'Smart' textiles is not a phrase commonly applied to natural fibres. The following paper from the UK's Leeds University School of Textile Industries makes the point that inherent reactions, plus enhancement technology, means that some of them are 'smarter' than we think.

Smart textiles





Reactive textiles for optimum water vapour transmission performance

The use of reactive textiles in foul weather clothing to maintain weather proof performance and high comfort levels is not new. Natural textile fibres have been applied to this problem since the protective factor in clothing was first recognised and their use has become more effective as their desirable properties have been identified and measured and fabrics engineered specifically for the purpose.

Table 1. illustrates the absorption properties of common natural fibres and the effect of wetting on their strength. Wetting also causes the fibres to swell and this property in cotton has been exploited by producing closely woven fabrics with long staple fibres in low twist yarns. These are extremely comfortable in wear and become water resistant on wetting due to the swelling of the cotton.

Another form of natural reactive fibre is found in the keratin of animal hairs, which have been modified genetically over time to give very specific protection to their host. Wool allows sheep to cope with rain and endure temperatures ranging from 40°C to -20°C. Wool is a most remarkable fibre since its surface cuticle is hydrophobic yet the whole fibre absorbs more water vapour than cotton. Before the advent of manmade fibres its unique water shedding properties were used widely in performance and survival under-garments. More recently wool's basic contribution to comfort has been recognised by the development of Sportwool where the yarns are blended with manmade fibres to maximise the positive properties of both.

Coating factors

Recently it has been shown that reactive polymers can give improved comfort performance to foul weather clothing systems. Traditional foul weather shell clothing has provided high levels of durability and protection by using neoprene rubber or PVC coatings on natural fabrics. These have very high resistance to water penetration, but they do not allow moisture vapour to dissipate - which in turn leads to overheating, discomfort and condensation problems. More recently, expanded microporous polytetraflouroethylene (PTFE) and polyurethane laminates and coatings have been employed. They have very high resistance to liquid water but allow the passage of water vapour. The rate of transmission through the porous systems obeys Fick's law of diffusion i.e. the rate is proportional to the water vapour concentration difference across the film, the thickness of the film and its temperature.

Another approach to the problem is the use of hydrophilic polyurethane copolymers as a coating or laminate. These are solid films and do not contain pores. They transmit water vapour by a hydrogen bonding transfer system which increases their transport rates as the water content increases. The diffusion equation still applies but the rate 'constant' is replaced by a term which describes the accelerating effect of the water content on the amount of water vapour transmitted.

Standard test method deficiencies

The standard methods of test for water vapour transmission have been found to seriously underestimate the efficiency of hydrophilic polyurethane films in clothing systems since the test methods operate under isothermal conditions and at mean levels of relative humidity well below 100%. In real clothing systems, when working in foul weather, such films



Table 1. The effect of water and water vapour on common natural fibres

	Cotton	Flax	Wool	Silk
% Regain at 65% RH	8	9	14	10
% Regain at 100% RH	15	18	35	36
% Liquid Water Absorption	45	70	40	50
Effect of Wetting on Tensile Strength	+20%	+6%	-25%	-20%

(RH = Relative Humidity)

Table 2. Measured parameters on Microporous, Hydrophilic and Bicomponent laminated natural fabrics.

	Microporous	Hydrophilic-PU	Bicomponent-PTFE
Moisture Vapour Transmission (gm/m2/24hr) Dish 33°C - ambient 5°C 65% RH	2400	2510	2530
As above but under rainfall	0	1050	1800
Condensation accumulation under rain conditions (gm/m2/hr)	127	95	63
Temperature difference across laminated layer without rain (°C)	4.1	4.0	4.1
Temperature difference across laminated layer with rain (°C)	1.25	1.75	2.5
Temperature difference across laminated layer during rainfall: measured in controlled wearer trials (°C)	0.2	1.9	2.2

operate under a temperature gradient at relative humidities of about 100%. It has been found that the relative humidity and not the concentration of water vapour is the critical factor in determining the transmission coefficient for hydrophilic polyurethane.This is because the relative humidity is a direct measure of the propensity of water vapour to form hydrogen bonds which it does so preferentially with the hydrophilic parts of the polyurethane film.

Laboratory tests have been devised to determine reproducible water vapour transmission rates as single layers or simulated multilayered clothing systems under realistic temperature gradients and also under rain. It was found that neither the water vapour resistance values (Ret) nor the percentage transmission readings of individual clothing layers can be used to accurately predict the overall transmission of a clothing system under realistic temperature gradients. The Ret values are not additive and the fractional multiplier system based on BS 7209 which works well on isothermal multiple layers usually underestimates the overall transmission rate. Transmission tests with and without rain were carried out on multiple layer clothing systems mounted on tilted heated dishes.

Microporous, hydrophilic polyurethane and bicomponent PTFE laminates on the same face fabric were assessed.

All the transmission rates fell under rain conditions. Condensation readily occurs at low outside temperatures or under rain and this in turn lowers the temperature of the outer layer which reduces the transmission rate and hence causes more condensation. The microporous film used in this study had high transmission rates when dry but fell to near zero under rain. Other types of microporous film may not exhibit this behaviour. Hydrophilic polyurethane films have slightly lower transmission rates when dry but only reduce moderately with condensation while bicomponent films of microporous polymer protected by a hydrophilic layer have the highest transmission rates whether dry or with condensation. The relative performance of the hydrophilic and bicomponent films seem to be related to the temperature difference across the fabrics which is determined by their overall conductivities.

Trial by wearer

These laboratory results correlated with controlled wearer trials monitored by humidity sensors. The tests were performed with the same exercise regimes wearing identical natural textile jackets made from the same three laminate types tested in the laboratory and worn over the same layered clothing system. Comparisons were made in both wet and dry conditions.Temperature differences across the laminates during rain were similar to those measured in the laboratory dish tests (see Table 2) but that for the microporous was much lower. It was found that a 100% relative humidity microclimate was attained by the microporous jacket after 20 minutes, by the hydrophilic in 48 minutes and by the bicomponent jacket in 60 minutes.

The same jackets and clothing systems worn in an all day mountain field trial and also monitored by humidity sensors tell a different story. During the morning, rain caused the jackets to succumb to condensation in the expected order but, although the rain ceased, the microporous and bicomponent jackets maintained 100% relative humidity for the rest of the trial, since developed condensation remained in the garments. The hydrophilic laminate condensed before the bicomponent but later recovered by absorbing the condensation when the rain ceased and its microclimate fell to 90% relative humidity.

The ability of hydrophilic polyurethane to transmit water vapour and absorb liquid water has been demonstrated to have great significance in the development of outer fabrics which transmit water vapour efficiently under foul weather conditions. Other hydrophilic polymer systems may provide better performance and the neglected study of the behaviour of the wetted fabric could also lead to more improvements in durability and performance.

All the above laboratory and field trials were conducted with a polyester fleece midlayer which has minimal regain. It has been shown that in extreme conditions and/or high work rates condensation takes place even in the highest water vapour transmitting clothing systems. Hydrophilic polymers are effective in removing some condensation but the mid layer could also absorb large quantities by utilising the massive regain of natural fibres such as wool and therefore act as a water vapour buffer.

D. B. Brook, J. C. Gretton, and S. C. Harlock.
(J.C. Gretton is now a Fabric Technologist at Perseverance Mills).