, Alan Burton, sitting in his office at the Institute of Aviation Medicine in Toronto, deemed that the business suit he was wearing and in which he was thermally comfortable at 20°C with a relative humidity of 50 per cent would be 1 CLO of insulation. From this was established a whole series of CLO values for different types of clothing.

For instance, full Arctic clothing measures approximately 3.5 CLO and an Arctic sleeping bag measures 6.0 CLO. In order to survive for six hours in the winter North Atlantic or North Sea, the insulation value of a survival suit must be about 3.5 CLO measured in air. When the suit is immersed in water the hydrostatic squeeze will reduce this to a value of about 0.75 immersed CLO. This is the reason why all immersion suits are very bulky, hot, uncomfortable and, particularly for helicopter aircrew and passengers who must use them as constant wear suits, extremely unpopular.

To measure the CLO values of various clothing ensembles, Alan Burton designed a five segmented papier mache manikin into which he installed electric heaters, and temperature sensors were secured to the surface of the skin. The manikins of today are similar. Knowing the surface area of the manikin and by simply setting the skin temperature at a certain value, it is possible to measure how much current is required to maintain the skin temperature at a steady state. Different combinations of clothing can be put on the manikin and the CLO values can be calculated from the results. The manikin has never been intended to mimic the human physiology of thermoregulation, but to provide a quick easy tool for examining the insulation values of different fabrics, different layering principles, the effects of wind on the clothing, and the effects of hydrostatic squeeze.

Up until three years ago, all evaluations of survival suits both on humans and manikins were done in relatively still water which was gently stirred to ensure a constant temperature throughout the tank. The pundits argued with this author that it was all well and good to test and approve a suit in still water, but how good would the thermal properties of the suit be in five or ten metre seas? There was no answer to this question except to investigate the problem. However, morally and ethically, it is now not possible to simply immerse a whole series of humans in cold water unless there is a very good reason for doing it. This is where the thermal manikin becomes so useful. At the time of the request, the CORD Group in Dartmouth, Nova Scotia had just finished testing their new Thermal Insulated Manikin (TIM); he had passed all his immersion trials, and his joints and electrical connections were all leak tight (Figure 1).

In 1994, we at the Defence and Civil Institute of Environmental Medicine (DCIEM) in Toronto took TIM to the wave tank at the Institute of Marine Dynamics in St John's, Newfoundland. Here he was dressed in cotton underwear and socks, a Helly Hansen woolly bear liner, a commercial Typhoon diver's dry suit, neoprene gloves and hood, and an aviation style lifejacket. From previous testing, we knew that in air this clothing combination measured 3.0 CLO and in still water 0.60 CLO. TIM was then mounted in his cradle, adjustments were made for the flotation angle, and he was lowered into the water. Over ten days, he was randomly exposed to still water and a series of wave heights from five to 60 cm. The wave conditions were deliberately chosen to represent the North Sea and North Atlantic conditions (JONSWAP waves). Finally, a repeat still water CLO value was measured, which was identical to that at the start of the experiment.

Throughout the experiment the suit remained completely dry. The results were quite significant. There was a remarkable 30 per cent reduction in the insulation value of the suit with waves (Figure 2); moreover, the reduction had not reached its limit at 60 cm wave height.

Unfortunately, it was not possible to create larger waves in the tank to find out if, and at what wave height, the curve levelled off. When these results were reviewed back at DCIEM, the pundits again argued that they had been obtained on a manikin and did not represent what would happen to a human. Now there was justification to do human testing.

The next year, Dr Ducharme and I from DCIEM, and Mr Paul Potter from CORD, took TIM and six human subjects back to the Institute of Marine Dynamics and with the able help of Antonio Simoes Re, who orchestrated the different wave heights, repeated the experiment. Each human was placed in the tank side by side with the manikin.

All were dressed in an identical manner to the previous experiment. The manikin recorded the same 30 per cent reduction in insulation and the humans recorded 15 per cent reduction. The shape of the curve was similar for both humans and manikin, and at 70cm wave height the curve had still not levelled off. The difference in the percentage loss of insulation could be explained by the different flotation angle adopted by the humans compared to the manikin.

For instance, the human with a flexible back tended to ride the waves, whereas the manikin, being rigid, ploughed through them. Thus, the manikin spent more time underwater exposed to hydrostatic squeeze (and thus reduced CLO value). A second reason was that the human had to breathe and therefore keep the oronasal cavity and front of the chest out of the water in between breaking waves; therefore, there was also less hydrostatic squeeze on the

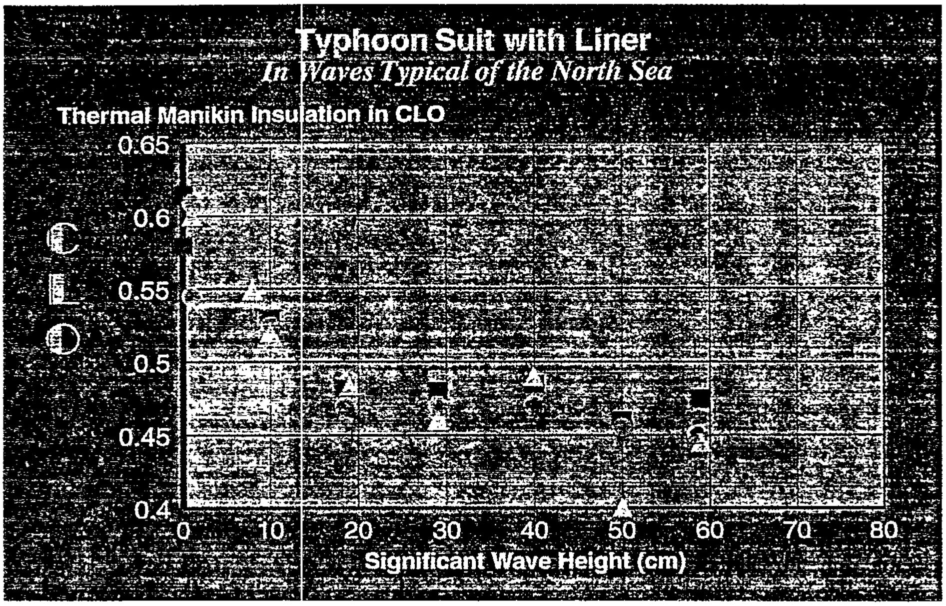


Figure 2: The graph illustrates the reduction of insulation of the Typhoon suit and lining with increased wave height.

front of the chest and abdomen in between each wave.

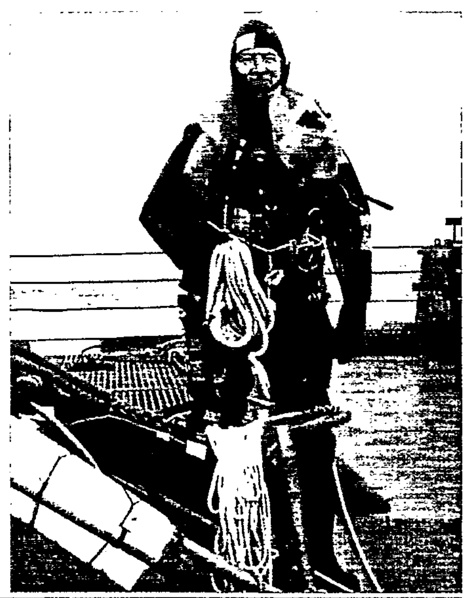
Nevertheless, we demonstrated that wave motion has a significant effect on reduction of CLO value on a survival suit. The effect can be explained by the laws of forced convection. What had not been established was whether there was any limit to the shape of the curve. In simple terms, this is the point at which the dwell time of water passing across the suit is not long enough to transfer any further heat from the suit to the water. It was realized that it was not practical to create wave heights of three to five metres in the laboratory, so our final step was to use one of the biggest wave tanks in the world, the North Atlantic. The Canadian Navy lent us the auxiliary vessel RIVERTON. She is one of their ocean going standby vessels and was perfect for the job. She was a good stable platform and could manoeuvre and anchor exactly where we wanted. She had plenty of room on her aft deck to hoist and deploy the manikin, the zodiac with safety swimmers, the human subjects, the wave rider for measuring wave height, frequency and drift; there was easy access to showers for rewarming; there was space adjacent to the aft deck for instrumenting, dressing and undressing the subjects; and most important, she had steady electrical power to run the computers for TIM (Figure 3).

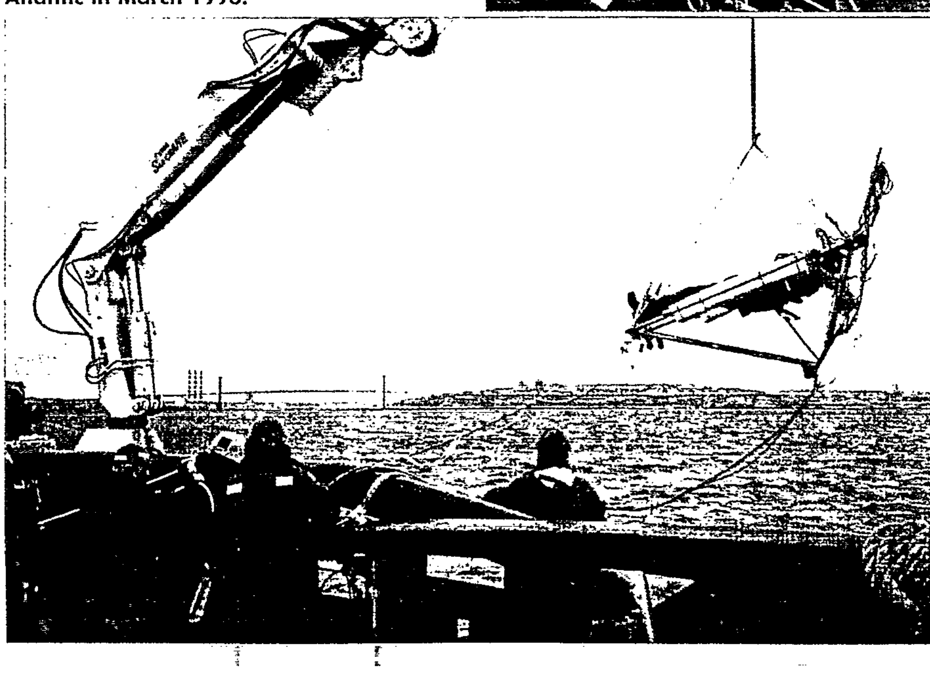
A special boom was constructed by the CORD Group to attach both the human and the manikin 20ft from the starboard side of the ship. In March 1996 the DCIEM team and TIM were deployed to sea approximately 20 miles off Halifax Harbour for five consecutive days. Each subject and the manikin were again dressed in the same clothing as in the two previous experiments. Two changes were made. The hard wiring of all physiological instrumentation to the ship was replaced by nine data loggers worn on a belt inside the suit; and the electrical signal from the ECG was transmitted directly to the ship. Each of the ten subjects spent approximately one hour in the water until the data loggers recorded a steady state, at which point the CLO value of the suit was determined (Figure 4). The sea water temperature was 1°C, typical for conditions in early spring off Nova Scotia. The sea state varied each day, but good data were recorded for wave heights of one to two metres, and some of the subjects were exposed to random, but not consistent, three to four metre waves.

At the time of writing the results are being analysed. It is intended that they will be presented at the Aerospace Medical Association Scientific Meeting in May 1997 in Chicago. Once this has occurred, it will be possible to review the EEC and IMO standards and, where necessary, make changes to the insulation values.

For the future, we will have a programme to look at the effects of wave motion on the insulation values of wet suits. ■

Figure 3 below: Conducting preliminary safety trials on board CFAV RIVERTON in Halifax Harbour for launching and recovering the thermal manikin. Figure 4 right: The author completely dressed and instrumented prior to immersion in the North Atlantic in March 1996.





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