WATER VAPOUR PERMEABLE BUOYANT INSULATION

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INTRODUCTION

Current common constant-wear garments worn in aviation and marine environments to provide buoyancy and hypothermia protection in case of accidental cold water immersion, lead to thermal stress and reduced comfort when worn in warm environments or when users engage in moderate physical activities.[1]

This study's purpose was to design a water vapour permeable, buoyant and thermally insulating material for use in the production of these garments. This material must have sufficient water vapour permeability to allow the disposal of sweat at a reasonable rate, yet must retain its buoyancy and thermal insulation upon immersion.

METHOD

This new material construction allows sweat to be rapidly absorbed from a user's skin/shirt, wicked through a layer of insulating, buoyant closed-cell **PVC** foam, and then spread to a thin outer fabric layer for evaporation. This material allows some evaporation directly from the skin, since this aids in keeping the user cool and dry during periods of moderate activity with low but appreciable amounts of sweat.

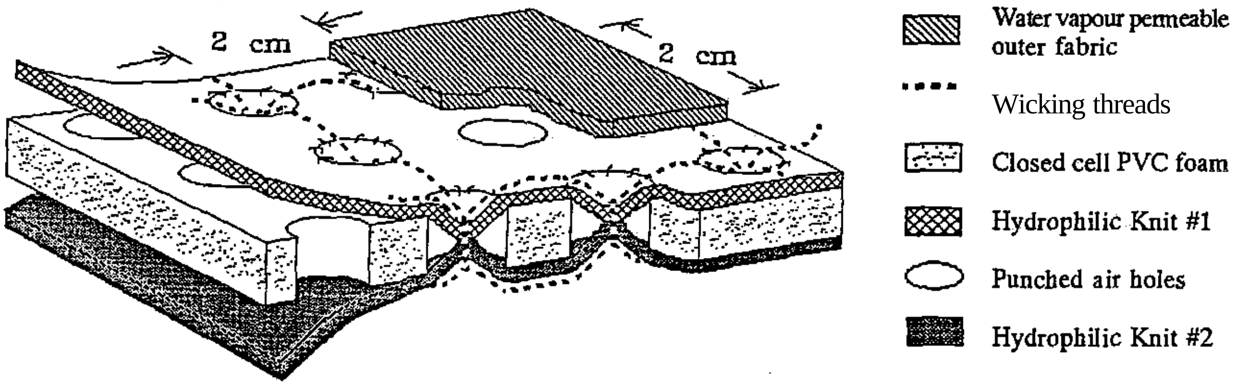

Fig 1 - Cut-away view of material

The individual parameters of this material which required optimization were as follows:

(1) The ratio of the area of punched holes to the area of solid foam.
(2) The wicking and drying rates of the hydrophilic fabrics.
(3) The wicking rate of threads sewn through the closed cell foam.
(4) The water vapour permeability of the outer waterproof "breathable" fabric.

A combination of theory[2] and sweating hot plate experiments'" were conducted **on** samples with a variety of ratios of punched hole area-to-solid foam area, to quantify the increased heat loss due to the addition of evaporative pathways. Flexibility, tear strength and buoyancy were important mechanical properties which also required consideration.

The vertical and horizontal wicking rates of water in various hydrophilic knit fabrics and threads were measured. A hydrophilic gradient was desired between the inner and outer knit fabrics to ensure that liquid water transport followed a uni-directional pathway away from the skin or shirt The drying rates and fabric weights (dry/saturated) were measured for these knits. Minimum fabric weights and maximum drying rates were desired.

The water vapour permeabilities of different nylon fabrics with "breathable" microporous coatings or membranes were measured to find a suitable outer material which allows rapid evaporation.[4]

Human testing consisted of soaking the subject's underclothing with 1 kg of water, then allowing it to dry while resting (t ≥ 1 hr; T = 22 ± 1°C; R.H. = 60 ± 1%), in non-breathable and breathable versions of a Mustang MS2175 worksuit. The mass of water remaining in the undergarments, transferred into the worksuit and lost by evaporation was measured at 15 min time intervals.

RESULTS

The optimum ratio of punched hole area to solid foam area was 25% - 75%. The thickness of the foam had to be increased by 25% in order to provide the equivalent buoyancy as foam with no holes (F_b = 0.91 g/cm²). Sweating hot plate experiments showed the heat losses through the dry material increased ≈10%, while during sweating they increased ≈35%, over a non-breathable material (T = 4.7 ± 1°C; R.H. = 61 ± 1%). (See Fig 2)

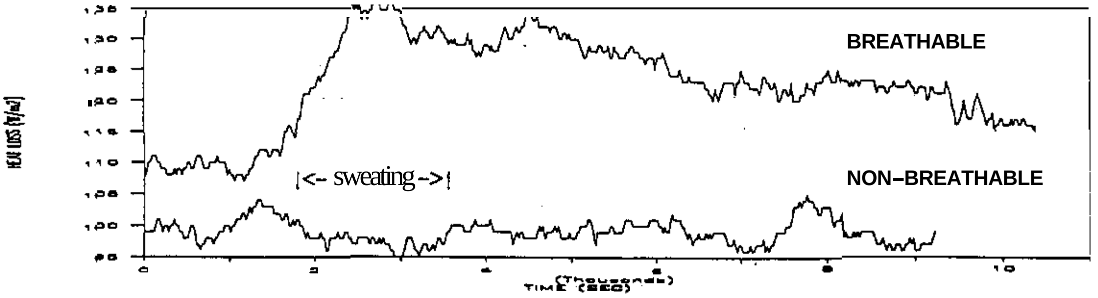

Fig 2 - Heat loss vs time on sweating hot plate (12mm thick breathable foam)

The immersed thermal resistance was measured by placing the material between a hot plate and a cold water bath and slowly circulating water between the material and plate. An immersed thermal resistance of 0.073 ± 0.004 m²K/W (0.47 ± 0.03 clo) and a dry resistance of 0.273 ± 0.010 m²K/W (1.76 ± 0.06 clo) were measured. The average immersed thermal resistance for an entire suit has yet to be determined.

Light-weight knits treated with hydrophilic finishes provide the highest rates of wicking and evaporation and do not hinder the flexibility of the material. The punching of holes in the foam doubles its flexibility.

Threads consisting of three cotton-covered polyester yams, twisted helically were found to wick water the highest and fastest. A 4cm x 4cm thread grid was chosen, although larger amounts of these "liquid pathways" would provide greater liquid transport from the skin, the material's tear strength and asthetic appeal decreased with the denser thread grids. Wicking was enhanced when the thread grid was sewn through the punched holes since this provides direct contact between the two knit layers within the punched hole. (See Fig 1)

The lowest water vapour resistance of all waterproof "breathable" fabrics currently available was 54.0 ± 1.2 s/m (fabric in contact with saturated surface). This is equivalent to the resistance of a 1.4 mm air layer.

Drying experiments, conducted on humans wearing a breathable worksuit, show that 41.6 ± 0.6% of the water initially introduced to the underclothing was removed after 15 min of drying. In a non-breathable worksuit, only 6.6 ± 0.9% of the initial water in the undergarments was removed after 15 min. (See Fig 3)

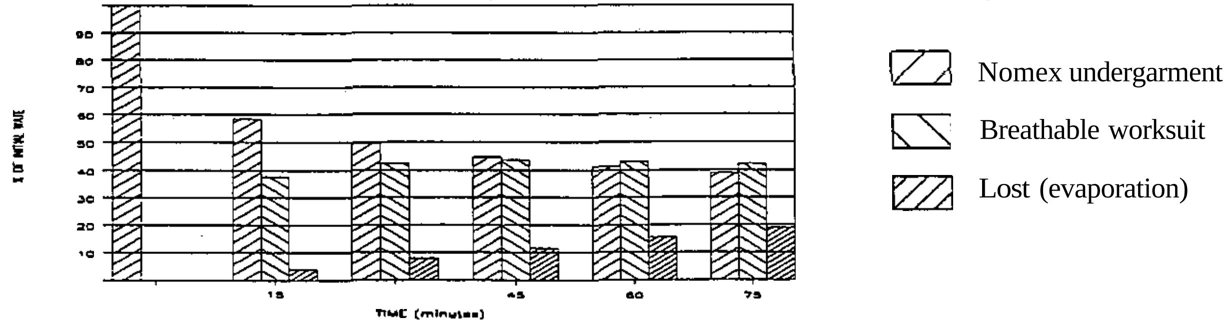

Fig 3 - Water distribution vs time for humans in breathable worksuit

CONCLUSIONS

Garments designed with this material provide increased comfort due to better drying times than vapour impermeable garments. This material provides sufficient buoyancy and significant thermal insulation during cold water immersion while providing protection from rain and other sources of water.

REFERENCES

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