HOW SHOULD IMMERSED DRY SUIT INSULATION BE MEASURED?

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INTRODUCTION

The insulation provided by an immersed dry suit is usually measured using a thermal manikin that computes insulation values for the clothing from its steady state power consumption and from the temperature difference between the manikin surface and the surrounding water. A component of this insulation is provided by the boundary layer of water immediately surrounding the clothed manikin. Usually measurements are made in water which is stirred in a variety of ways to reduce the effect of this boundary layer. As far as the authors are aware there is no standard method of achieving this and no data on the effects of water movement on immersed clothing insulation. This paper describes a preliminary study to investigate the effects on immersed insulation of water movement caused by bubbling and by realistic sea waves.

METHOD

A 13 segment thermally instrumented manikin (TIM, Cord Group Ltd, Dartmouth, Nova Scotia) was used for this *study*. Three different clothing assemblies were used: Assembly A consisted of Helly Hansen One Piece Pile Underwear (100% polyester, F456), Helly Hansen pile socks (100% polyester, F454), Typhoon Ranger Immersion Suit (1 10716) *(All* Size Medium), Fitzwright Neoprene gloves and Hood, and a Mustang Inflatable Aviation Lifevest. A second series of measurements were made without the pile underwear (Assembly B).

In order to position the manikin in the water in an attitude representative of that adopted by a floating survivor wearing a lifejacket (immersed to the neck facing on coming waves at approximately 30° with the arms and hands just below the water surface), the Manikin was secured to a buoyant frame which was allowed to float loosely tethered in a large wave tank (National Research Council Institute for Marine Dynamics, St John's Newfoundland, Canada). Once immersed in the water, excess air from inside the dry suit was allowed to vent naturally using a tube inserted under the dry suit neck seal. This method was used to simulate the venting that most wearers induce to provide a more upright flotation angle in the water and to ensure that the same conditions were recreated each time the manikin was immersed.

Measurements were made in still water over a 12 hour period, in water made turbulent by bubbling air underneath the TIM also over a 12 hour period, and in waves with significant wave heights which ranged from 0.01m to 0.6m. The spectra of the waves used were those recorded by the Joint Offshore North Sea Wave Project (JONSWAP) and periods were chosen of maximum energy for the various significant wave heights as set out by Bhattacharyya'.

The insulation provided by Assembly C (long cotton underwear, RAF Inner Knitted Coverall Mkl, Musto Ocean Dry Suit, Aircrew Helmet, Gloves, Socks and Boots, Full coverage Anti-G trousers and Chest Counter-pressure Garment) was measured in still water and in water made turbulent by bubbling air underneath the TIM at 50, 120, and 240 $l.min^{-1}$.

RESULTS

The immersed insulation of Assembly A was unaffected by 12 hours of immersion in still water (0.59clo) or in water made turbulent by bubbling (0.55clo). Increasing wave heights reduced the insulation to 70 - 75% of the still water value for significant wave heights of 0.6m (Figure 1). This was primarily due to the effect of waves on the insulation covering the head which reduced to 20% of the still water value. Waves also had significant effects on the insulation covering the hands, chest, back and legs. The abdomen, buttocks, arms and feet were least affected.

The insulation provided by Assembly B (0.09clo) showed a similar reduction in waves (Figure 2). A 0.3m significant wave height resulted in a 50% reduction in insulation largely due to reductions in the insulation covering the head, chest, arms, legs and hands. The buttocks, back and abdomen were also affected.

Assembly C was tested in still water and in water made turbulent by bubbling air at different flow rates. Immersed insulation decreased to *75%* of the still water value (0.70clo) as air flow increased to 240 $l.min^{-1}$ (Figure 3). The head, chest, back, hands and legs showed the biggest decrements in insulation.

None of the immersion suits used in these experiments leaked.

DISCUSSION

The insulation provided by dry suits can be reduced by leakage into the suit, by the effect of hydrostatic squeeze reducing the air trapped in the insulating layers, by the effect of waves compressing the insulation, and by movement of the water over the surface of the suit effectively increasing the heat transfer coefficient at the surface. The suits in these tests did not leak, and prolonged immersion in still and turbulent water did not affect the TIM measures of insulation. It is unlikely that the compression effect of the waves was responsible for the decrement in insulation seen with Assembly **A** since a similar decrement was seen with Assembly B, which had no compressible insulating layer. Therefore, it is highly probable that some of the decrement in insulation seen in waves is due to the effect of water movement over the manikin surface. This is borne out by the observation that there **was** greater decrement in insulation in those body segments exposed to greater water movement, namely, the head, hands, chest and back. In addition, it is likely that some of the effect on the head, which in still water is not immersed, was due to splashing and evaporation. The findings of this preliminary investigation highlight the need to specify carefully the conditions under which dry suits are tested. Furthermore, estimates of "calm water survival time", used by many authorities to guide the selection of the amount of insulation to be worn, should be treated with caution.

CONCLUSIONS

The immersed insulation of dry suits is significantly affected by movement of the water in which the measurements are made. This effect must be taken into consideration when measurements from different laboratories are compared and when estimates of survival time are made. Further work to investigate this effect on human subjects and for other types of immersion clothing is necessary.

Figure 1 - Effect of Waves
Assembly A

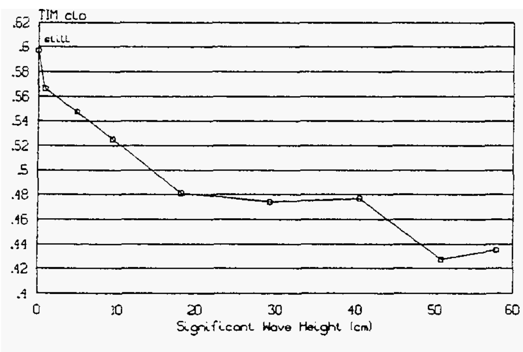


Figure 2 - Effect of Waves
Assembly B

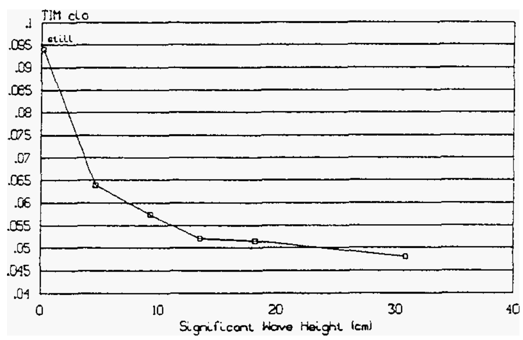
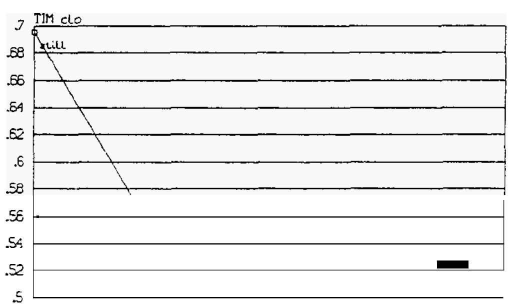


Figure 3 - Effect of Turbulent Water
Assembly C



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1. Bhattacharyya, R 1978, Dynamics of Marine Vehicles (John Wiley & Sons, New York), p104