Charlie, James and Gloria hold the clues to fitness for purpose

Performance reliability, fitness for purpose, excellence in design and value for money are the four criteria in the marketing world for high enduramce textile products when it comes to the presentation of competing product claims for commercial success. Research and testing are essential for all advanced products and simulation of 'real world' conditions the goal of all good manufacturers and designers.

Unfortunately the human body in all its forms is an extremely varied device which, while conforming to a broad type across whole populations of similar backgrounds, resolutely refuses to be categorised or perform to 'norms' on an individual or small group basis.

How then are the products setting out to gain niche market supremacy in outdoor apparel, to be evaluated in a scientific way without undue reliance on whole-life trialling with real test subjects? In three different countries, two independent national institutes and one major university school of textiles set out their intellectual prowess in providing results that are relevant and rewarding. The Hohenstein Institute in Germany, the Swiss Federal Laboratories for Materials and Research - EMPA - and the School of Textile Industries at the University of Leeds, England, have been centres of fundamental research into all aspects of performance textiles for outdoor activities for as long as the definition has existed. All of them use manikins - known respectively as Charlie at Hohenstein, James at EMPA and Gloria in Leeds - and rain rooms for their basic research and all are actively engaged in applied research commissioned by a wide range of commercial brand owners in the outdoor field. The whole focus of technology in providing both waterproof, windproof and breathable garments has produced a universal need for meaningful tests of garment performance which can be readily understood.

Fabrics and finishes have developed to a very high level of acceptability over the past 20-30 years and all components individually can be described as fully fit for their purpose. However the garment manufacture will always be subject to the pressures of applied skill to the components. Stitching, seam taping, water transfer around or through zippers and pocket flaps are all areas where individual attributes cease and become part of the whole.



'Charlie' Hohenstein.

Predictive consequences

Suitability for market by reference to the human body is the broad approach to manikin testing adopted at Hohenstein Institute under the guidance and leadership of Professor Karl Heinz Umbach. Charlie, the resident manikin at Hohenstein, is designed to produce computer controlled models of the thermoregulation of the human body. Using Charlie, the physiological properties of clothing are measured and values and performance levels established for, amongst others, thermal insulation and air ventilation in clothing.

From these tests temperature ranges matched to particular types of clothing can be defined, wearer comfort can be closely estimated and the predicted physiological strains on the wearer can be forecast with some degree of accuracy. These researches, together with the long experience of the Hohensteiner staff, are the bases on which recommendations for the construction and use of performance wear and protective clothing can be provided to enable manufacturers to provide garments which reduce stress, improve the wearer's performance, and prevent damage to health.

At Hohenstein a 5-level system for analysis of the physiological properties of performance apparel is in use. At Level 1 textiles are tested as fabric layers. A thermoregulated model of human skin (Skin Model) is applied which simulates the heat and moisture exchange from the human skin under various activity levels. Similarly, with specific apparatus, the sensory properties of textiles are measured which stem from their mechanical contact with the skin and predetermined 'hand'.

However, the wear properties of a clothing ensemble are not only determined by the different fabrics included and their interaction, but also by the air volumes trapped inside the clothing due to their pattern, or adhering to its outer surface.

Therefore at analysis Level 2 a life-sized, an articulated manikin is employed to represent the thermoregulatory effect of a human body. The thermal insulation of clothing ensembles can be measured and, by making use of the Skin Model tests, their moisture transport properties can be determined and expressed by specific physiological values. These values can be applied as input in predictive calculations which yield the ensemble's utilitarian temperature range where, within a given physical activity, the wearer will not suffer from either hypo- or hyperthermia. With a given scenario of climate and activity conditions, the wearer's degree of physiological comfort can be predicted.

Because these predictive calculations are based on the results of fundamental wearer trials with human subjects, their level of accuracy is actually so high that the wearer trials of Levels 3-5 of the system are in most cases not required by the manufacturer or user of performance apparel.

Using hundreds of results from real life tests compared with manikin tests over a period of years, Hohenstein has developed a predictive formula to express a textile's thermo-physiological wear measured under typical practical use conditions.

These results ranging from 1 - 'very good comfort wear' to 6 - 'completely unsatisfactory', compare very favourably with actual results as perceived by the wearers

Air - heat - and more of Charlie

The wear properties of layered protective apparel, are not only determined by the different fabrics included and their interaction, but also by the air surface. Therefore, at Level 2, the thermal insulation and moisture transport properties of the whole clothing ensemble (including underwear and outerwear fabrics as well as the air layers within the microclimate between the fabrics and adhering to the clothes' outer surface) are determined by the use of Charlie. The manikin's body is made from copper and electrically heated to human skin temperature by wires soldered to its inner side. Sixteen separately controlled body sections allow the simulation of characteristic temperature gradients. The integral thermal resistance of a clothing ensemble can be directly measured - via heat flux from the manikin's body to the surrounding air of a climatic chamber - as well as its local insulating effect at different body sections. It is essential that the manikin can simulate all the body positions (i.e. standing, walking or lying) occurring in normal usage and therefore the arms and legs are articulated and driven by an electric motor. Thus the influence of convection and ventilation caused by body movements of the wearer on the garment's microclimate can also be evaluated.

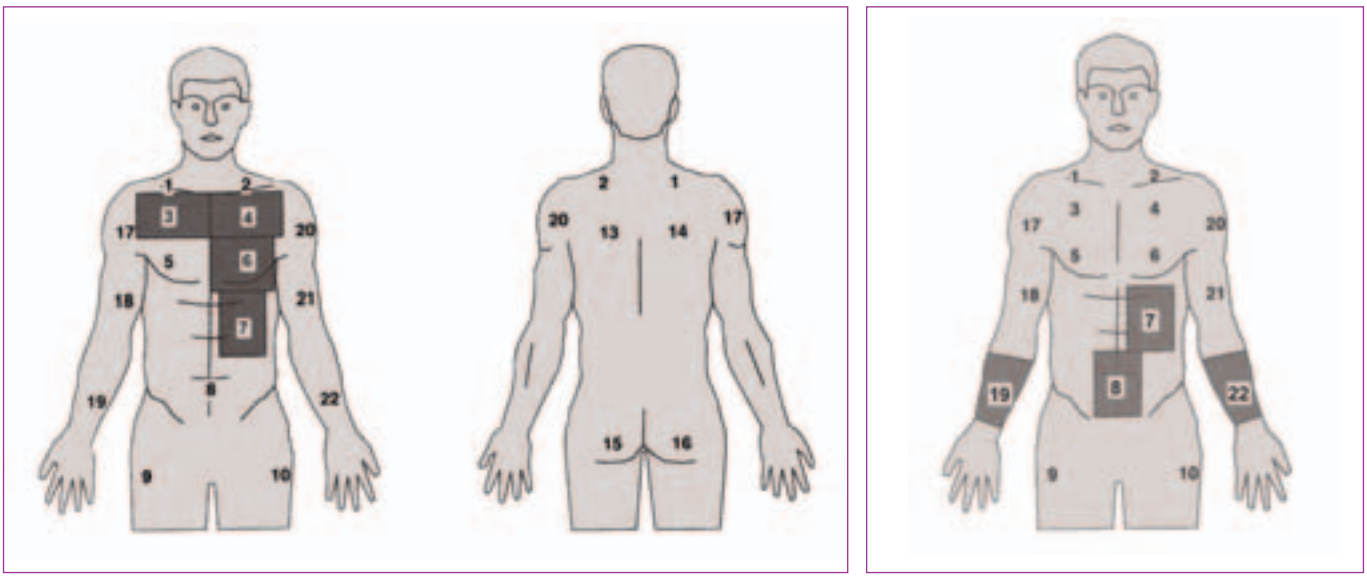
An important factor in the testing of low-temperature performance clothing is the measurement of the influence of the external wind speed - the 'chill factor'. Hohenstein researchers measure this by placing a wind machine in front of the manikin and recording the results.

Evaluation of all these fundamental test results has shown a correlation between physiological data measured on a person's body and the perceived sensation of comfort. In contrast to a widespread belief, Hohenstein says that wear comfort is not an individually different and undefined varying sensation, but is the direct result of physiological values on the body. From this laboratory/wearer test interaction was developed the predictive calculations described. Hohenstein suggests that the high accuracy of the predictive model has rendered redundant a great many existing clothing trials.

In some instances, however, it might be advisable to verify the test results of Levels 1 and 2. In this case the controlled wearer trials (Level 3) are performed to check the results of the



Rain tower test with James.



(Far left): 'James' with the distribution of the 22 sensors and (above), the hydrophilic lining wicks moisture inside the jacket (sensors 7, 8, 19 and 22 wet).

predictive calculations for one particular wear situation. Where they agree it can be deduced that the model's predictions with regard to other wear situations are also valid. Furthermore the wearer tests of Levels 4 and 5, either with a limited or large number of subjects, can actually be restricted to a small number of items optimised systematically in their comfort characteristics through Levels 1-3 of the system. Levels 4 and 5 tests are conducted in the field and indicate whether parameters not included in the predictive calculations have some bearing on the physiological comfort perceived by the wearer.

Swiss variations on the theme

At EMPA, 'James' provides a whole garment test facility in a Rain Room environment. Using moisture sensors measuring where and when water percolation occurs James can operate under three different types of laboratory rain - cloud burst, persistent rain and drizzle - at infinitely variable time intervals. James himself is an acronym of Jacket Assessment Measuring by Exposure to a Shower and with 22 sensors James accurately records all locations of water ingress. James when connected is exposed to the chosen rainfall type for a pre-determined time. A cotton shirt is put on the manikin underneath the jacket. Water absorbed by the shirt changes the electrical conductivity and is registered as water penetration by the sensors. After completion of the test (which usually lasts for one hour), the wet surface of the shirt is assessed visually and is rated from 1-5, depending on the wetted area. Three jackets per type are measured and the mean value of the wet area is taken as the result for not only the particular jacket, but also for the design as a whole.

Water repellency can be decisive for the comfort of the wearer: if rain can penetrate the outer shell, it will act as a barrier for sweat (water vapour) produced by the body. If the rain persists for a longer time, the microclimate between the wearer and the jacket will cool down due to the cold rain. Sweat will condense and be perceived as water ingress by the wearer even if no water could actually penetrate.

On the figure (above right), water has gathered at the end of the sleeves and has penetrated inside the jacket through the cuffs. This jacket had a hydrophilic lining which wicked water. In order to avoid this problem, a hydrophobic band of several centimetres width is sewn at the lower edge of the jacket and at the ends of the sleeves to prevent the wicking effect. Touch 'n close closures can also be an area of potential weakness in waterproofing as water can under some circumstances gather there and be transported to the inside through the seams. At EMPA most jackets are tested in a new state, usually after three washes. After extensive use and several wash cycles, the test results can be radically altered. The materials are mechanically stressed and one of the biggest problems is that hydrophobic effect of the outer shell decreases during washes and even during exposure to rain. The clothing can be re-impregnated, but the water repellent properties are often not the same as for a new jacket.

Several coated and breathable performance jackets were tested at EMPA in 'cloudburst rain' after one year of use. The results showed that no used jacket was 'watertight'. All the jackets were measured three times and the standard deviations were usually small. On the other hand EMPA found the differences between the jackets of the same type were sometimes very large. One used jacket actually stayed dry for longer than the new jacket, thus demonstrating quality variations in the basic fabric coating or in the making of the jackets.

Using James, EMPA has enhanced both the Bundesmann rain shower test and the standard hydrostatic test by introducing performance evaluations under different rainfall types. Significantly, the results show that the watertight ability of tested garments drops significantly with age. In EMPA's opinion the age of clothing and its effect on performance is not given enough emphasis in standardised tests on waterproofing

and thermal protection. Tests should be developed, according to Markus Ruedi at EMPA, which provide meaningful consumer data and descriptions relating to wear and the likely fitness for purpose after varying levels of garment usage.

Accurate simulation in Leeds

The School of Textile Industries, at Leeds University in the UK, has been providing rain room testing of garments for commercial clients and basic research for several years. The Leeds rain room has 'Gloria' as test 'candidate' and rainfall simulations can be adjusted to suit any climatic experience. Interestingly the test-rig at the rain room has actually been calibrated with 'real' rain, and the test conditions were found to exactly replicate the normal variations in downpours experienced by Leeds residents.

Work at Leeds tends to be directly applied to manufacturers' current problems, and a large number of the key players in the European outdoor garment manufacturing business use the facilities on an *ad hoc* basis. A service of rapid response analysis is offered where whole garments or specific parts of garments can be tested and the aim is to provide meaningful work-in-progress calibration so that designers of outerwear can check within the product development phase that the likely results will be acceptable.

Much experience in the outdoor world is available and the practical approach is focused on three aspects of fitness for purpose:

First, the materials are of adequate standard for the projected use - simply put, is the shell actually waterproof?

Second, are the features of the construction of adequate quality? Do the seams leak? Are zip and pocket insertions watertight? Are the cuff and hem areas of poor design and allow water input?

Third, has the design incorporated problem solving features? Are the weak points in the garment fitted with second lines of defence against water ingress?

All these 'oversights' of experience have created an impressive fund of practical knowledge which the Ph.D students and the technical staff pass on to clients as part of the service provided. Designers are usually subject to very short time frames in producing a new product and use of the rain room for a four to five hour period allows the design to be rapidly tested. This is a significant cost-saving function, as it quickly highlights inadequate designs before the significant costs involved in volume production are incurred.

In performance wear, as in every other field of manufacture, too often the delivered product fails at the first test. The resultant loss of brand integrity and low product sales are expensive and potentially fatal. A series of straightforward tests of performance against specified criteria are the services offered, and by the intelligent application of Charlie, James and Gloria manufacturers can have insurance against physical failure of a new garment in a stressful environment.

Irving Scott



Gloria from Leeds