The thermal insulation values of clothing were measured on a thermal mannequin. The tests were carried out in two stages. In the first stage the effect of wear and laundering on three different cold protective clothing types was measured:

a) cotton/nylon outer fabric and quilting
b) cotton/nylon outer fabric and pile, quilted sleeves
c) nylon outer fabric with a polyurethane coating on the inside, pile lining

Thermal insulation was measured when the suits were new, after three launderings, and after eight launderings. The suits had been worn in a cold store.

In the second stage the tests were carried out for four different cold protective clothing types:

d) nylon outer fabric with a polyurethane coating on the inside and a lining quilted wadding with cotton
e) outer fabric of 100% polyester, pile lining
f) same as type c
g) cotton/nylon outer fabric, special quilted wadding polyester lining

Thermal insulation was measured when the suits were new and after three, five, ten and twenty launderings. After launderings dimensional changes and the changes in fabric thickness were measured.

After wearing and three launderings, there were no significant differences in insulation values when compared to new suits. After wearing and eight launderings, insulation values were 10-15% lower.

When the effects of laundering were tested without wear, the changes in thermal insulation were slight, being 0-2% after three launderings for both pile and special quilting lined suits. The decrease in thermal insulation after suits with regular quilted linings had undergone three launderings was 9%.

The decrease in thermal insulation for all of the suits except the one with the special quilted lining (type g) was near 10% after ten launderings and 10-15% after 20 launderings. The decrease in thermal insulation for the suit with special quilted lining was only 3.5% after 20 launderings.

The dimensional changes of all the suits were under 5%. The suits did not differ in this respect. The changes in material thickness were notably greater, being 6-20%.

The compression of fabrics while being worn and laundered decreases the thermal insulation of cold protective suits somewhat faster than launderings alone. The decrease was greater for normal quilted linings than for pile linings. The thermal insulation of the suit with the special quilted lining decreased under 5% after 20 launderings, whereas the thermal insulation of the other suits was 10-11% lower.

Session VII
Physiological Basis for Performance Standards of Immersion Protective Clothing
Abstracts 35-42

35 **The physiological basis for the development of immersion protective clothing**

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The purpose of immersion protection clothing is to minimise the occurrence of cold shock, prevent hypothermia and non freezing cold injury, and in conjunction with personal buoyancy aids prevent drowning from wind and wave splash as well as from facial immersion. Several analyses were performed on predicting model data which related survival time to the environmental, anthropometric and clothing characteristics.

If survival time is determined solely by body temperature (e.g. core<34°C), the analyses show that the clothing, water temperature and body fat thickness are the three most important factors determining the likely survival time in water. Various multiple interactions involving clothing, temperature, fat and weight were involved but were of less importance; the three single variables accounting for over 80% of the variance in the predicted survival time.

If we are to continue to use mathematical models of thermal regulation as a technical basis for the performance standards for immersion protection clothing, it is essential that the physiological basis for the model is rigorously researched and validated. The predictive models are only as good as the information on which they are based and therefore we require a thorough knowledge of the effects of clothing, body composition, waves, water temperature and heat production on any change in body temperature and susceptibility to cold injury.

This paper attempts to highlight, by example, areas of continued controversy and experimental activity within cold physiology which are relevant to immersion protection. Three areas are examined followed by a summary section suggesting the physiological design criteria one could adopt for the optimum performance of immersion suit protection. The three areas are: 1) Factors affecting heat production, which include habituation and regional sensitivity, fatigue and physical fitness; 2) Insulation and body fat, dealing with effects of flushing and waves on the clothing insulation and the measurement of body fat insulation by magnetic resonance imaging, and 3) The measurement and impact of heat loss, with particular attention to the results found during long slow cooling in water.

36 **Temperature parameters for manned survival suit evaluation**

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In 1984, delegates from seafaring nations on the Maritime Safety Committee of the International Maritime Organization (IMO) completed writing the new lifesaving requirements for the Safety of Life at Sea (SOLAS) 1974 Convention. These new regulations introduce for the first time requirements for "immersion suits", "exposure suits" or "survival suits" which are just some of the names of the same protective suits. With regards to the thermal qualities of the suits the regulations require that the suit can protect the wearer from a core temperature drop of more than 2°C, and that skin temperatures measured at hand, foot and lumbar region do not drop below 10°C for a test period of 2 or 6 hours depending on the type of suit.

It is clear from the regulations that the tests are to be performed using human subjects.

Test results of suits are not only of interest to the approving authorities but naturally also to the manufacturers during a development process. It seems as if the parameters specified have become the essential parameters for the manufacturers' development work. Rectal temperature for the test subjects are in particular used as an "index" for the suit's thermal qualities. Unfortunately the rectal temperature does not always reflect the real properties of the suit, at least not when the test is performed for only a limited time (2 or 6 hours). For instance, test results can show that a 2mm neoprene suit could be equally good or even better than a 5mm suit when based on rectal temperatures over a 2 hour test period. A Ventile fabric suit has shown the same confusing results when tested with or without a thinsulate inner lining as the rectal temperatures indicated no difference.

The explanation for these unexpected results, is the fact that in the colder suits shivering will compensate for the increased heat loss, and will manage to keep the rectal temperature at a reasonably high level for the test period. This is clearly demonstrated when oxygen consumption is included as a parameter. Including oxygen consumption as a part of the test procedure increases the complexity of the test with cost implications as well. Results have shown that the skin temperature at the lower back region can be a better index of the thermal quality of the suits than rectal temperature.